SAMPLING OF AGGREGATES
FOP FOR AASHTO T 2

Scope

This procedure covers sampling of coarse, fine, or a combination of coarse and fine aggregates (CA and FA) in accordance with AASHTO T 2-91. Sampling from conveyor belts, transport units, roadways, and stockpiles is covered.

Apparatus

- Shovels or scoops, or both
- 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* mm (in.)	Minimum Mass g (lb)
2.36 (No. 8)	10,000 (25)
4.75 (No. 4)	10,000 (25)
9.5 (3/8)	10,000 (25)
12.5 (1/2)	15,000 (35)
19.0 (3/4)	25,000 (55)
25.0 (1)	50,000 (110)
37.5 (1 1/2)	75,000 (165)
50 (2)	100,000 (220)
63 (2 1/2)	125,000 (275)
75 (3)	150,000 (330)
90 (3 1/2)	175,000 (385)

* 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 2 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 a minimum of 3 approximately equal increments.
5. Combine the increments 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 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 to form a single sample.

Roadways

Method A (Berm or Windrow):

1. Obtain sample prior to spreading.
2. Take the increments from a minimum of 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 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 prior to compacting.

2. Take the increments from 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 to form a single sample.

Stockpiles

Method A – Coarse, Fine, or a Combination of Coarse and Fine Aggregates:

1. Create, with a loader if one is available, horizontal surfaces with vertical faces in the top, middle, and bottom third of the stockpile. When no equipment is available a shovel may be used to create the horizontal surfaces with vertical faces.

2. Prevent continued sloughing by shoving a flat board in 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 form a single sample.

Method B – Fine Aggregate (Alternate Tube Method):

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 form a single sample.

Note 3: Obtaining samples at stockpiles should be avoided whenever possible due to problems involved in obtaining a representative gradation of material.

Report

- On forms approved by the agency
- Date
- Time
- Sample ID
- Location
- Quantity represented

Standard Method of Test for

Bulk Density ("Unit Weight") and Voids in Aggregate

AASHTO Designation: T 19M/T 19-14
ASTM Designation: C 29/C 29M-09

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

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

AASHTO Designation: T 19M/T 19-14
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1. SCOPE

1.1. This test method covers the determination of bulk density (“unit weight”) of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

Note 1—Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume or density).

1.2. The values stated in either inch-pound units or acceptable metric units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the metric values are the standard as stated in ASTM E 11. Within the text, inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 121M/T 121, Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- T 248, Reducing Samples of Aggregate to Testing Size

2.2. *ASTM Standards*:

- C 29/C 29M, Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
- C 125, Standard Terminology Relating to Concrete and Concrete Aggregates

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D 123, Standard Terminology Relating to Textiles
- E 11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. TERMINOLOGY

3.1. *definitions*—definitions are in accordance with ASTM C 125 unless otherwise indicated.

3.1.1. *bulk density, n*—of aggregate, the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. Expressed in kg/m^3(lb/ft^3).

3.1.1.1. *discussion*—units of mass are the kilogram (kg), the pound (lb), or units derived from these. Mass may also be visualized as equivalent to inertia, or the resistance offered by a body to change of motion (acceleration). Masses are compared by weighing the bodies, which amounts to comparing the forces of gravitation acting on them. ASTM D 123.

3.1.2. *unit weight, n*—weight (mass) per unit volume. (Deprecated term—use preferred term “bulk density.”)

3.1.2.1. *discussion*—the term weight means the force of gravity acting on the mass.

3.1.3. *weight, n*—the force exerted on a body by gravity. (See also mass.)

3.1.3.1. *discussion*—weight is equal to the mass of the body multiplied by the acceleration due to gravity. Weight may be expressed in absolute units (newtons, poundals) or in gravitational units (kgf, lbf), for example: on the surface of the earth, a body with a mass of 1 kg has a weight of 1 kgf (approximately 9.81 N), or a body with a mass of 1 lb has a weight of 1 lbf (approximately 4.45 N or 32.2 poundals). Because weight is equal to mass times the acceleration due to gravity, the weight of a body will vary with the location where the weight is determined, while the mass of the body remains constant. On the surface of the earth, the force of gravity imparts to a body that is free to fall an acceleration of approximately $9.81\ m/s^2$ [$32.2\ ft/s^2$]. ASTM D 123.

3.2. *Descriptions of Terms*:

3.2.1. *voids, n*—in unit volume of aggregate, the space between particles in an aggregate mass not occupied by solid mineral matter.

3.2.1.1. *discussion*—voids within particles, either permeable or impermeable, are not included in voids as determined by T 19M/T 19.

4. SIGNIFICANCE AND USE

4.1. This test method is often used to determine bulk density values that are necessary for use for many methods of selecting proportions for concrete mixtures.

4.2. The bulk density also may be used for determining mass/volume relationships for conversions in purchase agreements. However, the relationship between degree of compaction of aggregates in a hauling unit or stockpile and that achieved in this method is unknown. Further, aggregates in hauling units and stockpiles usually contain absorbed and surface moisture (the latter affecting bulking), while this method determines the bulk density on a dry basis.

4.3. A procedure is included for computing the percentage of voids between the aggregate particles based on the bulk density determined by this method.

5. APPARATUS

5.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

5.2. *Tamping Rod*—A round, straight steel rod, 16 mm [$^5/_8$ in.] in diameter and approximately 600 mm [24 in.] in length, having one end rounded to a hemispherical tip of the same diameter as the rod.

5.3. *Measure*—A cylindrical metal measure, preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure should have a height approximately equal to the diameter, but in no case shall the height be less than 80 percent nor more than 150 percent of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.25 mm [0.01 in.] and shall be parallel to the bottom within 0.5 degrees (Note 2). The interior wall of the measure shall be a smooth and continuous surface.

Table 1—Capacity of Measures

Nominal Maximum Size of Aggregate		Capacity of Measure[a]	
mm	in.	L (m^3)	ft^3
12.5	$^1/_2$	2.8 (0.0028)	$^1/_{10}$
25.0	1	9.3 (0.0093)	$^1/_3$
37.5	$1^1/_2$	14 (0.014)	$^1/_2$
75	3	28 (0.028)	1
100	4	70 (0.070)	$2^1/_2$
125	5	100 (0.100)	$3^1/_2$

[a] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 percent of the nominal volume listed.

Note 2—The top rim is satisfactorily plane if a 0.25 mm [0.01 in.] feeler gauge cannot be inserted between the rim and a piece of 6 mm [$^1/_4$ in.] or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 percent in any direction.

5.3.1. If the measure also is to be used for testing for bulk density of freshly mixed concrete according to T 121M/T 121, the measure shall be made of steel or other suitable metal not readily subject to attack by cement. Reactive materials such as aluminum alloys are permitted, where as a consequence of an initial reaction, a surface film is formed that protects the metal against further corrosion.

5.3.2. Measures larger than nominal 28-L [1-ft^3] capacity shall be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 should be suitably increased.

Table 2—Requirements for Measures

Capacity of Measure	Thickness of Metal, Min Bottom	 Upper $1^1/_2$ in. or 38 mm of Wall[a]	 Remainder of Wall
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
Over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
Over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm
Less than 0.4 ft^3	0.20 in.	0.10 in.	0.10 in.
0.4 ft^3 to 1.5 ft^3, incl	0.20 in.	0.20 in.	0.12 in.
Over 1.5 to 2.8 ft^3, incl	0.40 in.	0.25 in.	0.15 in.
Over 2.8 to 4.0 ft^3, incl	0.50 in.	0.30 in.	0.20 in.

[a] The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

5.4. *Shovel or Scoop*—A shovel or scoop of convenient size for filling the measure with aggregate.

5.5. *Calibration Equipment*

5.5.1. *Plate Glass*—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 measure to be calibrated.

5.5.2. *Grease*—A supply of water insoluble grease.

Note 3—Petroleum jelly, vacuum grease, water pump grease, or chassis grease are examples of suitable material used to form a seal between the glass plate and measure.

5.5.3. *Thermometer*—A thermometer having a range of at least 10 to 32°C [50 to 90°F] and that is readable to at least 0.5°C [1°F].

5.5.4. *Balance*—A balance as described in Section 5.1.

6. SAMPLING

6.1. Obtain the sample in accordance with T 2, and reduce to test sample size in accordance with T 248.

7. SAMPLE

7.1. The size of sample shall be approximately 125 to 200 percent of the quantity required to fill the measure and shall be handled in a manner to avoid segregation. Dry the sample of aggregate to constant mass, preferably in an oven at 110 ± 5°C [230 ± 9°F].

8. CALIBRATION OF MEASURE

8.1. Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

8.2. Place a thin layer of grease on the rim of the measure to prevent leakage of water from the measure.

8.3. Determine the mass of the plate glass and measure to the nearest 0.05 kg [0.1 lb].

8.4. Fill the measure with water that is at room temperature and cover with the plate glass in such a way as to eliminate bubbles and excess water. Remove any water that may have overflowed onto the measure or plate glass.

8.5. Determine the mass of the water, plate glass, and measure to the nearest 0.05 kg [0.1 lb].

8.6. Measure the temperature of the water to the nearest 0.5°C [1°F] and determine its density from Table 3, interpolating if necessary.

Table 3—Density of Water

Temperature			
°C	°F	kg/m^3	lb/ft^3
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
(23.0)	(73.4)	(997.54)	(62.274)
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

8.7. Calculate the volume, *V*, of the measure. Alternatively, calculate the factor, *F*, for the measure.

$$V = (B - C)/D \quad (1)$$

$$F = D/(B - C) \quad (2)$$

where:

V = volume of the measure, m^3 (ft^3);

B = mass of the water, plate glass, and measure, kg (lb);

C = mass of the plate glass and measure, kg (lb);

D = density of the water for the measured kg/m^3 (lb/ft^3); and

F = factor for the measure, 1/m^3 (1/ft^3).

Note 4—For the calculation of bulk density, the volume of the measure in acceptable metric units should be expressed in cubic meters, or the factor as 1/m^3. However, for convenience, the size of the measure may be expressed in liters (equal to m^3/1000).

9. SELECTION OF PROCEDURE

9.1. The shoveling procedure for loose bulk density shall be used only when specifically stipulated. Otherwise, the compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 37.5 mm [$1^1/_2$ in.] or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 37.5 mm [$1^1/_2$ in.] and not exceeding 125 mm [5 in.].

10. RODDING PROCEDURE

10.1. Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

10.2. In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

Note 5—In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

10.3. Determine the mass of the measure plus contents, and the mass of the measure alone and record the values to the nearest 0.05 kg [0.1 lb].

11. JIGGING PROCEDURE

11.1. Fill the measure in three approximately equal layers as described in Section 10.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 50 mm [2 in.], and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

11.2. Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

12. SHOVELING PROCEDURE

12.1. Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm [2 in.] above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

12.2. Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

13. CALCULATION OF RESULTS

13.1. *Bulk Density*—Calculate the bulk density for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \tag{3}$$

or,

$$M = (G - T) \times F \tag{4}$$

where:

M = bulk density of aggregate, kg/m^3 (lb/ft^3);

G = mass of aggregate plus the measure, kg (lb);

T = mass of the measure, kg (lb);

V = volume of measure, m^3 (ft^3); and
F = factor for measure, m^{-3} (ft^{-3}).

13.1.1. The bulk density determined by this method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated surface-dry (SSD) condition is desired, use the exact procedure in this method, and then calculate the SSD bulk density by the following formula:

$$M_{SSD} = M\left[1 + \left(A/100\right)\right] \tag{5}$$

where:

M_{SSD} = bulk density in SSD condition, kg/m^3 (lb/ft^3); and
A = absorption, percent, determined in accordance with T 84 or T 85.

13.2. *Void Content*—Calculate the void content in the aggregate using the bulk density determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\text{voids }\% = \frac{100\left[\left(S \times W\right) - M\right]}{S \times W} \tag{6}$$

where:

M = bulk density of aggregate, kg/m^3 (lb/ft^3);
S = bulk specific gravity (dry basis) as determined in accordance with T 84 or T 85; and
W = density of water, 998 kg/m^3 [62.3 lb/ft^3].

14. REPORT

14.1. *Report the results for bulk density to the nearest 10 kg/m^3 [1 lb/ft^3] as follows*:

14.1.1. Bulk density by rodding,

14.1.2. Bulk density by jigging, or

14.1.3. Loose bulk density.

14.2. *Report the results for void content to the nearest one percent as follows*:

14.2.1. Voids in aggregate compacted by rodding, percent,

14.2.2. Voids in aggregate compacted by jigging, percent, or

14.2.3. Voids in loose aggregate, percent.

14.3. Indicate the procedure used.

15. PRECISION AND BIAS

15.1. The following estimates of precision for this method are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, with testing conducted by this method and ASTM C 29/C 29M. There are no significant differences between the two methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

15.2. *Coarse Aggregate (bulk density)*:

15.2.1. *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.2.2. *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 30 kg/m^3 [1.87 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 85 kg/m^3 [5.3 lb/ft^3] (d2s).

15.2.3. These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for bulk density by rodding of normal-weight aggregates having a nominal maximum aggregate size of 25.0 mm [1 in.], and using a 14-L [$^1/_2$-ft^3] measure.

15.3. *Fine Aggregate (bulk density)*:

15.3.1. *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.3.2. *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 44 kg/m^3 [2.76 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 125 kg/m^3 [7.8 lb/ft^3] (d2s).

15.3.3. These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for loose bulk density from laboratories using a 2.8-L [$^1/_{10}$-ft^3] measure.

15.4. No precision data on void content are available. However, as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in Sections 15.2 and 15.3 of this method and in T 84 and T 85.

15.5. *Bias*—The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

5.5 Retainers

5.5.1 A pair of metal fixtures that provide support for and alignment of the pads and the cylinder's end. The upper and lower retainer includes a ring that is welded to or manufactured integrally with the base plate. Retainer Internal Diameter shall not be less than 102% or greater than 107% of the cylinder diameter with a minimum Base Plate Thickness for 6 in. Retainer of 0.47 in. and for the 4in. Retainer of 0.30 in. Have a minimum Wall Thickness for the 6 in. Retainer of 0.47 in. and for the 4in. Retainer of 0.35 in. See figure 1 in ASTM C1231 for diagram.

- **Under Section 7 Procedures add:**

7.3.1 Neoprene pad caps are used to replace caps complying with AASHTO T 231 they may be used on one or both ends of the cylinder.

7.3.2 Each side of the pad must be examined for excessive wear or other damage. Replace pads having cracks on either side exceeding $^3/_8$ inch in length regardless of depth. Pads are to be inserted into the retainer before placing on cylinder following manufacturer's recommendations.

7.4.0.1 Center the cylinder in the retainer(s) and place the unit on the lower bearing block. Take care to align the unit of cylinder and retainer(s) in the center of the upper and lower bearing blocks.

7.4.1.1 Apply a load, not to exceed 10% of the anticipated cylinder strength, pausing to check the unit is centered within $^1/_8$" in 12" and that the cylinder is centered in the retainer ring, upper and lower. If these conditions are not met remove load, re-center and re-apply the load, checking for the same tolerances.

Oregon
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October 31, 2013

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:

This yellow sheet is for the use of Neoprene Pads; see ASTM 1231 for entire procedure and cautionary disclosures.

- **Under Section 4 Significance and Use add:**

4.5 The use of unbonded caps as defined by ASTM C1231 for the determination of compressive strength is allowed. Meet the guide lines as laid out in this yellow sheet and ASTM C1231.

- **Under Section 5 Apparatus add:**

5.4 Elastomeric Pad

5.4.1 Neoprene Pad’s thickness shall be ½” $^{+}/_{-}$ $^{1}/_{16}$”. Neoprene pad’s diameter shall not be more than $^{1}/_{16}$” smaller than the inside diameter of the retaining ring.

5.4.2 Use Neoprene Pads made of polychloroprene meeting the requirements of ASTM C1231. Other materials maybe allowed if they meet the qualification testing as outlined in section 8 of ASTM C1231.

5.4.3 Provide neoprene pads having the following information:

5.4.3.1 Manufacturer’s or supplier’s contact information
5.4.3.2 Shore A hardness and applicable compressive strength range from Table 1 of ASTM C1231.

5.4.4 The user shall maintain a record log stating the date the pads were put into service, the Durometer of the pad, and number of uses the pads is subjects to each date with the date of those uses.

(See Next Page)

Standard Method of Test for

Compressive Strength of Cylindrical Concrete Specimens

AASHTO Designation: T 22-14[1]
ASTM Designation: C 39/C 39M-05

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Compressive Strength of Cylindrical Concrete Specimens

AASHTO Designation: T 22-14[1]
ASTM Designation: C 39/C 39M-05

1. SCOPE

1.1. This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 800 kg/m^3 (50 lb/ft^3).

1.2. The values stated in SI units are the preferred standard.

1.3. *This standard may involve hazardous materials, operations, or equipment. 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.*

Warning—Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture increases with increasing concrete strength (Note 1).

Note 1—The safety precautions given in the *Manual of Aggregate and Concrete Testing*, located in the Related Materials section of Volume 04.02 of the *Annual Book of ASTM Standards*, are recommended.

1.4. The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- R 39, Making and Curing Concrete Test Specimens in the Laboratory
- T 23, Making and Curing Concrete Test Specimens in the Field
- T 24M/T 24, Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- T 231, Capping Cylindrical Concrete Specimens

2.2. *ASTM Standards*:

- C 31/C 31M, Standard Practice for Making and Curing Concrete Test Specimens in the Field
- C 42/C 42M, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- C 192/C 192M, Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
- C 617/C 617M, Standard Practice for Capping Cylindrical Concrete Specimens
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

- C 873/C 873M, Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
- C 1077, Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
- C 1231/C 1231M, Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders
- E 4, Standard Practices for Force Verification of Testing Machines
- E 74, Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
- *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02

3. SUMMARY OF TEST METHOD

3.1. This test method consists of applying a compressive axial load to molded cylinders or cores at a rate that is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. SIGNIFICANCE AND USE

4.1. Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method because strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication, and the age, temperature, and moisture conditions during curing.

4.2. This test method may be used to determine compressive strength of cylindrical specimens prepared and cured in accordance with R 39, T 23, T 24M/T 24, T 231, and ASTM C 873/C 873M.

4.3. The results of this test method may be used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specification; and control for evaluating effectiveness of admixtures and similar uses.

5. APPARATUS

5.1. *Testing Machine*—The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in Section 7.5.

5.1.1. Verify calibration of the testing machines in accordance with ASTM E 4, except that the verified loading range shall be as required in Section 5.3. Verification is required under the following conditions:

5.1.1.1. At least annually, but not to exceed 13 months;

5.1.1.2. On original installation or immediately after relocation;

5.1.1.3. Immediately after making repairs or adjustments that affect the operation of the force applying system or the values displayed on the load indicating system, except for zero adjustments that compensate for the mass (weight) of tooling, or specimen, or both; or

5.1.1.4. Whenever there is reason to suspect the accuracy of the indicated loads.

5.1.2. *Design*—The design of the machine must include the following features:

5.1.2.1. The machine must be power-operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of Section 7.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power- or hand-operated.

5.1.2.2. The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device that is of sufficient capacity to cover the potential loading range of the testing machine and that complies with the requirement of ASTM E 74.

Note 2—The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving rings or load cells.

5.1.3. *Accuracy*—The accuracy of the testing machine shall be in accordance with the following provisions:

5.1.3.1. The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed ±1.0 percent of the indicated load.

5.1.3.2. The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one-third of the difference between the maximum and minimum test loads.

5.1.3.3. The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, E, and the percentage of error, E_p, for each point from these data as follows:

$$E = A - B \tag{1}$$

$$E_p = 100\,(A - B)/B \tag{2}$$

where:

A = load, kN (or lbf) indicated by the machine being verified; and

B = applied load, kN (or lbf) as determined by the calibrating device.

5.1.3.4. The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value that is 100 times the smallest change of load that can be estimated on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10 percent of the maximum range capacity.

5.1.3.5. In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

5.1.3.6. The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.

5.2. The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 3), one of which is a spherically seated block that will bear on the upper surface of the specimen, and the other a solid block on which the specimen shall rest. Bearing faces of the blocks shall have a minimum dimension at least 3 percent greater than the diameter of the specimen to be tested. Except for the concentric circles described below, the bearing faces shall not depart from a plane by more than 0.02 mm (0.001 in.) in any 150 mm (6 in.) of blocks 150 mm (6 in.) in diameter or larger, or by more than 0.02 mm (0.001 in.) in the diameter of any smaller block; and new blocks shall be manufactured within one-half of this tolerance. When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by more than 13 mm (0.5 in.), concentric circles not more than 0.8 mm (0.03 in.) deep and not more than 1 mm (0.04 in.) wide shall be inscribed to facilitate proper centering.

Note 3—It is desirable that the bearing faces of blocks used for compression testing of concrete have a Rockwell hardness of not less than 55 HRC.

5.2.1. Bottom bearing blocks shall conform to the following requirements:

5.2.1.1. The bottom bearing block is specified for the purpose of providing a readily machinable surface for maintenance of the specified surface conditions (Note 4). The top and bottom surfaces shall be parallel to each other. Its least horizontal dimension shall be at least 3 percent greater than the diameter of the specimen to be tested. Concentric circles as described in Section 5.2 are optional on the bottom block.

Note 4—The block may be fastened to the platen of the testing machine.

5.2.1.2. Final centering must be made with reference to the upper spherical block when the lower bearing block is used to assist in centering the specimen. The center of the concentric rings, when provided, or the center of the block itself must be directly below the center of the spherical head. Provision shall be made on the platen of the machine to assure such a position.

5.2.1.3. The bottom bearing block shall be at least 25 mm (1 in.) thick when new and at least 22.5 mm (0.9 in.) thick after resurfacing operations.

Note 5—If the testing machine is so designed that the platen itself can be readily maintained in the specified surface condition, a bottom block is not required.

5.2.2. The spherically seated bearing block shall conform to the following requirements:

5.2.2.1. The maximum diameter of the bearing face of the suspended spherically seated block shall not exceed the values given in Table 1.

Table 1—Maximum Diameter of Bearing Face

Diameter of Test Specimens, mm (in.)	Max Diameter of Bearing Face, mm (in.)
50 (2)	105 (4)
75 (3)	130 (5)
100 (4)	165 (6.5)
150 (6)	255 (10)
200 (8)	280 (11)

Note 6—Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

5.2.2.2. The center of the sphere shall coincide with the surface of the bearing face within a tolerance of ±5 percent of the radius of the sphere. The diameter of the sphere shall be at least 75 percent of the diameter of the specimen to be tested.

5.2.2.3. The ball and the socket shall be designed so that the steel in the contact area does not permanently deform when loaded to the capacity of the test machine.

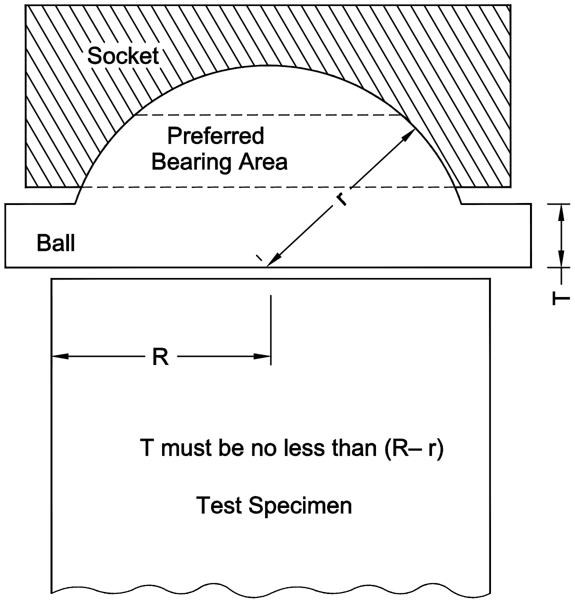
Note 7—The preferred contact area is in the form of a ring (described as “preferred bearing area”) as shown in Figure 1.

5.2.2.4. The curved surfaces of the socket and the spherical portion shall be kept clean and shall be lubricated with a petroleum-type oil such as conventional motor oil, not with a pressure-type grease. After contacting the specimen and application of a small initial load, further tilting of the spherically seated block is not intended and is undesirable.

5.2.2.5. If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere. (See Figure 1.)

5.2.2.6. The movable portion of the bearing block shall be held closely in the spherical seal, but the design shall be such that the bearing face can be rotated freely and tilted at least 4 degrees in any direction.

5.2.2.7. If the ball portion of the upper bearing block is a two-piece design composed of a spherical portion and a bearing plate, a mechanical means shall be provided to ensure that the spherical portion is fixed and centered on the bearing plate.



Note: Provision shall be made for holding the ball in the socket and for holding the entire unit in the testing machine.

Figure 1—Schematic Sketch of a Typical Spherical Bearing Block

5.3. *Load Indication*:

5.3.1. If the load of a compression machine used in concrete tests is registered on a dial, the dial shall be provided with a graduated scale that can be read to at least the nearest 0.1 percent of the full scale load (Note 8). The dial shall be readable within 1 percent of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment located outside the dial case and easily accessible from the front of the machine while observing the zero mark and dial pointer. Each dial shall be equipped with a suitable device that at all times, until reset, will indicate to within 1 percent accuracy the maximum load applied to the specimen.

Note 8—As close as can reasonably be read is considered to be 0.5 mm (0.02 in.) along the arc described by the end of the pointer. Also, one-half of the scale interval is about as close as can reasonably be read when the spacing on the load-indicating mechanism is between 1 mm (0.04 in.) and 2 mm (0.06 in.). When the spacing is between 2 mm and 3 mm (0.06 in. and 0.12 in.), one-third of a scale interval can be read with reasonable certainty. When the spacing is 3 mm (0.12 in.) or more, one-fourth of a scale interval can be read with reasonable certainty.

5.3.2. If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read. The numerical increment must be equal to or less than 0.10 percent of the full-scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 percent for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1.0 percent system accuracy the maximum load applied to the specimen.

5.4. Provide a means for containing fragments in the event of explosive rupture of the cylinders during testing.

6. SPECIMENS

6.1. Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 percent (Note 9).

Note 9—This may occur when single-use molds are damaged or deformed during shipment, when flexible single-use molds are deformed during molding, or when a core drill deflects or shifts during drilling.

6.2. Neither end of compressive test specimens, when tested, shall depart from perpendicularity to the axis by more than 0.5 degrees (approximately equivalent to 3 mm in 300 mm (0.12 in. in 12 in. for a 6-by-12-in. cylinder) or 2 mm in 200 mm (0.08 in. in 8 in. for a 4-by-8-in. cylinder)). The ends of compression test specimens that are not plane within 0.050 mm (0.002 in.) shall be sawed or ground to meet that tolerance or capped in accordance with either T 231 or, when permitted, ASTM C 1231. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.25 mm (0.01 in.) by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

6.3. The number of individual cylinders measured for determination of average diameter may be reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.5 mm (0.02 in.). When the average diameters do not fall within the range 0.5 mm (0.02 in.) or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in the calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.

6.4. If the purchaser of the testing services requests measurement of density of the test specimen, determine the mass of the specimen before capping. Remove any surface moisture with a towel and measure the mass of the specimen using a balance or scale that is accurate to within 0.3 percent of the mass being measured. Measure the length of the specimen to the nearest 1 mm (0.05 in.) at three locations spaced evenly around the circumference. Compute the average length and record to the nearest 1 mm (0.05 in.). Alternatively, determine the cylinder density by weighing the cylinder in air and then submerged under water at 23.0 ± 2.0°C (73.5 ± 3.5°F), and computing the volume according to Section 8.3.1.

6.5. When density determination is not required and the length to diameter ratio is less than 1.8 or more than 2.2, measure the length of the specimen to the nearest 0.05*D*.

7. PROCEDURE

7.1. Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

7.2. Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

7.3. All test specimens for a given test age shall be broken within the permissible time tolerances prescribed as shown in Table 2.

Table 2—Permissible Time Tolerances

Test Age	Permissible Tolerance
12 h	±0.25 h or 2.1%
24 h	±0.5 h or 2.1%
3 days	2 h or 2.8%
7 days	6 h or 3.6%
28 days	20 h or 3.0%
56 days	40 h or 3.0%
90 days	2 days or 2.2%

7.4. *Placing the Specimen*—Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper- and lower-bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

7.4.1. *Zero Verification and Block Seating*—Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 10). As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

Note 10—The technique used to verify and adjust the load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

7.5. *Rate of Loading*—Apply the load continuously and without shock, except as permitted by ASTM C 1231/C 1231M.

7.5.1. The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of 0.25 ± 0.05 MPa/s (35 ± 7 psi/s) (Note 11). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

Note 11—For a screw-driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

7.5.2. During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. Apply the higher loading rate in a controlled manner so the specimen is not subjected to shock loading.

7.5.3. Do not adjust the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

7.6. Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (Figure 2). For a testing machine equipped with a specimen break detector, automatic shutoff of the testing machine is prohibited until the load has dropped to a value that is less than 95 percent of the peak load. When testing with unbonded caps, a corner fracture may occur before the ultimate capacity of the specimen has been attained. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to Figure 2. If the fracture pattern is not one of the typical patterns shown in Figure 2, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify that end preparations were in accordance with T 231 or ASTM C 1231/C 1231M.

8. CALCULATION

8.1. Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as described in Section 6 and express the result to the nearest 0.1 MPa (10 psi).

8.2. If the specimen length-to-diameter (*L*/*D*) ratio is 1.75 or less, correct the result obtained in Section 8.1 by multiplying the appropriate correction factor shown in the following table (Note 12):

L/*D* ratio	1.75	1.50	1.25	1.00
Factor	0.98	0.96	0.93	0.87

Use interpolation to determine correction factors for *L*/*D* values between those given in the table.

Note 12—Correction factors depend on various conditions, such as moisture condition, strength level, and elastic modulus. Average values are given in the table. These correction factors apply to lightweight concrete weighing between 1600 and 1920 kg/m^3 (100 and 120 lb/ft^3) and to normal weight concrete. They are applicable to concrete dry or soaked at the time of loading and for nominal concrete strengths from 15 to 45 MPa (2000 to 6000 psi). For strengths higher than 45 MPa (6000 psi) correction factors may be larger than the values listed above.[2]

8.3. When required, calculate the density of the specimen to the nearest 10 kg/m^3 (1 lb/ft^3) as follows:

$$\text{density} = \frac{W}{V} \qquad (3)$$

where:

W = mass of specimen, kg (lb); and

V = volume of specimen computed from the average diameter and average length or from weighing the cylinder in air and submerged, m^3 (ft^3).

8.3.1. When the volume is determined from submerged weighing, calculate the volume as follows:

$$V = \frac{W - W_s}{\gamma_w} \qquad (4)$$

where:

W_s = apparent mass of submerged specimen, kg (lb); and

γ_w = density of water at 23°C (73.5°F) = 997.5 kg/m^3 (62.27 lb/ft^3).

9. REPORT

9.1. *The report shall include the following*:

9.1.1. Identification number;

9.1.2. Diameter (and length, if outside the range of 1.8D to 2.2D), in millimeters or inches;

9.1.3. Cross-sectional area, in square centimeters or square inches;

9.1.4. Maximum load, in kilonewtons or pounds-force;

9.1.5. Compressive strength calculated to the nearest 0.1 MPa (10 psi);

9.1.6. Type of fracture, if other than the usual cone (see Figure 2);

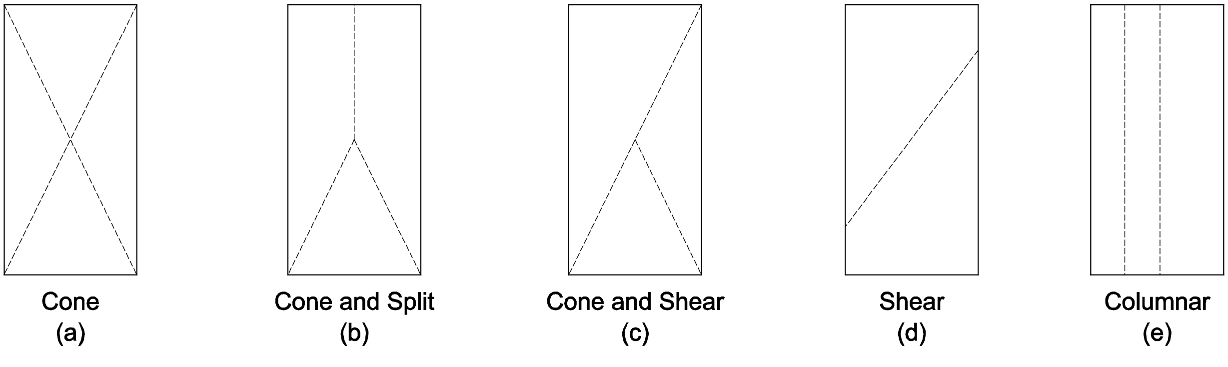


Figure 2—Sketches of Types of Fracture

9.1.6.1. *Cone (a)*—Well-formed cones on both ends;

9.1.6.2. *Cone and Split (b)*—Well-formed cone on one end, vertical cracks(s) through the other end;

9.1.6.3. *Cone and Shear (c)*—Well-formed cone on one end, with a diagonal fracture extending to the other end;

9.1.6.4. *Shear (d)*—Diagonal fracture with no cracking through the ends; or

9.1.6.5. *Columnar (e)*—Columnar vertical cracking through the specimen.

9.1.7. Defects in either specimen or caps; and

9.1.8. Age of specimen.

9.1.9. When determined, record the density to the nearest 10 kg/m^3 (1 lb/ft^3).

10. PRECISION AND BIAS

10.1. *Precision*:

10.1.1. *Within-Test Precision*—The following table provides the within-test precision of tests of 150-by-300-mm (6-by-12-in.) and 100-by-200-mm (4-by-8-in.) cylinders made from a well-mixed sample of concrete under laboratory conditions and under field conditions (see Section 10.1.2):

	Coefficient of Variation[a]	Acceptable Range[a] of Individual Cylinder Strengths	
		2 Cylinders	3 Cylinders
150 × 300 mm (6 × 12 in.)			
Laboratory conditions	2.4%	6.6%	7.8%
Field conditions	2.9%	8.0%	9.5%
100 × 200 mm (4 × 8 in.)			
Laboratory conditions	3.2%	9.0%	10.6%

[a] These numbers represent respectively the (1s) and (d2s) limits as described in ASTM C 670.

10.1.2. The within-test coefficient of variation represents the expected variation of measured strength of companion cylinders prepared from the same sample of concrete and tested by one laboratory at the same age. The values given for the within-test coefficient of variation of 150-by-300-mm (6-by-12-in.) cylinders are applicable for compressive strengths between 15 and 55 MPa (2000 and 8000 psi) and those for 100-by-200-mm (4-by-8-in.) cylinders are applicable for compressive strengths between 17 and 32 MPa (2500 and 4700 psi.) The within-test coefficients of variation for 150-by-300-mm (6-by-12-in.) cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions and a collection of 1265 test reports from 225 commercial testing laboratories in 1978 (ASTM Research Report RR: C09-1006).[3] The within-test coefficient of variation of 100-by-200-mm (4-by-8-in.) cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions (ASTM Research Report RR C09-1027).[4]

10.1.3. *Multilaboratory Precision*—The multilaboratory coefficient of variation for compressive strength test results of 150-by-300-mm (6-by-12-in.) cylinders has been found to be 5.0 percent; therefore, the results of properly conducted tests by two laboratories on specimens prepared from the same sample of concrete are not expected to differ by more than 14 percent of the average (see Note 13). A strength test result is the average of two cylinders tested at the same age.

Note 13—The multilaboratory precision does not include variations associated with different operators preparing test specimens from split or independent samples of concrete. These variations are expected to increase the multilaboratory coefficient of variation.

10.1.4. The multilaboratory data were obtained from six separate organized strength testing round-robin programs where 150-by-300-mm (6-by-12-in.) cylindrical specimens were prepared at a single location and tested by different laboratories. The range of average strength from these programs was 17.0 to 90 MPa (2500 to 13,000 psi).

Note 14—ASTM Subcommittee C09.61 will continue to examine recent concrete proficiency sample data and field test data and make revisions to precision statements when data indicate that they can be extended to cover a wider range of strengths and specimen sizes.

10.2. *Bias*—Because there is no accepted reference material, no statement on bias is being made.

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[1] This method agrees technically with C 39/C 39M-05 except for the use of SI units, and C 39 provides qualification restrictions for concrete laboratory technicians performing acceptance tests.

[2] Barlett, F. M., and J. G. MacGregor. "Effect of Core Length-to-Diameter Ratio on Concrete Core Strength." *ACI Materials Journal*, Vol. 91, No. 4, July–August, 1994, pp. 339–348.

[3] Supporting data may be obtained by requesting Research Report RR: C09-1006 from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[4] Supporting data may be obtained by requesting Research Report RR: C09-1027 from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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October 31, 2010

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 23**

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 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 T 23

Scope

This procedure covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO T 23-14.

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

Apparatus and Test Specimens

- 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 38 mm (1.5 in.). Specimens shall be cast and hardened with the long axes horizontal.
- Standard tamping rod: 16 mm (5/8 in.) in diameter and approximately 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 150mm (6 in.) x 300 mm (12 in.) cylinders.
- Small tamping rod: 10 mm (3/8 in.) diameter and approximately 305 mm (12 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 7000 vibrations per minute, with a diameter no more than ¼ the diameter or width of the mold and at least 75 mm (3 in.) longer than the section being vibrated for use with low slump concrete.
- 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.

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 prior to 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 – 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. 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. 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 mm^2 (2 in^2) 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. 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. 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 ¼ in. of a level surface, and free from vibrations or other disturbances.
- Maintain initial curing temperature of 16 to 27°C (60 to 80°F) or 20 to 26°C (68 to 78°F) for concrete with 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

- After 24 to 48 hours of initial curing, the specimens will be transported to the laboratory for a 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.
- While in transport, specimens shall be protected from jarring, extreme changes in temperature, freezing, or moisture loss.
- Cylinders shall be secured so that the axis is vertical.
- Transportation time shall not exceed 4 hours.

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° ±2°C (73 ±3°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 prior to testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested.
- Final curing of beams must include immersion in lime-saturated water for at least 20 hours prior to 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.

Oregon
Theodore R. Kulongoski, Governor

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Construction Section
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DATE: October 31, 2007

TO: All Holders of the Manual of Field Test Procedures File Code:

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.**
- **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

Sieve analysis determines the gradation or distribution of aggregate particle sizes within a given sample.

Accurate determination of material smaller than 75 µm (No. 200) cannot be made with AASHTO T 27 alone. If quantifying this material is required, it is recommended that AASHTO T 27 be used in conjunction with AASHTO T 11.

This FOP covers sieve analysis in accordance with AASHTO T 27-14 and materials finer than 75 µm (No. 200) in accordance with AASHTO T 11-05 performed in conjunction with AASHTO T 27. The procedure includes three method choices: 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 AASHTO M 92
- Mechanical sieve shaker: Meeting the requirements of AASHTO T 27
- Suitable drying equipment (see 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
- Optional mechanical washing device

Sample Sieving

- In all procedures, it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification.
- The sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve.

- Sieves are shaken in a mechanical shaker for approximately 10 minutes, or the minimum time determined to provide complete separation for the sieve shaker being used. As established by the Time Evaluation.

Time Evaluation

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.

If more than 0.5 percent by mass of the total sample prior to 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.

Overload Determination

- 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 × (sieve opening in mm) × (effective sieving area). See Table 1.

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 overload.

TABLE 1
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 mm (in.)		203 dia (8)	305 dia (12)	305 by 305 (12 × 12)	350 by 350 (14 × 14)	372 by 580 (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

Sample Preparation

Obtain samples in accordance with the FOP for AASHTO T 2 and reduce to the size shown in Table 2 in accordance with the FOP for AASHTO T 248. These sample sizes are standard for aggregate testing but, due to equipment restraints, samples may need to be partitioned into several “subsamples.” For example, a gradation that requires 100 kg (220 lbs) of material would not fit into a large tray shaker in one batch.

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 test sample sizes.

TABLE 2
Sample Sizes for Aggregate Gradation Test

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

*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.

Selection of Procedure

Agencies may specify what method will be performed. If a method is not specified method A will be performed.

Overview

Method A

- Determine dry mass of original sample
- Wash through a 75µm (No. 200) sieve
- Determine dry mass of washed sample
- Sieve material

Method B

- Determine dry mass of original sample
- Wash through a 75µm (No. 200) sieve
- Determine dry mass of washed sample
- Sieve coarse material
- Determine dry mass of fine material
- Reduce fine portion
- Determine mass of reduced portion
- Sieve fine portion

Method C

- Determine dry mass of original sample
- Sieve coarse material
- Determine mass of fine material
- Reduce fine portion
- Determine mass of reduced portion
- Wash through a 75µm (No. 200) sieve
- Determine dry mass of washed sample
- Sieve reduced fine portion

Procedure Method A

1. Dry the sample to a constant mass in accordance with the FOP for AASHTO T 255, and record to the nearest 0.1 percent of the total sample mass or 0.1 g.

2. When the specification requires that the amount of material finer than 75 µm (No. 200) be determined, perform Step 3 through Step 11; otherwise, skip to Step 12.

3. Nest a sieve, such as a 2.0 mm (No. 10), above the 75 µm (No. 200) sieve.

4. Place the test sample in a container and add sufficient water to cover it.

   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 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.

5. 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. When using a mechanical washing device, exercise caution to avoid degradation of the sample.

6. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.

7. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 6. Repeat the operation until the wash water is reasonably clear. If a detergent or dispersing agent is used, continue washing until the agent is removed.

8. Remove the upper sieve, return material retained to the washed sample.

9. Rinse the material retained on the 75 µm (No.200) sieve until water passing through the sieve is reasonably clear.

10. Return all material retained on the 75 µm (No.200) sieve to the container by flushing into the washed sample.

Note 2: Excess water may be carefully removed with a bulb syringe as long as the removed water is discharged back over the No. 200 sieve to preclude loss of fines.

11. Dry the washed aggregate to constant mass in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the "dry mass after washing."

12. Select sieves to furnish the information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.

13. 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).

    Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

14. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in full openings of the sieve are cleaned out and included in the mass retained.

    Note 4: For sieves No. 4 and larger, material trapped in less than a full opening shall be checked 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. In the case of coarse / fine aggregate mixtures, the minus 4.75 mm (No. 4) may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

Calculations

The total mass of the material after sieving, for both coarse and fine portions should check closely with the original mass of sample placed on the sieves. If performing T 11 with T 27, this would be the dry mass after wash. If performing just T 27 this would be the original dry mass. When the masses before and after sieving differ by more than 0.3 percent, do not use the results for acceptance purposes.

Check Sum

Total mass of material after sieving must agree with mass before sieving to within 0.3 percent.

$$\frac{dry\ mass\ after\ washing - total\ mass\ after\ sieving}{dry\ mass\ after\ washing} \times 100$$

Calculate the total percentages passing, individual or cumulative percentages retained, or percentages in various size fractions to the nearest 0.1 percent by dividing the masses for

Method A, or adjusted masses for methods B and C, on the individual sieve masses or cumulative sieve masses by the total mass of the initial dry sample. If the same test sample was first tested by T 11, use the total dry sample mass prior to washing in T 11 as the basis for calculating all percentages. Report percent passing as indicated in the "Report" section at the end of this FOP.

Percent Retained

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

Where:

IPR= Individual Percent Retained
CPR= Cumulative Percent Retained
M= Total Dry Sample mass before washing
IMR= Individual Mass Retained OR Adjusted Individual mass from Methods B or C
CMR= Cumulative Mass Retained OR Adjusted Cumulative Mass from Methods B or C

Percent Passing (Calculated):

$$PP=PPP-IPR \qquad or \qquad PP=100-CPR$$

Where:

PP= Percent Passing
PPP= Previous Percent Passing

Method A Sample Calculation

Calculate percent retained on and passing each sieve on the basis of the total mass of the initial dry sample. This will include any material finer than 75 µm (No. 200) that was washed out.

Example:

Dry mass of total sample, before washing: 5168.7 g
Dry mass of sample, after washing out the 75µm (No. 200) minus: 4911.3 g
Amount of 75µm (No. 200) minus washed out: 5168.7 g – 4911.3 g = 257.4 g

Gradation on All Sieves

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Individual Percent Retained (IPR)	Cumulative Mass Retained g (CMR)	Cumulative Percent Retained (CPR)	Calc'd Percent Passing (CPP)	Reported Percent Passing* (RPP)
19.0 (3/4)	0	0	0	0.0	100.0	100
12.5 (1/2)	724.7	14.0	724.7	14.0	86.0	86
9.5 (3/8)	619.2	12.0	1343.9	26.0	74.0	74
4.75 (No. 4)	1189.8	23.0	2533.7	49.0	51.0	51
2.36 (No. 8)	877.6	17.0	3411.3	66.0	34.0	34
1.18 (No. 16)	574.8	11.1	3986.1	77.1	22.9	23
0.600 (No. 30)	329.8	6.4	4315.9	83.5	16.5	17
0.300 (No. 50)	228.5	4.4	4544.4	87.9	12.1	12
0.150 (No. 100)	205.7	4.0	4750.1	91.9	8.1	8
0.075(No. 200)	135.4	2.6	4885.5	94.5	5.5	5.5
Pan	20.4		4905.9			

*Report 75 µm (No. 200) sieve to 0.1 percent. Report all others to 1 percent.

Check sum:

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

This is less than 0.3 percent therefore the results can be used for acceptance purposes.

Percent Retained:

9.5 mm (3/8) sieve:

$$\frac{619.2\ g}{5168.7\ g} \times 100 = 12.0\% \qquad or \qquad \frac{1343.9\ g}{5168.7\ g} \times 100 = 26.0\%$$

Percent Passing (Calculated):

9.5 mm (3/8) sieve:

$$86.0\% - 12.0\% = 74.0\% \quad or \quad 100.0\% - 26.0\% = 74.0\%$$

Procedure Method B

1. Perform steps 1 through 11 from the "Procedure – Method A," then continue as follows:

2. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the 4.75 mm (No. 4) with a pan at the bottom to retain the minus 4.75 mm (No. 4).

3. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker, or 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).

   Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

4. Determine the individual or cumulative mass retained on each sieve to the nearest 0.1 percent or 0.1 g. Ensure that all particles trapped in full openings of the sieve are cleaned out and included in the mass retained.

   Note 4: For sieves No. 4 and larger, material trapped in less than a full opening shall be checked 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.

5. Determine the mass of the material in the pan [minus 4.75 mm (No. 4)] (M_1).

6. Reduce the minus 4.75 mm (No. 4) using a mechanical splitter in accordance with the FOP for AASHTO T 248 to produce a sample with a mass of 500 g minimum. Determine and record the mass of the minus 4.75 mm (No. 4) split (M_2).

7. Select fine sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the 75 µm (No. 200) with a pan at the bottom to retain the minus 75µm (No. 200).

8. Repeat steps 3 and 4, Method B, with the minus 4.75 mm (No. 4) including determining the mass of the material in the pan.

9a. Compute the "Adjusted Individual Mass Retained" of the size increment of the original sample as follows when determining "Individual Mass Retained."

$$IMR = \frac{M_1}{M_2} \times B$$

where:

IMR = adjusted individual mass retained of the size increment on a total sample basis

M_1 = mass of minus 4.75mm (No. 4) sieve in total sample

M_2 = mass of minus 4.75mm (No. 4) sieve actually sieved

B = individual mass of the size increment in the reduced portion sieved

9b. Compute the "Adjusted Cumulative Mass Retained" of the size increment of the original sample as follows when determining "Cumulative Mass Retained":

$$CMR = \left(\frac{M_1}{M_2} \times B\right) + D$$

where:

CMR = Total cumulative mass retained of the size increment based on a total sample
M_1 = mass of minus 4.75mm (No. 4) sieve in total sample
M_2 = mass of minus 4.75mm (No. 4) sieve actually sieved
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 Sample Calculation

Sample calculation for percent retained and percent passing each sieve in accordance with Method B when the previously washed 4.75mm (No. 4) minus material is split:

Example:

Dry mass of total sample, before washing: 3214.0 g
Dry mass of sample, after washing out the 75 µm (No. 200) minus: 3085.1 g
Amount of 75 µm (No. 200) minus washed out: 3214.0 g – 3085.1 g = 128.9 g

Gradation on Coarse Sieves

Sieve Size mm (in.)	**Individual Mass Retained g (IMR)**	**Individual Percent Retained (IPR)**	**Cumulative Mass Retained g (CMR)**	**Cumulative Percent Retained (CPR)**	**Calculated Percent Passing (CPP)**
16.0 (5/8)	0	0	0	0	100
12.5 (1/2)	161.1	5.0	161.1	5.0	95.0
9.50 (3/8)	481.4	15.0	642.5	20.0	80.0
4.75 (No. 4)	475.8	14.8	1118.3	34.8	65.2
Pan	1966.7 (**M_1**)		3085.0		

Coarse check sum:

$$\frac{3085.1\ g - 3085.0\ g}{3085.1\ g} \times 100 = 0.0\%$$

This is less than 0.3 percent therefore the results can be used for acceptance purposes.

Note 5: The pan mass determined in the laboratory (M_1) and the calculated mass (3085.1 – 1118.3 = 1966.7) should be the same if no material was lost.

The pan (1966.7 g) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was **512.8 g**. This is **M_2**.

In order to account for the fact that only a portion of the minus 4.75mm (No. 4) material was sieved, the mass of material retained on the smaller sieves is adjusted by a factor equal to M_1/M_2. The factor determined from M_1/M_2 must be carried to three decimal places. Both the individual mass retained and cumulative mass retained formulas are shown.

Individual Mass Retained:

M_1 = total mass of the minus 4.75mm (No. 4) before reducing.
M_2 = mass before sieving from the reduced portion of the minus 4.75 mm (No. 4).

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

Each "individual mass retained" on the fine sieves must be multiplied by this adjustment factor.

For example, the overall mass retained on the 2.00mm (No. 10) sieve is:

3.835 × 207.1 g = 794.2 g, as shown in the following table:

Final Gradation on All Sieves
Calculation by Individual Mass

Sieve Size mm (in.)	**Individual Mass Retained, g (IMR)**	**Adjusted Individual Mass Retained (AIMR)**	**Individual Percent Retained (IPR)**	**Calc'd Percent Passing (CPP)**	Reported Percent Passing* (RPP)
16.0 (5/8)	0	0	0.0	100.0	100
12.5 (1/2)	161.1	161.1	5.0	95.0	95
9.5 (3/8)	481.4	481.4	15.0	80.0	80
4.75 (No. 4)	475.8	475.8	14.8	65.2	65
2.0 (No. 10)	207.1 *× 3.835*	794.2	24.7	40.5	41
0.425 (No. 40)	187.9 *× 3.835*	720.6	22.4	18.1	18
0.210 (No. 80)	59.9 *× 3.835*	229.7	7.1	11.0	11
0.075 (No. 200)	49.1 *× 3.835*	188.3	5.9	5.1	5.1
Pan	7.8 *× 3.835*	29.9			
Dry mass of total sample, before washing: 3214.0 g					

*Report 75 µm (No. 200) sieve to 0.1 percent. Report all others to 1 percent.

Fine check sum:

$$\frac{512.8\ g - 511.8\ g}{512.8\ g} \times 100 = 0.2\%$$

This is less than 0.3 percent therefore the results can be used for acceptance purposes.

For Percent Passing (Calculated) see "Calculation" under Method A.

Cumulative Mass Retained:

M_1 = mass of the minus 4.75 mm (No. 4) before split
M_2 = mass before sieving of the split of the minus 4.75 mm (No. 4)

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

Each "cumulative mass retained" on the fine sieves must be multiplied by this adjustment factor then the cumulative mass of plus 4.75 mm (No. 4) portion of sample is added to equal the adjusted cumulative mass retained .

For example, the adjusted cumulative mass retained on the 0.425 mm (No. 40) sieve is:

$$3.835 \times 395.0\ g\ =\ 1514.8\ g$$

1514.8 + 1118.3 g = 2633.1: "Total Cumulative Mass Retained" as shown in the following table:

Final Gradation on All Sieves
Calculation by Cumulative Mass

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Adjusted Cumulative Mass Retained, g (ACMR)	Total Cumulative Mass Retnd. g (TCMR)	Cumulative Percent Retnd. (CPR)	Calc'd Percent Passing (CPP)	Reported Percent Passing* (RPP)
16.0 (5/8)	0		0	0.0	100.0	100
12.5 (1/2)	161.1		161.1	5.0	95.0	95
9.5 (3/8)	642.5		642.5	20.0	80.0	80
4.75 (No. 4)	1118.3		1118.3	34.8	65.2	65
2.0 (No. 10)	207.1 × *3.835*	794.2 + *1118.3*	1912.5	59.5	40.5	41
0.425 (No. 40)	395.0 × *3.835*	1514.8 + *1118.3*	2633.1	81.9	18.1	18
0.210 (No. 80)	454.9 × *3.835*	1744.5 + *1118.3*	2862.8	89.1	10.9	11
0.075 (No. 200)	504.0 × *3.835*	1932.8 + *1118.3*	3051.1	94.9	5.1	5.1
Pan	511.8 × *3.835*	1962.8 + *1118.3*	3081.1			

*Report 75 µm (No. 200) sieve to 0.1 percent. Report all others to 1 percent.

Fine check sum:

$$\frac{512.8\ g - 511.8g}{512.8\ g} \times 100 = 0.2\%$$

This is less than 0.3 percent therefore the results can be used for acceptance purposes.
For Percent Passing (Calculated) see "Calculation" under Method A.

Procedure Method C

1. Dry sample in accordance with the FOP for AASHTO T 255. Determine and record the total dry mass of the sample to the nearest 0.1 percent.

   Note 6: AASHTO T 27 allows for coarse aggregate to be run in a moist condition unless the nominal maximum size of the aggregate is smaller than 12.5 mm (1/2 in.), the coarse aggregate (CA) contains appreciable material finer than 4.75 mm (No. 4), or the coarse aggregate is highly absorptive.

2. Break up any aggregations or lumps of clay, silt or adhering fines to pass the 4.75 mm (No. 4) sieve. If substantial coatings remain on the coarse particles in amounts that would affect the percent passing any of the specification sieves, the sample should be tested with either Method A or Method B.

3. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the 4.75 mm (No.4) with a pan at the bottom to retain the minus 4.75 mm (No. 4).

4. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker or 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).

   Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

5. Determine the cumulative mass retained on each sieve to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in full openings of the sieve are cleaned out and included in the mass retained.

   Note 4: For sieves No. 4 and larger, material trapped in less than a full opening shall be checked by 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.

6. Determine the mass of material in the pan [minus 4.75 mm (No. 4)] (M_1).

7. Reduce the minus 4.75mm (No. 4), using a mechanical splitter in accordance with the FOP for AASHTO T 248, to produce a sample with a mass of 500 g minimum.

8. Determine and record the mass of the minus 4.75mm (No. 4) split ($M_{-\#4}$).

9. Perform steps 3 through 11 of Method A (Wash) on the minus 4.75mm (No. 4) split.

10. Select fine sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the 75µm (No. 200) with a pan at the bottom to retain the minus 75 µm (No. 200).

11. Repeat steps 4 and 5, Method C, with the minus 4.75mm (No. 4) including determining the mass of the material in the pan.

12. Compute the "Cumulative Percent Retained" and "Cumulative Percent Passing" for the 4.75 mm (No. 4) and larger as follows:

$$CPR = \frac{CMR}{M} \times 100 \qquad CPP = 100 - CPR$$

where:

CMR = Cumulative Mass Retained
CPR= Cumulative Percent Retained
M= Total Dry Sample mass before washing
CPP= Cumulative Percent Passing

13. Compute the "Cumulative Percent Retained" and/or "Cumulative Percent Passing" for the minus 4.75 mm (No. 4) as follows:

$$CPR_{-\#4} = \frac{CMR_{-\#4}}{M_{-\#4}} \times 100 \qquad CPP_{-\#4} = 100 - CPR_{-\#4} \qquad CPP = \frac{(CPP_{-\#4} \times CPP_{\#4})}{100}$$

where:

$CMR_{-\#4}$ = Cumulative mass retained for the sieve size based on a minus#4 split sample
$CPR_{-\#4}$ = Calculated cumulative percent retained based on the minus #4 split
$CPP_{-\#4}$ = Calculated percent passing based on the minus #4 split
$M_{-\#4}$ = Total mass of the minus #4 split before washing
$CPP_{\#4}$ = Calculated percent passing the #4 sieve

Also note that for minus No. 4 material using this method that:

$$CPP = \frac{CPP_{-\#4} \times (M_{-\#4} - CMR_{-\#4})}{M_{-\#4}}$$

Method C Sample Calculation

Sample calculation for percent retained and percent passing each sieve in accordance with Method C when the minus 4.75mm (No. 4) material is reduced and then washed:

Dry Mass of total sample (M): 3304.5 g

Dry Mass of minus 4.75mm (No. 4) reduced portion before wash ($M_{-\#4}$): 527.6 g

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

Gradation on Coarse Sieves

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Cumulative Percent Retained (CPR)	Cumulative Percent Passing (CPP)	Reported Percent Passing* (RPP)
16.0 (5/8)	0	0.0	100.0	100
12.5 (1/2)	125.9	3.8	96.2	96
9.50 (3/8)	604.1	18.3	81.7	82
4.75 (No. 4)	1295.6	39.2	**60.8**	61
Pan	2008.9			
Total Dry Sample (**M**) = 3304.5				

Coarse check sum:

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

This is less than 0.3 percent therefore the results can be used for acceptance purposes.

The pan (2008.9 g) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was $M_{-\#4}$ = **527.6 g**.

Gradation on -#4 Sieves

Sieve Size mm (in.)	Cumulative Mass Retained g ($CMR_{-\#4}$)	Cumulative Percent Retained$_{-\#4}$ ($CPR_{-\#4}$)	Cumulative Percent Passing$_{-\#4}$ ($CPP_{-\#4}$)	Cumulative Percent Passing (CPP)	Reported Percent Passing* (RPP)
2.0 (No. 10)	194.3	36.8	63.2	38.4	38
0.425 (No. 40)	365.6	69.3	30.7	18.7	19
0.210 (No. 80)	430.8	81.7	18.3	11.1	11
0.075 (No. 200)	484.4	91.8	8.2	5.0	5.0
Pan	495.1				
Dry mass of minus 4.75 mm (No. 4) sample, before washing (**$M_{-\#4}$**) : 527.6 g Dry mass of minus 4.75 mm (No. 4) sample, after washing: 495.3 g Calculated percent passing the #4 sieve (**$CPP_{-\#4}$**) = 60.8%					

Fine check sum:

$$\frac{495.3\ g - 495.1\ g}{495.3\ g} \times 100 = 0.04\%$$

This is less than 0.3 percent therefore the results can be used for acceptance purposes.

Final Gradation on All Sieves
Calculation by Cumulative Mass

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Cumulative Percent Retained (CPR)	Cumulative Percent Passing (CPP)	Cumulative Percent Passing (CPP)	Reported Percent Passing* (RPP)
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**	61
2.0 (No. 10)	194.3	36.8	63.2	38.4	38
0.425 (No. 40)	365.6	69.3	30.7	18.7	19
0.210 (No. 80)	430.8	81.7	18.3	11.1	11
0.075 (No. 200)	484.4	91.8	8.2	5.0	5.0
Pan	495.1				

*Report 75 µm (No. 200) sieve to 0.1 percent. Report all others to 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 FA 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
			$\sum = 785$				$\sum = 278$
			FM = 7.85				FM = 2.78

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

Report

- Results on forms approved by the agency
- Sample ID
- Individual mass retained on each sieve
- Individual percent retained on each sieve
- Cumulative mass retained on each sieve
- Cumulative percent retained on 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.

Oregon
John A. Kitzhaber, M.D., Governor

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October 31, 2014

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:

- **Under Mass Verification step 1 – Delete the second and third sentence.**
- **Under Procedure step 2 – Dispersing agents or wetting solutions are optional**
- **Under Procedure step 8 – delete this step**
- **Under Procedure step 12 - Shaking time will be a minimum of 10 minutes.**
- **Under Calculations step 4 – Aggregate Correction Factors are at the option of the Engineer.**
- **Under Report 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 bituminous mix samples in accordance with AASHTO T 30-15. This FOP utilizes the aggregate recovered from the ignition oven 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 in order 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
- Sieves
- Mechanical sieve shaker
- Mechanical Washing Apparatus (optional)
- Suitable drying equipment (see 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

Sample Sieving

- In this procedure it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification.
- Sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve.
- Sieves are shaken in a mechanical shaker for approximately 10 minutes or the minimum time determined to provide complete separation for the sieve shaker being used as established by the Time Evaluation.

Time Evaluation

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 prior to 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.

Overload Determination

- 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 kg) shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table 1.

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 1
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 mm (in.)		**203 dia (8)**	**305 dia (12)**	**305 by 305 (12 × 12)**	**350 by 350 (14 × 14)**	**372 by 580 (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

Mass Verification

1. Using the aggregate sample obtained from the FOP for AASHTO T 308, determine and record the mass of the sample, $M_{(T30)}$, to 0.1 g. This mass shall agree with the mass of the aggregate remaining after ignition, M_f from T 308, within 0.10 percent. If the variation exceeds 0.10 percent the results cannot be used for acceptance.

$$\frac{M_{f\,(T308)} - M_{(T30)}}{M_{f\,(T308)}} \times 100$$

Where:

$M_{(T30)} =$ 2422.3 g
$M_{f(T308)} =$ 2422.5 g

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

Procedure

1. Nest a sieve, such as a 2.0 mm (No. 10) or 1.18 mm (No. 16), above the 75µm (No. 200) sieve.

2. Place the test sample in a container and add sufficient water to cover it. Add a detergent, dispersing agent, or other wetting solution to the water to assure a thorough separation of the material finer than the 75µm (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.

3. Agitate vigorously to ensure complete separation of the material finer than 75µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. When using a mechanical washing device, exercise caution to avoid degradation of the sample. 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 75µm (No. 200) sieve.

4. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.

5. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 5. Repeat the operation until the wash water is reasonably clear. Continue washing until the agent is removed.

6. Rinse the material on the nested sieves until water passing through the sieve is reasonably clear.

7. Remove the upper sieve, return material retained to the washed sample.

8. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear.

9. Return all material retained on the 75 µm (No. 200) sieve to the washed sample by flushing into the washed sample.

10. Dry the washed aggregate to constant mass in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the “dry mass after washing.”

11. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.

12. 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).

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

13. Determine the mass retained on each sieve (individual/cumulative) to the nearest 0.1 g. Ensure that all material trapped in full openings of the sieves are cleaned out and included in the mass retained.

    Note 3: For sieves No. 4 and larger, material trapped in less than a full opening shall be checked 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.

Calculation

1. The total mass of the material after sieving should check closely with the original mass of sample placed on the sieves (dry mass after washing). When the masses before and after sieving differ by more than 0.2 percent, do not use the results for acceptance purposes.

2. Divide the masses for each sieve (individual/cumulative) by the total dry mass before washing and multiply by 100 to determine the percent retained on and passing each sieve.

3. Calculate the percent retained and passing each sieve to the nearest 0.1 percent.

4. Apply the Aggregate Correction Factor to the calculated percent passing, as required in the FOP for AASHTO T 308 “Correction Factor” Steps 10 through 12, to obtain the reported percent passing. Report percentages to the nearest 1percent except for the percent passing the 75 µm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

CHECK SUM

Total mass of material after sieving must agree with mass before sieving to within 0.2 percent.

$$\frac{dry\ mass\ after\ washing - total\ mass\ after\ sieving}{dry\ mass\ after\ washing} \times 100$$

PERCENT RETAINED:

Where:

IPR= Individual Percent Retained
CPR= Cumulative Percent Retained
M= Total Dry Sample mass before washing
IMR= Individual Mass Retained
CMR= Cumulative Mass Retained

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

PERCENT PASSING and REPORTED PERCENT PASSING:

Where:

PP= Calculated Percent Passing

PCP= Previous Calculated Percent Passing

RPP= Reported Percent Passing

$$PP = PCP - IPR \quad \boldsymbol{OR} \quad PP = 100 - CPR$$

$$RPP = PP + \text{Aggregate Correction Factor}$$

Example:

Dry mass of total sample, before washing (M): 2422.3 g

Dry mass of sample, after washing out the 75 µm (No. 200) minus: 2296.2 g

Amount of 75 µm (No. 200) minus washed out: 2422.3 g – 2296.2g = 126.1 g

Percent Retained 75 µm (No. 200):

$$\frac{63.5\ g}{2422.3\ g} \times 100 = 2.6\% \quad or \quad \frac{2289.6\ g}{2422.3\ g} \times 100 = 94.5\%$$

Percent Passing: 8.1% – 2.6% = 5.5% or 100 %– 94.5% = 5.5%

Reported Percent Passing: 5.5% + (-0.6%) = 4.9%

Gradation on All Screens

Sieve Size mm (in.)	Mass Retained (g) (MR)	Percent Retained (PR)	Cumulative Mass Retained (g) (CMR)	Cumulative Percent Retained (CPR)	Calc'd Percent Passing (PP)	Agg. Corr. Factor from T 308 (ACF)	Reported Percent Passing (RPP)
19.0 (3/4)	0.0		0.0	0	100.0		100
12.5 (1/2)	346.9	14.3	346.9	14.3	85.7		86
9.5 (3/8)	207.8	8.6	554.7	22.9	77.1		77
4.75 (No. 4)	625.4	25.8	1180.1	48.7	51.3		51
2.36 (No. 8)	416.2	17.2	1596.3	65.9	34.1		34
01.18 (No. 16)	274.2	11.3	1870.5	77.2	22.8		23
0.600 (No. 30)	152.1	6.3	2022.6	83.5	16.5		16
0.300 (No. 50)	107.1	4.4	2129.7	87.9	12.1		12
0.150 (No. 100)	96.4	4.0	2226.1	91.9	8.1		8
75 µm (No. 200)	63.5	2.6	2289.6	94.5	5.5	-0.6	4.9
Pan	5.7		2295.3				

Check sum:

$$\frac{2296.2\ g - 2295.3\ g}{2296.2\ g} \times 100 = 0.04\%$$

This is less than 0.2 percent therefore the results can be used for acceptance purposes.

Report

- Results 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
- Reported percent passing to the nearest 1 percent, except 75 µm (No. 200) sieve to the nearest 0.1 percent.

Standard Method of Test for

Specific Gravity and Absorption of Fine Aggregate

AASHTO Designation: T 84-13[1]
ASTM Designation: C 128-12

1. SCOPE

1.1. This method covers the determination of bulk and apparent specific gravity, 23/23°C (73.4/73.4°F), and absorption of fine aggregate.

1.2. This method determines (after 15–19 h of soaking in water) the bulk specific gravity and the apparent specific gravity, the bulk specific gravity on the basis of mass of saturated surface-dry aggregate, and the absorption.

1.3. The values stated in SI units are to be regarded as the standard.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 6, Fine Aggregate for Hydraulic Cement Concrete
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 11, Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 100, Specific Gravity of Soils
- T 133, Density of Hydraulic Cement
- T 248, Reducing Samples of Aggregate to Testing Size
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. *ASTM Standards*:

- C 128, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI 10, American National Standard for Metric Practice

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *absorption*—the increase in the mass of aggregate due to water in 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 ± 5°C for sufficient time to remove all uncombined water by reaching a constant mass.

3.1.2. *specific gravity*—the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.

3.1.2.1. *apparent specific gravity*—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.2. *bulk specific gravity*—the ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.3. *bulk specific gravity (SSD)*—the ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for 15–19 h (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4. SIGNIFICANCE AND USE

4.1. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Bulk specific gravity is also used in the computation of voids in aggregate in T 19M/T 19. Bulk specific gravity determined on the saturated surface-dry basis is used if the aggregate is wet; that is, if its absorption has been satisfied. Conversely, the bulk specific gravity determined on the oven-dry basis is used for computations when the aggregate is dry or assumed to be dry.

4.2. Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

4.3. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after soaking dry aggregate in water. Aggregates mined from below the water table may have a higher absorption when used, if not allowed to dry. Conversely, some aggregates when used may contain an amount of absorbed moisture less than that achieved by the required amount of soaking time: For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by T 255 by drying.

5. APPARATUS

5.1. *Balance*, conforming to the requirements of M 231, Class G 2.

5.2. *Pycnometer*—A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced with ±100 mm^3. The volume of the container filled to mark shall be at least 50 percent greater than the space required to accommodate the test sample. A volumetric flask of 500-mL capacity or a fruit jar fitted with a pycnometer top is satisfactory for a 500-g test sample of most fine aggregates. A Le Chatelier flask as described in T 133 is satisfactory for an approximately 55-g test sample.

5.3. *Mold*—A metal mold in the form of a frustum of a cone with dimensions as follows: 40 ± 3 mm inside diameter at the top, 90 ± 3 mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm.

5.4. *Tamper*—A metal tamper having a mass of 340 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

6. SAMPLING

6.1. Sampling shall be accomplished in general accordance with T 2.

7. PREPARATION OF TEST SPECIMEN

7.1. Obtain approximately one kilogram of the fine aggregate from the sample using the applicable procedures described in T 248.

7.1.1. Dry it in a suitable pan or vessel to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Allow it to cool to comfortable handling temperature, cover with water, either by immersion or by the addition of at least 6 percent moisture to the fine aggregate and permit to stand for 15 to 19 h.

7.1.2. As an alternative to Section 7.1.1, where the absorption and specific gravity values are to be used in proportioning concrete mixtures with aggregates used in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and, if the surfaces of the particles have been kept wet, the required soaking may also be eliminated.

Note 1—Values for absorption and for specific gravity in the saturated surface-dry condition may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 7.1.1.

7.2. Decant excess water with care to avoid loss of fines, spread the sample on a flat, nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. If desired, mechanical aids such as tumbling or stirring may be employed to assist in achieving the saturated surface-dry condition. As the material begins to dry sufficiently, it may be necessary to work it with the hands in a rubbing motion to break up any conglomerations, lumps, or balls of material that develop. Continue this operation until the test specimen approaches a free-flowing condition. Follow the procedure in Section 7.2.1 to determine whether or not surface moisture is present on the constituent fine aggregate particles. It is intended that the first trial of the cone test will be made with some surface water in the specimen. Continue drying with constant stirring, and if necessary, work the material with a hand-rubbing motion, and test at frequent intervals until the test indicates that the specimen has reached a surface-dry condition. If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few milliliters of water with the fine aggregate and permit the specimen to stand in a covered container for 30 min. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

7.2.1. *Cone Test for Surface Moisture*—Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling until overflow occurs and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Each drop should start about 5 mm (0.2 in.) above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. When the fine aggregate slumps slightly, it indicates that it has reached a surface-dry condition. Some angular fine aggregate or material with a high proportion of fines may not slump in the cone test upon reaching a surface-dry condition. This may be the case if fines become airborne upon dropping a handful of the sand from the cone test 100 to 150 mm onto a surface. For these materials, the saturated surface-dry condition should be considered as the point that one side of the fine aggregate slumps slightly upon removing the mold.

Note 2—The following criteria have also been used on materials that do not readily slump:

1. *Provisional Cone Test*—Fill the cone mold as described in Section 7.2.1 except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using three and two drops of the tamper, respectively. Level off the material even with the top of the mold; remove loose material from the base; and lift the mold vertically.
2. *Provisional Surface Test*—If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100 g of the material on a flat, dry, clean, dark, or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After 1 to 3 s, remove the fine aggregate. If noticeable moisture shows on the test surface for more than 1 to 2 s, then surface moisture is considered to be present on the fine aggregate.
3. Colorimetric procedures described by Kandhal and Lee, *Highway Research Record No. 307*, p. 44.
4. For reaching the saturated surface-dry condition on a single-size material that slumps when wet, hard-finish paper towels can be used to surface dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

8. PROCEDURE

8.1. Make and record all mass determinations to 0.1 g.

8.2. Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared as described in Section 7, and fill with additional water to approximately 90 percent of capacity. Manually roll, invert, and agitate or use a combination of these actions to eliminate all air bubbles in the pycnometer (Note 3). Accomplish mechanical agitation by external vibration of the pycnometer in a manner that will not degrade the sample. A level of agitation adjusted to just set individual particles in motion is sufficient to promote de-airing without degradation. A mechanical agitator shall be considered acceptable for use if comparison tests for each six-month period of use show variations less than the acceptable range of two results (d2s) indicated in Table 1 from results of manual agitation on the same material. Adjust its temperature to 23.0 ± 1.7°C (73.4 ± 3°F), if necessary by immersion in circulating water, and bring the water level in the pycnometer to its calibrated capacity. Determine total mass of the pycnometer, specimen, and water.

Note 3—It normally takes about 15 to 20 min to eliminate air bubbles by manual methods. Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles, or adding a few drops of isopropyl alcohol, after removal of air bubbles and just prior to bringing the water level to its calibrated capacity, has also been found useful in dispersing foam on the water surface. Do not use isopropyl alcohol when using the alternative method described in Section 8.2.1.

Table 1—Precision

	Standard Deviation (1s)[a]	Acceptable Range of Two Results (d2s)[a]
Single-operator precision:		
Bulk specific gravity (dry)	0.011	0.032
Bulk specific gravity (SSD)	0.0095	0.027
Apparent specific gravity	0.0095	0.027
Absorption,[b] percent	0.11	0.31
Multilaboratory precision:		
Bulk specific gravity (dry)	0.023	0.066
Bulk specific gravity (SSD)	0.020	0.056
Apparent specific gravity	0.020	0.056
Absorption,[b] percent	0.23	0.66

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15- to 19-h saturation times and other laboratories using 24 ± 4 h of saturation time. Testing was performed on aggregates of normal specific gravities, and started with aggregates in the oven-dry condition.

[b] Precision estimates are based on aggregates with absorptions of less than 1 percent and may differ for manufactured fine aggregates having absorption values greater than 1 percent.

8.2.1. *Alternative to Determining the Mass in Section 8.2*—The quantity of added water necessary to fill the pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Compute the total mass of the pycnometer, specimen, and water as follows:

$$C = 0.9975\,V_a + S + W \tag{1}$$

where:

C = mass of pycnometer with specimen and water to calibration mark, g;

V_a = volume of water added to pycnometer, mL;

S = mass of saturated surface-dry specimen, g; and

W = mass of the pycnometer empty, g.

8.2.2. *Alternative to the Procedure in Section 8.2*—Use a Le Chatelier flask initially filled with water to a point on the stem between the 0- and the 1-mL mark. Record this initial reading with the flask and contents within the temperature range of 23.0 ± 1.7°C (73.4 ± 3°F). Add 55 ± 5 g of fine aggregate in the saturated surface-dry condition (or other mass as necessary to result in raising the water level to some point on the upper series of graduation). After all fine aggregate has been introduced, place the stopper in the flask and roll the flask in an inclined position, or gently whirl it in a horizontal circle so as to dislodge all entrapped air, continuing until no further bubbles rise to the surface (Note 4). Take a final reading with the flask and contents within 1°C (1.8°F) of the original temperature.

Note 4—When using the Le Chatelier flask method, slowly adding a small measured amount (not to exceed 1 mL) of isopropyl alcohol, after removal of air bubbles, has been found useful in dispersing foam appearing on the water surface. The volume of alcohol used must be subtracted from the final reading (R_2).

8.3. Remove the fine aggregate from the pycnometer, dry to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for 1.0 ± 0.5 h and determine the mass.

Note 5—In lieu of drying and determining the mass of the sample that has been removed from the pycnometer, a second portion of the saturated surface-dry sample may be used to determine the oven-dry mass. This sample must be obtained at the same time and be within 0.2 grams of the mass of the sample that is introduced into the pycnometer.

8.3.1. If the Le Chatelier flask method is used, a separate sample portion is needed for the determination of absorption. Weigh a separate 500 ± 10 g portion of the saturated surface-dry fine aggregate, dry to constant mass, and reweigh. This sample must be obtained at the same time as the sample that is introduced into the Le Chatelier flask.

8.4. Determine the mass of the pycnometer filled to its calibration capacity with water at 23.0 ± 1.7°C (73.4 ± 3°F).

8.4.1. *Alternative to Determining the Mass in Section 8.4*—The quantity of water necessary to fill the empty pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Calculate the mass of the pycnometer filled with water as follows:

$$B = 0.9975\,V + W \tag{2}$$

where:

B = mass of flask filled with water, g;
V = volume of flask, mL; and
W = mass of the flask empty, g.

9. BULK SPECIFIC GRAVITY

9.1. Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as follows:

$$\text{Bulk sp gr} = A/(B + S - C) \tag{3}$$

where:

A = mass of oven-dry specimen in air, g;
B = mass of pycnometer filled with water, g;
S = mass of saturated surface-dry specimen, g; and
C = mass of pycnometer with specimen and water to calibration mark, g.

9.1.1. If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, as follows:

$$\text{Bulk sp gr} = \frac{S_1(A/S)}{0.9975\,(R_2 - R_1)} \tag{4}$$

where:

S_1 = mass of saturated surface-dry specimen used in Le Chatelier flask, g;
R_2 = final reading of water level in Le Chatelier flask; and
R_1 = initial reading of water level in Le Chatelier flask.

10. BULK SPECIFIC GRAVITY (SATURATED SURFACE-DRY BASIS)

10.1. Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the basis of mass of saturated surface-dry aggregate as follows:

$$\text{Bulk sp gr}\left(\text{saturated surface-dry basis}\right) = S/(B+S-C) \tag{5}$$

10.1.1. If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, on the basis of saturated surface-dry aggregate as follows:

$$\text{Bulk sp gr}\left(\text{saturated surface-dry basis}\right) = \frac{S_1}{0.9975\left(R_2 - R_1\right)} \tag{6}$$

11. APPARENT SPECIFIC GRAVITY

11.1. Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F) as follows:

$$\text{Apparent sp gr} = A/\left(B + A - C\right) \tag{7}$$

12. ABSORPTION

12.1. Calculate the percentage of absorption as follows:

$$\text{Absorption, percent} = \left[\left(S - A\right)/A\right] \times 100 \tag{8}$$

13. REPORT

13.1. Report specific gravity results to the nearest 0.001 (Fine Aggregate meeting M 6 requirements may be reported to the nearest 0.01) and absorption to the nearest 0.1 percent. The Appendix gives mathematical interrelationships among the three types of specific gravities and absorption. These may be useful in checking the consistency of reported data or calculating a value that was not reported by using other reported data.

13.2. If the fine aggregate was tested in a naturally moist condition other than the oven dried and 15-h soaked condition, report the source of the sample and the procedures used to prevent drying prior to testing.

14. PRECISION AND BIAS

14.1. The estimates of precision of this test method (listed in Table 1) are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this test method and ASTM C 128. The significant difference between the methods is that ASTM C 128 requires a saturation period of 24 ± 4 h, and T 84 requires a saturation period of 15 to 19 h. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

14.2. Because there is no accepted reference material suitable for determining the bias for the procedure in T 84 for measuring specific gravity and absorption of fine aggregate, no statement on bias is being made.

APPENDIX

(Nonmandatory Information)

X1. POTENTIAL DIFFERENCES IN BULK SPECIFIC GRAVITY AND ABSORPTION DUE TO PRESENCE OF MATERIAL FINER THAN 75 μM (NO. 200)

X1.1. It has been found that there may be significant differences in bulk specific gravity and absorption between fine aggregate samples tested with the material finer than 75 μm (No. 200) present and not present in the samples. Samples from which the material finer than 75 μm is not removed usually give a higher absorption and a lower bulk specific gravity compared with testing the same fine aggregate from which the material finer than 75 μm is removed following the procedures of Test Method T 11. Samples with material finer than 75 μm may build up a coating around the coarser fine aggregate particles during the surface-drying process. The resultant specific gravity and absorption that is subsequently measured is that of the agglomerated and coated particles and not that of the parent material. The difference in absorption and specific gravity determined between samples from which the material finer than 75 μm have not been removed and samples from which the material finer than 75 μm have been removed depends on both the amount of the material finer than 75 μm present and the nature of the material. When the material finer than 75 μm is less than about 4 percent by mass, the difference in specific gravity between washed and unwashed samples is less than 0.03. When the material finer than 75 μm is greater than about 8 percent by mass, the difference in specific gravity obtained between washed and unwashed samples may be as great as 0.13.

X1.2. The material finer than 75 μm, which is removed, can be assumed to have the same specific gravity as the fine aggregate. Alternatively, the specific gravity of the material finer than 75 μm may be further evaluated using T 100; however, this test determines the apparent specific gravity and not the bulk specific gravity.

X2. INTERRELATIONSHIPS BETWEEN SPECIFIC GRAVITIES AND ABSORPTION AS DEFINED IN T 84 AND T 85

X2.1. Let:

S_d = bulk specific gravity (dry-basis),
S_s = bulk specific gravity (SSD-basis),
S_a = apparent specific gravity, and
A = absorption in percent.

Then:

$$S_s = \left(1 + A/100\right) S_d \tag{X1.1}$$

$$S_a = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \tag{X1.2}$$

Or:

$$S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} = \frac{S_s}{1 - \frac{A}{100}\left(S_s - 1\right)} \tag{X1.3}$$

$$A = \left(\frac{S_s}{S_d} - 1\right) 100 \tag{X1.4}$$

$$A = \left(\frac{S_a - S_s}{S_a\left(S_s - 1\right)}\right) 100 \tag{X1.5}$$

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[1] This method is technically equivalent to ASTM C 128-12.

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 85-14. 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 ±5°C (230 ±9°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 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, conforming to AASHTO M 92.

- Large absorbent towel

Sample Preparation

1. Obtain the sample in accordance with the FOP for AASHTO T 2 (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 T 248.

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 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. 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 ±1.7°C (73.4 ±3°F). Shake the container to release entrapped air before recording the weight. Re-inspect the immersion tank to insure the water level is at the overflow outlet height. 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 in accordance with the FOP for AASHTO T 255 / T 265 (Aggregate section) and cool in air at room temperature for 1 to 3 hours. Designate this mass as “A.”

Calculations

Perform calculations and determine values using the appropriate formula below. In these formulas, A = oven dry mass, B = SSD mass, and C = weight in water.

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

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

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

- Results on forms approved by the agency
- Sample ID
- Specific gravity values to 3 decimal places
- Absorption to 0.1 percent

DETERMINING THE LIQUID LIMIT OF SOILS FOP FOR AASHTO T 89

Scope

This procedure covers the determination of the liquid limit of a soil in accordance with AASHTO T 89. It is used in conjunction with AASHTO T 90, Determining the Plastic Limit and Plasticity Index of Soils. The three values are used for soil classification and other purposes.

Apparatus

- Dish: preferably unglazed porcelain or similar mixing dish, about 115 mm (4.5 in.) in diameter.
- Spatula: having a blade 75 to 100 mm (3 to 4 in.) long and about 20 mm (3/4 in.) wide.
- Liquid Limit Device: manually or mechanically operated, consisting of a brass cup, carriage, and base plate.
- Grooving Tool: used to cut the soil in the liquid limit device cup.
- Gauge: part of the grooving tool or a separate metal bar, 10.0 ±0.2 mm (0.394 ±0.008 in.) thick and approximately 50 mm (2 in.) long.
- Containers: corrosion resistant, suitable for repeated heating and cooling, having close fitting lids to prevent the loss of moisture. One container is needed for each moisture content determination.
- Balance: conforming to AASHTO M 231, class G1, sensitive to 0.01 g with a 1200 g capacity.
- Oven: thermostatically controlled, capable of maintaining temperatures of 110 ±5°C (230 ±9°F).
- Graduated cylinders for measuring distilled or demineralized water.

Adjustment of Liquid Limit Device

The liquid limit device shall be inspected to determine that the device is in good working order; that the pin connecting the cup is not worn to permit side play; that the screws connecting the cup to the hanger are tight; that the points of contact on the cup and base are not excessively worn; that the lip of the cup is not excessively worn; and that a groove has not been worn in the cup. The grooving tool shall be inspected to determine that the critical dimensions are correct.

> ***Note 1:*** Wear is considered excessive when the point of contact on the cup or base exceeds approximately 13 mm (0.5 in.) in diameter, or when any point on the rim of the cup is worn to approximately 1/2 the original thickness. A slight groove in the center of the cup is not objectionable. If the groove becomes pronounced, the cup shall be replaced. A base that is excessively worn may be refinished as long as it is maintained within the tolerances specified.

Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10.0 ±0.2 mm (0.394 ±0.008 in.).

> ***Note 2:*** Check the height of the drop, before each new sample, by turning the crank at two revolutions per second while holding the gauge in position against the cup. If a ringing or clicking sound is heard without the cup rising from the gauge, the adjustment is correct. If no ringing is heard or if the cup rises from gauge, readjust the height of the drop. If the cup rocks on the gauge during this checking operation, the cam follower pivot is excessively worn and should be replaced.

Sample

Samples must be prepared per AASHTO T 87 or T 146. Obtain a sample with a mass of about 100 g taken from the portion of the material passing the 0.425 mm (No. 40) sieve.

The mass required depends upon the method chosen. Method A (multi-point method) requires approximately 100 g. Method B (single point method) requires approximately 50 g.

Procedure – Method A (Multi-Point)

1. Place the sample in the dish and thoroughly mix with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be in increments of 1 to 3 mL. Each increment shall be thoroughly mixed with the soil before another increment is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit device shall not be used for mixing soil and water. If too much water is added, the sample shall either be discarded or mixed and kneaded until natural evaporation lowers the moisture content.

   > ***Note 3:*** Some soils are slow to absorb water. It is possible to add water so fast that a false LL value is obtained. This can be avoided by allowing more mixing and/or time. Also, tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water.

2. Add sufficient water to form a uniform mass of a stiff consistency.
3. Place enough material in the cup so that, when squeezed and spread with the spatula, the soil will rest in the cup above the spot where the cup rests on the base and will be 10 mm thick at the point of maximum thickness. Use as few strokes of the spatula as possible, taking care to prevent the entrapment of air bubbles in the sample.
4. Divide the soil in the cup with a firm stroke of the grooving tool. Avoid tearing of the sides of the groove or slipping of the soil cake on the cup. Up to six strokes are permitted. The depth of the groove should be increased with each stroke, and only the last stroke should scrape the bottom of the cup.
5. Lift and drop the cup by turning the crank at a rate of approximately two revolutions per second until the two halves of the soil pat come together along a distance of about 13 mm (0.5 in.). Do not hold the base while the crank is turned. Record the number of shocks required to close the groove.

   > ***Note 4:*** Some soils tend to slide on the cup instead of flowing. If this occurs, water should be added, the sample remixed, and the procedure repeated. If the soil continues to slide on the cup, the test is not applicable and a note should be made that the liquid limit could not be determined.

6. Obtain a moisture content sample by slicing through the soil pat perpendicularly with the spatula and through the center of the groove. Place it into a suitable container for subsequent moisture determination.
7. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil).
8. Place the soil remaining in the cup back in the mixing dish and add 1 to 3 mL of water, or use previously prepared portions to which sufficient water has been added to result in a more fluid condition.
9. Repeat Steps 3 through 8, a minimum of two times. The object is to have a determination in all three shock ranges 25-35, 20-30, & 15-25.

Flow Curve – Method A

Prepare a flow curve on a semi-logarithmic graph with moisture content on the arithmetic vertical axis and the number of shocks on the logarithmic horizontal axis. The flow curve is a straight line drawn as closely as possible through three or more plotted points.

Liquid Limit – Method A

Determine the liquid limit. The moisture content at the intersection of the flow curve and the 25 shock line is the liquid limit.

Procedure – Method B (Single-Point)

1. Place the sample in the dish and thoroughly mix with 8 to 10 mL of distilled or demineralized water, and following the mixing procedure in Method A, Step 1.
2. Follow the procedure in Method A except that the soil pat should be prepared with water to produce a consistency that will close the two halves of the soil pat at least 13 mm (0.5 in.) within 22 to 28 shocks of the cup.

   Note: Groove closures occurring between 15 and 40 blows may be accepted if variations of ±5 percent of the true liquid limit are tolerable.
3. Return the soil remaining in the cup to the mixing dish and, without adding any additional water, repeat Step 2. If the closure again occurs within the acceptable range, obtain a moisture content specimen.
4. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil).

Liquid Limit – Method B

Calculate the liquid limit as follows:

$$LL = (w_N)(N/25)^{0.121}$$

N	**$(N/25)^{0.121}$**	**N**	**$(N/25)^{0.121}$**
22	0.985	26	1.005
23	0.990	27	1.009
24	0.995	28	1.014
25	1.000		

$$LL = (w_N)(N/25)^{0.121}$$

where

LL = liquid limit
w_N = moisture content of sample at N blows
N = number of blows

Example:

$w_N = 16.0$ % and $N = 23$
$LL = (16.0)(23/25)^{0.121} = 15.8$, say 16%

Report

Results shall be reported on standard forms approved by the agency. Report LL to the nearest whole percent.

DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS FOP FOR AASHTO T 90

Scope

This procedure covers the determination of the plastic limit and plasticity index of soil in accordance with AASHTO T 90. It is used in conjunction with AASHTO T 89, Determining the Liquid Limit of Soils. The three values are used for soil classification and other purposes. This FOP will cover the hand rolling method only. If the plastic limit device method is approved by the agency see AASHTO T 90 for that procedure.

Apparatus

- Dish: preferably unglazed porcelain or similar mixing dish, about 115 mm (4.5 in.) in diameter.
- Spatula: having a blade 75 to 100 mm (3 to 4 in.) long and about 20 mm (3/4 in.) wide.
- Rolling Surface: a ground glass plate or piece of smooth, unglazed paper.
- Containers: corrosion resistant, suitable for repeated heating and cooling, having close fitting lids to prevent the loss of moisture. One container is needed for each moisture content determination.
- Balance: conforming to AASHTO M 231, class G1, sensitive to 0.01 g with a 1200 g capacity.
- Oven: thermostatically controlled, capable of maintaining temperatures of 110 ±5°C (230 ±9°F)

Sample

The plastic limit procedure is often run in conjunction with the liquid limit procedure. If this is the case, the plastic limit sample should be obtained from the soil prepared for the liquid limit test at any point in the process at which the soil is plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed. Obtain approximately 8 g of soil to run the plastic limit test.

If the plastic limit only is to be determined, the sample must be prepared per AASHTO T 87 or T 146. Obtain about 20 g of material passing the 0.425 mm (No. 40) sieve. Mix the soil with distilled or demineralized water until the mass becomes plastic enough to be easily shaped into a ball. Obtain approximately 8 g of soil to run the plastic limit test.

> ***Note 1:*** Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water.

Procedure (Hand Rolling Method)

1. From the sample pull a 1.5 to 2 g mass.

2. Squeeze and form the test sample into an ellipsoidal-shape mass.

3. Roll this mass between the fingers or palm and the rolling surface with just sufficient pressure to roll the mass into a thread of uniform diameter along its length. Roll out between 80 and 90 strokes per minute, counting a stroke as one back and forth motion. The sample must be rolled into the 3 mm (1/8 in.) thread in no longer than 2 minutes.

4. Break the thread into six or eight pieces when the diameter of the thread reaches 3 mm (1/8 in.).

5. Squeeze the pieces together between the thumbs and fingers of both hands into an ellipsoidal-shape mass and reroll.

6. Continue this process of alternately rolling to a thread 3 mm (1/8 in.) in diameter, cutting into pieces, gathering together, kneading and rerolling until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread.

   Note 2: Crumbling may occur when the thread has a diameter greater than 3 mm (1/8 in.). This shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3 mm (1/8 in.) in diameter. The crumbling will manifest itself differently with various types of soil. Some soils fall apart in many pieces; others form an outside tubular layer that splits at both ends; splitting progresses toward the middle, and the thread falls apart in small platy particles. Heavy clay requires much pressure to deform the thread, particularly as it approaches the plastic limit, and the thread breaks into a series of barrel-shaped segments each 6 to 9 mm (1/4 to 3/8 in.) long. At no time shall the tester attempt to produce failure at exactly 3 mm (1/8 in.) diameter. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal-shaped mass nearer to the required 3 mm (1/8 in.) final diameter.

7. Gather the portions of the crumbled soil together and place in a suitable, tared container & cover.

8. Repeat steps one through seven until 8 g of sample have been tested and placed in the covered container.

9. Determine the moisture content of the sample in accordance with the FOP for T 255/T 265.

Plastic Limit

The moisture content, as determined in Step 9 above, is the Plastic Limit. It is advisable to run several trials on the same material to ensure a proper determination of the Plastic Limit of the soil.

Plasticity Index

The Plasticity Index (PI) of the soil is equal to the difference between the Liquid Limit (LL) and the Plastic Limit (PL).

PI = LL – PL

Examples:	**#1**	**#2**
	LL = 34 and PL = 17	LL = 16 and PL = 10
	PI = 34 – 17 = 17	PI = 16 – 10 = 6

Example Calculation

Container	**Container Mass, g**	**Container and Wet Soil Mass, g**	**Wet Soil Mass, g**	**Container and Dry Soil Mass, g**	**Dry Soil Mass, g**
1	14.44	22.65	8.21	21.45	7.01
2	14.18	23.69	9.51	22.81	8.63

Water Mass, g	**Moisture Content**	**Plastic Limit**
1.20	17.1	17
0.88	10.2	10

Report

Results shall be reported on standard forms approved by the agency. Report the PL and PI to the nearest whole number.

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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 Section

Earthwork and other graded Aggregates, except Base Aggregate Applications:

- **Less than 10% plus 4.75 mm (No. 4) (Method A), no coarse particle correction is required.**
- **10%-- 40% plus 4.75 mm (No. 4) (Method A), a coarse particle correction is required.**
- **Over 40% plus 4.75 mm (No. 4) (Method A), re-screen material and perform T 99 method D.**
- **Less than 10% plus 19.00 mm (3/4 in.) (Method D), no coarse particle correction is required.**
- **10%-- 30% plus 19.00 mm (3/4 in.) (Method D), a coarse particle correction is required.**
- **Over 30% plus 19.00 mm (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 4.75 mm (No. 4) and/or 19.00 mm (3/4 in.) screen use the average values to compute the coarse particle correction.**

Oregon
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October 31, 2015

To: All Holders of the Manual of Field Test Procedu

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 4.75mm (No. 4) screen exceeds 40% then use Method D.**
    2. **If the amount of material retained on the 19.00mm (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, 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 13, delete the second sentence and 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 99-15: Methods A, B, C, and D
- AASHTO T 180-15: 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 (¾ in.) 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. 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 moist 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 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 the “Calibration of Measure” section of AASHTO T 19 for Unit Mass of Aggregate.
- 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 (3/8 in.) in diameter, spaced approximately 90 degrees apart and approximately 19 mm (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 the FOP for 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 ±5°C (230 ±9°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.), conforming to AASHTO M 92.

- 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 ± 0.000001	Methods A, C: 0.000943 ±0.000001
	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	457
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: 0.0750 ±0.0009	Methods B, D: 0.0750 ±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	18
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.

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

Note 2: 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. 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.

Procedure

During compaction, the mold shall rest 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 0.005 kg (0.01 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. See Note 2. For many materials this condition can be identified by forming a cast by hand.

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 3: 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. Determine the mass of the mold and wet soil to the nearest 1 g (0.005 lb) or better.

7. Determine the wet mass of the sample by subtracting the mass in Step 1 from the mass in Step 6.

8. Calculate the wet density as indicated below under "Calculations."

9. Extrude the material from the mold. For soils and soil-aggregate mixtures, slice vertically through the center and take a representative moisture content sample from one of the cut faces, ensuring that all layers are represented. For granular materials, a vertical face will not exist. Take a representative sample. This sample must meet the sample size requirements of the test method used to determine moisture content.

Note 4: 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.

10. Determine the moisture content of the sample in accordance with the FOP for AASHTO T 255 / T 265.

11. 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. See Note 2.

12. Add sufficient water to increase the moisture content of the remaining soil by approximately 1 to 2 percentage points and repeat steps 3 through 11.

13. Continue determinations until there is either a decrease or no change in the wet density. There will be a minimum of three points on the dry side of the curve and two points on the wet side.

Note 5: In cases of free-draining granular material, the development of points on the wet side of optimum may not be practical.

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 = 1.916 kg (4.22 lb)

   Measured volume of the mold = 0.000946 m^3 (0.0334 ft^3)

$$Wet\ Density = \frac{1.1916\ kg}{0.000946\ m^3} = 2025\ kg/m^3$$

$$Wet\ Density = \frac{4.22\ lb}{0.0334\ ft^3} = 126.3\ lb/ft^3$$

2. Calculate the dry density as follows.

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

Where:

ρ_d = Dry density, kg/m^3 (lb/ft^3)
ρ_w = Wet density, kg/m^3 (lb/ft^3)
w = Moisture content, as a percentage

Example:

ρ_w = 2030 kg/m^3 (126.6 lb/ft^3)
w = 14.7%

$$\rho_d = \left(\frac{2030\ kg/m^3}{14.7 + 100}\right) \times 100 = 1770\ kg/m^3 \quad \rho_d = \left(\frac{126.6\ lb/ft^3}{14.7 + 100}\right) \times 100 = 110.4\ lb/ft^3$$

or

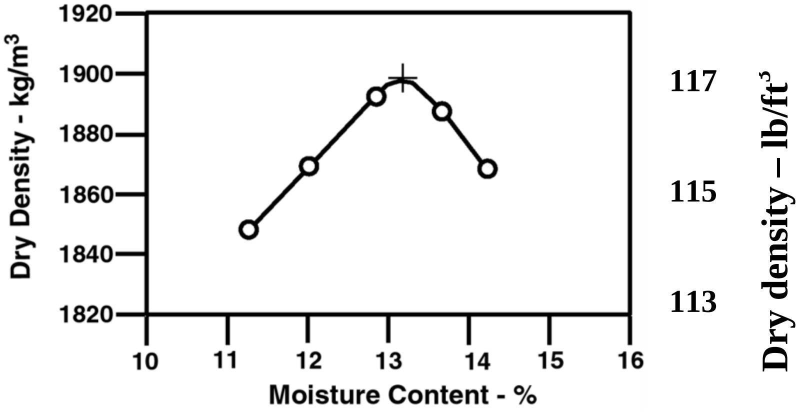
$$\rho_d = \left(\frac{2030\ kg/m^3}{\frac{14.7}{100} + 1}\right) = 1770\ kg/m^3 \quad \rho_d = \left(\frac{126.6\ lb/ft^3}{\frac{14.7}{100} + 1}\right) = 110.4\ lb/ft^3$$

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**	
1846	114.3	11.3
1868	115.7	12.1
1887	116.9	12.8
1884	116.7	13.6
1871	115.9	14.2



In this case, the curve has its peak at:

Maximum dry density = 1890 kg/m^3 (117.0 lb/ft^3)
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 closest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the closest 0.1 percent

ANNEX

CORRECTION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE FOR OVERSIZED PARTICLES

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, adjusted 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.

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 60ºC (140ºF).
   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.

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

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.

$$P_f = \frac{100 M_{DF}}{M_{DF} + M_{DC}} \qquad \frac{100 \ \times 15.4\ lb}{15.4\ lbs + 5.7\ lb} = 73\% \qquad \frac{100 \ \times 7.034\ kg}{7.03\ kg + 2.602\ kg} = 73\%$$

And

$$P_c = \frac{100 M_{DC}}{M_{DF} + M_{DC}} \qquad \frac{100 \ \times 5.7\ lb}{15.4\ lbs + 5.7\ lb} = 27\% \qquad \frac{100 \ \times 2.602\ kg}{7.03\ kg + 2.602\ kg} = 27\%$$

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 fine particles
M_{DC} = mass of oversize particles

Adjustment Equation Optimum Moisture

1. Calculate the corrected moisture content as follows:

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

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.

Adjustment Equation Density

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

$$D_d = \frac{100\%}{\frac{P_f}{D_f} + \frac{P_c}{k}}$$

Where:

D_d = corrected total dry density (combined fine and oversized particles) kg/m^3 (lb/ft^3)

D_f = dry density of the fine particles kg/m^3 (lb/ft^3), determined in the lab

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

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

k = Metric: 1,000 * Bulk Specific Gravity (G_{sb}) (oven dry basis) of coarse particles (kg/m^3).

k = English: 62.4 * Bulk Specific Gravity (G_{sb}) (oven dry basis) of coarse particles (lb/ft^3)

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

Sample Calculations:

- Metric:

Maximum laboratory dry density (D_f):	1890 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

$$D_d = \frac{100\%}{\frac{P_f}{D_f} + \frac{P_c}{k}}$$

$$D_d = \frac{100\%}{\frac{73\%}{1890\, kg/m^3} + \frac{27\%}{2697\, kg/m^3}}$$

$$D_d = \frac{100\%}{0.03862\, kg/m^3 + 0.01001\, kg/m^3}$$

$$D_d = 2056.3\, kg/m^3\ report\ \ 2056\, kg/m^3$$

English:

Maximum laboratory dry density (D_f): 117.0 lb/ft^3

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/ft^3

$$D_d = \frac{100\%}{\frac{P_f}{D_f} + \frac{P_c}{k}}$$

$$D_d = \frac{100\%}{\frac{73\%}{117.0\, lb/ft^3} + \frac{27\%}{168.3\, lb/ft^3}}$$

$$D_d = \frac{100\%}{0.6239\ \ lb/ft^3 + 0.1604\ \ lb/ft^3}$$

$$D_d = \frac{100\%}{0.7843\ \ lb/ft^3}$$

$$D_d = 127.50\ \ lb/ft^3 \quad report\ 127.5\ \ lb/ft^3$$

Report

- Results on forms approved by the agency
- Sample ID
- Adjusted maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Adjusted optimum moisture to the 0.1 percent

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 119-13. It is not applicable to non-plastic and non-cohesive concrete. With concrete using 37.5mm (1½ in.) or larger aggregate, the +37.5mm (1½ in.) aggregate must be removed in accordance with the FOP for WAQTC TM 2.

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

Apparatus

- Mold: The metal mold shall be 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.
- Mold: If other than metal, it must conform to AASHTO T 119, Sections 5.1.2.1 & 5.1.2.2.
- Tamping rod: 16 mm (5/8 in.) diameter and approximately 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 cone

Procedure

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate 37.5mm (1½ in.) or larger aggregate is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

   Note 1: Testing shall begin within five minutes of obtaining the sample.

2. Dampen the inside of the cone and place it on a dampened, rigid, nonabsorbent surface that is level and firm.
3. Stand on both foot pieces in order to hold the mold firmly in place.

4. Use the scoop to fill the cone 1/3 full by volume, to a depth of approximately 67 mm (2 5/8 in.) by depth.
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 cone 2/3 full by volume, to a depth of approximately 155 mm (6 1/8 in.) by depth.
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 cone 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 cone, stop, add more concrete, and continue rodding for a total of 25 strokes. Keep an excess 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.

    The entire operation from the start of the filling through removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2 1/2 minutes. Immediately measure the slump by:
13. Invert the slump cone and set it next to the specimen.
14. Lay the tamping rod across the mold so that it is over the test specimen.
15. 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 2: If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make 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.
16. Discard the tested sample.

Report

- Results on forms approved by the agency
- 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 Cemetitious 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 procedure covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121-15. 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 metal cylindrical 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 approximately 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: 7000 vibrations per minute, 19 to 38 mm (3/4 to 1 1/2 in.) in diameter, and the length of the shaft shall be at least 610 mm (24 in.).

- 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 ±0.5 lb) for use with measures of 0.014 m^3 (1/2 ft^3) or less, or having a mass of 1.02 ±0.23 kg (2.25 ±0.5 lb) for use with measures of 0.028 m^3 (1 ft^3).

Table 1
Dimensions of Measures

Capacity m^3 (ft^3)	Inside Diameter mm (in.)	Inside Height mm (in.)	Minimum Thicknesses mm (in.) Bottom	Minimum Thicknesses mm (in.) Wall	Nominal Maximum Size of Coarse Aggregate** mm (in.)
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: 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.

Standardization of Measure

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.

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 2, 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, from Table 2.

$$V_m = \frac{Mass\ of\ Water}{Density\ of\ Water}$$

Example: at 23°C (73.4°F)

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

Table 2
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)

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 slumps less than 25 mm (1 in.), consolidate the sample by internal vibration. When using measures greater than 0.0142 m^3 (1/2 ft^3) see AASHTO T 121.

Procedure – Rodding

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 prior to the FOP for AASHTO T 152.

   Note 1: If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

2. Determine the mass of the dry empty measure.

3. Dampen the inside of the measure.

4. 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.

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. Rod throughout its depth without hitting the bottom too hard.

6. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.

7. 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.

8. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.

9. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.

10. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

11. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.

12. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.

    Note 2: 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. Strike off by pressing the strike-off plate flat against the top surface, covering approximately 2/3 of the measure. Withdraw the strike-off plate with a sawing motion to finish the 2/3 originally covered. 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). 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.

14. Clean off all excess concrete from the exterior of the measure including the rim.

15. Determine and record the mass of the measure and the concrete.

16. If the air content of the concrete is to be determined, proceed to Rodding Procedure Step 13 of the FOP for AASHTO T 152.

Procedure - Internal Vibration

1. Perform Steps 1 through 3 of the rodding procedure.

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 in each layer. Do not let the vibrator touch the bottom or side of the measure.

   Note 3: Remove the vibrator slowly, so that no air pockets are left in the material.

   Note 4: 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. Fill the measure a bit over full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.

5. Insert the vibrator as in Step 3. Do not let the vibrator touch the side of the measure, but do penetrate the first layer approximately 25 mm (1 in.).

6. Return to Step 13 of the rodding procedure and continue.

Calculations

- **Density –** Calculate the net mass, M_m, of the concrete in the measure by subtracting the mass of the measure from the gross mass of the measure plus the concrete. Calculate the density, W, by dividing the net mass, M_m, by the volume, V_m, of the measure as shown below.

$$W = \frac{M_m}{V_m}$$

Example: $W = \frac{16.920\ kg}{0.007079\ m^3} = 2390\ \ kg/m^3$ $W = \frac{36.06\ lb}{0.2494\ ft^3} = 144.6\ \ lb/ft^3$

- **Yield –** Calculate the yield, Y (m^3 or yd^3), or volume of concrete produced per batch, by dividing the total mass of the batch, W_1, by the density, W, of the concrete as shown below.

$Y_{m^3} = \frac{W_1}{W}$ Example: $Y_{m^3} = \frac{2436\ kg}{2390\ kg/m^3} = 1.02m^3$

$$Y_{ft^3} = \frac{W_1}{W} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27\ ft^3/yd^3}$$

Example: $Y_{ft^3} = \frac{3978\ lb}{144.6\ lb/ft^3} = 27.51\ ft^3$ $Y_{yd^3} = \frac{27.51\ ft^3}{27\ ft^3/yd^3} = 1.02\ yd^3$

Note 5: The total mass, W_1, includes the masses of the cement, water, and aggregates in the concrete.

- **Cement Content –** Calculate the actual cement content, N, by dividing the mass of the cement, N_t, by the yield, Y, as shown below.

  Note 6: Specifications may require Portland cement content and cementitious materials content

$$N = \frac{N_t}{Y} \quad \text{Example:} \, N = \frac{261\,kg}{1.02\,m^3} = 256\,kg/m^3 \;\; N = \frac{602\,lb}{1.02\,yd^3} = 590\;lb/yd^3$$

- **Water Content** – Calculate the mass of water in a batch of concrete by summing the:
  - 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 the agency requires this)

This information is obtained from concrete batch tickets collected from the driver. Use the following 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

Calculate the mass of free water on aggregate as follows:

$$Free\ Water\ Mass = Total\ Aggregate\ Mass - \frac{Total\ Aggregate\ Mass}{1 + (Free\ Water\ Percentage/100)}$$

Example:

Total Wet Aggregate Mass = 3540 kg (7804 lb)

Free Water Percentage = 1.7*

∗ To determine Free Water percentage:

Total moisture content of the aggregates – absorbed moisture = Free Water

$$Free\ Water\ Mass = 3540\ kg - \frac{3540\ kg}{1 + (1.7/100)} \quad 7804\ lb - \frac{7804\ lb}{1 + (1.7/100)}$$

Example for actual water content:

Water added at batch plant =	300 L	79 gal
Water added in transit =	0 L	
Water added at jobsite =	40 L	11 gal
	340 L = 340 kg	90 gal = 751 lb

Coarse aggregate: 3540 kg (7804 lbs) @ 1.7% free water

Fine aggregate: 2490 kg (5489 lb) @ 5.9% free water

$$CA\ Free\ Water = 3540kg - \frac{3540\ kg}{1 + (1.7/100)} = 59\ kg \quad 7804\ lb - \frac{7804\ lb}{1 + (1.7/100)} = 130\ lb$$

$$FA\ Free\ Water = 2490kg - \frac{2490\ kg}{1 + (5.9/100)} = 139\ kg\ or$$

$$FA\ Free\ Water = 5489\ lb - \frac{5489\ lb}{1 + (5.9/100)} = 306lb$$

Mass of water in batch = 340 kg + 59 kg + 139 kg = 538 kg
751 lb + 130 lb + 306 lb = 1187 lb

Water/Cement Ratio – Calculate the water/cement ratio by dividing the mass of water in a batch of concrete by the mass of cementitious material in the batch. The masses of the cementitious materials are obtained from concrete batch tickets collected from the driver.

Example:

Cement:	950 kg	2094 lb
Fly Ash:	180 kg	397 lb
Water:	538 kg (from previous example)	1187 lb

$$W/C = \frac{538\ kg}{950\ kg + 180\ kg} = 0.476 \qquad W/C = \frac{1187\ lb}{2094\ lb + 397\ lb} = 0.477$$

Report 0.48

Report

- Results on forms approved by the agency
- Sample ID
- Density (unit weight) to 1 kg/m^3 (0.1 lb/ft^3)
- Yield to 0.01 m^3 (0.01 yd^3)
- Cement content to 1 kg/m^3 (1 lb/yd^3)
- Cementitious material content to 1 kg/m^3 (1 lb/yd^3)
- Water/Cement ratio to 0.01

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October 31, 2014

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 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.**

- **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 152-13, 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, and two methods for standardizing the gauge are presented.

Concrete containing aggregate that is 37.5 mm (1 ½ in.) or larger must be wet sieved. Sieve a sufficient amount of the sample over the 37.5 mm (1 ½ in.) sieve in accordance with the wet sieving portion of the FOP for WAQTC TM 2.

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
- 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 approximately 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: 7000 vibrations per minute, 19 to 38 mm (0.75 to 1.50 in.) in diameter, at least 75 mm (3 in.) longer than the section being vibrated for use with low slump concrete
- 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)

Standardization of Air Meter Gauge

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 log book 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. Determine the mass of the dry, empty air meter measure and cover assembly (mass method only).
2. Fill the measure nearly full with water.
3. Clamp the cover on the measure with the tube extending down into the water. Mark the petcock with the tube attached for future reference.
4. Add water through the petcock having the pipe extension below until all air is forced out the other petcock. Rock the meter slightly until all air is expelled through the petcock.
5. Wipe off the air meter measure and cover assembly, and determine the mass of the filled unit (mass method only).
6. 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.
7. 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.
8. Determine which petcock has the straight tube attached to it. Attach the curved tube to external portion of the same petcock.
9. 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 1 from the mass found in Step 5. 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 2: 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.

10. 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.
11. 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.
12. 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.
13. If an internal standardization vessel is used, follow steps 1 through 8 to set initial reading.
14. 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.)
15. Place the cover back on the measure and add water through the petcock until all the air has been expelled.
16. 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.
17. 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.
18. Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

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 slumps less than 25 mm (1 in.), consolidate the sample by internal vibration.

Procedure – Rodding

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate 37.5 mm (1½ in.) or larger is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

Note 3: Testing shall begin within five minutes of obtaining the sample.

2. Dampen the inside of the air meter measure and place on a firm level surface.

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.

Note 4: 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. 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.
13. Clean the top flange of the measure to ensure a proper seal.
14. Moisten the inside of the cover and check to see that both petcocks are open and the main air valve is closed.
15. Clamp the cover on the measure.
16. Inject water through a petcock on the cover until water emerges from the petcock on the other side.
17. Incline slightly and gently rock the air meter until no air bubbles appear to be coming out of the second petcock. The petcock expelling water should be higher than the petcock where water is being injected. Return the air meter to a level position and verify that water is present in both petcocks.
18. 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.
19. 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.

20. Close both petcocks.
21. Open the main air valve.
22. Tap around the perimeter of the measure smartly with the mallet.
23. 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.
24. Release or close the main air valve.
25. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and measure with clean water.
26. Open the main air valve to relieve the pressure in the air chamber.

Procedure - Internal Vibration

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate 37.5mm (1½ in.) or larger is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.
2. Dampen the inside of the air meter measure and place on a firm level surface.
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. 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.
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 as in Step 4. Do not let the vibrator touch the side of the measure, and penetrate the first layer approximately 25 mm (1 in.). 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. Return to Step 12 of the rodding procedure and continue.

Report

- Results 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.)

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October 31, 2013

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.**
- **When performing the Bulk Specific Gravity determination for Lab Fabricated Gyratory 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, use Method A. The Method C option is not allowed.**

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

Scope

This procedure covers the determination of bulk specific gravity (G_{mb}) of compacted hot mix asphalt (HMA) using three methods – A, B, and C – in accordance with AASHTO T 166-13. 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 from HMA 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.

Test specimens from HMA pavement will be sampled according to AASHTO R 67.

Terminology

Constant Mass: The mass at which further drying at 52 ±3°C (125 ±5°F) does not alter the mass by more than 0.05 percent. Samples shall initially be dried overnight and that mass determinations shall be made at 2-hour drying intervals. Recently molded laboratory samples that have not been exposed to moisture do not need drying.

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 110 ±5°C (230 ±9°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 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

Procedure - Method A (Suspension)

1. Dry the specimen to constant mass, if required.

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

2. Cool the specimen in air to 25 ±5°C (77 ±9°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 ±1°C (77 ±1.8°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.

8. Zero or tare the balance.

9. Immediately determine and record the mass of the 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 to exceed 15 seconds performing Steps 7 through 9.

Calculations - Method A (Suspension)

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

where:

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

C = Weight of specimen in water at 25 ±1°C (77 ±1.8°F), g

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

Example:

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

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

Apparatus - Method B (Volumeter)

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: Thermostatically controlled to 25 ±0.5°C (77 ±0.9°F).
- Thermometer: Range of 19 to 27°C (66 to 80°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 110 ±5°C (230 ±9°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.

Procedure - Method B (Volumeter)

1. Dry the specimen to constant mass, if required.

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

2. Cool the specimen in air to 25 ±5°C (77 ±9°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 for at least 10 minutes.

4. Fill the volumeter with distilled water at 25 ±1°C (77 ±1.8°F) making sure some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry. Determine the mass of the volumeter to the nearest 0.1 g. Designate this mass as "D."

5. At the end of the ten minute period, remove the specimen from the water bath and quickly surface dry with a damp cloth towel within 5 seconds.

6. Immediately determine and record the mass of the SSD specimen to the nearest 0.1 g.

7. 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 ±1°C (77 ±1.8°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 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)

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

where:

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 ±1°C (77 ±1.8°F), g

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

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

Example:

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

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

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

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. Determine which method to perform, A or B. Proceed with Method A or B, except that the dry mass, “A,” is determined last. In method A and B, start on Step 3 and complete that procedure, then continue as follows to determine mass “A.”

2. Place the specimen on a large, flat-bottom pan of known mass.

3. Heat at a minimum of 105°C (221°F), until the specimen can be easily separated to the point where the fine aggregate particles are not larger than 6.3 mm (¼ in.). In no case should the Job Mix Formula mixing temperature be exceeded.

4. Dry to constant mass. Constant mass is defined as the mass at which further drying at the temperature in Step 3 does not change by more than 0.05 percent after an additional 2 hour drying time.

5. Cool in air to 25 ±5°C (77 ±9°F).

6. Determine and record the mass of the pan and specimen to the nearest 0.1 g.

7. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the pan from the mass determined in Step 6. 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

- Results on forms approved by the agency
- Sample ID
- G_{mb} to 0.001
- Absorption to 0.01 percent
- Method performed

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October 31, 2009

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 168**

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

Sampling of mixture will conform to the following:

- **Drum Plants or Batch Plants – attached mechanical sampling device or from haul units at the production facility.**

SAMPLING OF BITUMINOUS PAVING MIXTURES
FOP FOR AASHTO T 168

Scope

This procedure covers the sampling of bituminous paving mixtures from HMA plants, haul units, and roadways in accordance with AASHTO T 168-03. Sampling is as important as testing, and every precaution must be taken to obtain a truly representative sample.

Apparatus

- Shovel
- Sample containers: such as cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers
- Scoops, trowels, or other equipment to obtain mix
- 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. Holes ¼ in. in diameter should be provided in each corner.
- 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 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

Sample Size

Sample size depends on the test methods specified by the agency for acceptance. Check agency requirement for the size required.

Sampling

General

- 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.

- 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 bituminous material will not migrate from the aggregate.

Attached Sampling Devices

Some agencies require mechanical sampling devices for hot mix asphalt (HMA) and cold feed aggregate on some projects. These are normally permanently attached devices that allow a sample container to pass perpendicularly through the entire stream of material or divert the entire stream of material into the container. Operation may be hydraulic, pneumatic, or manual and allows the sample container to pass through the stream twice, once in each direction, without overfilling. Special caution is necessary with manually operated systems since a consistent speed is difficult to maintain and non-representative samples may result. Check agency requirements for the specifics of required sampling systems.

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. Repeat until proper sample size has been obtained.

4. Transfer the HMA to an agency-approved container without loss of material.

Sampling from 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.

Sampling from Roadway Prior to Compaction (Plate Method)

Plate method using the “cookie cutter” sampling device.

There are two conditions that will be encountered when sampling hot mix asphalt (HMA) from the roadway prior to compaction. The two conditions are:

- Laying HMA on grade or untreated base material requires Method 1.
- Laying HMA on existing asphalt or laying a second lift of HMA 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 HMA.

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 Untreated Base:

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.
2. Secure the plate in place by driving a nail through the hole in the lead corner of the plate.
3. Pull the wire, attached to the outside corner of the plate, taut past the edge of the HMA mat and secure with a nail.

4. Let the paving operation proceed over the plate and wire. Immediately proceed with the sampling.

5. Using the exposed end of the wire, pull the wire up through the fresh HMA to locate the corner of the plate. 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 HMA to the plate.

6. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. Care shall be taken to prevent contamination of bituminous mixes by dust or other foreign matter, and to avoid segregation of aggregate and bituminous materials.

7. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose HMA.

Method 2 - Obtaining a Sample on Asphalt Surface:

1. After the paving machine has passed the sampling point, immediately place the "cookie cutter" sampling device on the location to be sampled. Push the cutter down through the HMA until it is flat against the underlying asphalt mat.

2. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. The hole made from the sampling must be filled by the contractor with loose HMA.

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, 2008

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 Procedure, Delete Step 8e.**
- **Run a minimum of Two Sand Equivalent samples. If these results do not meet the requirements of “Procedure, Step 8d.” 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 176-08. 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 ±5g. 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.).
- 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 T 248.
- Strike-off bar: A straightedge or spatula.
- Clock or watch reading in minutes and seconds.

- 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 a large number of determinations are to be made.

- Mechanical shaker: See AASHTO T 176 for equipment and procedure.

- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F).

- Thermometer: Calibrated liquid-in-glass or electronic digital type designed for total immersion and accurate to 0.1°C (0.2°F).

Materials

- Stock calcium chloride solution: Obtain commercially prepared calcium chloride stock solution meeting AASHTO requirements.

- Working calcium chloride solution: Dilute one 3 oz. measuring can (85 ±5 mL) of stock calcium chloride solution with 3.8 L (1 gal) distilled or demineralized water. Thoroughly mix the solution by filling the bottle with 2 L (1/2 gal) of water. Add the stock solution and agitate vigorously for 1 to 2 minutes. Add the remainder of the water, approximately 2 L (1/2 gal.). Repeat the agitation process. The shelf life of the working solution is approximately 30 days. 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.

  Note 2: Tap water may be used if it is proven to be non-detrimental to the test and if it is allowed by the agency.

Control

The temperature of the working solution should be maintained at 22 ±3°C (72 ±5°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 T 2 and reduce in accordance with the FOP for AASHTO T 248.

2. Prepare sand equivalent test samples from the material passing 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. All fines shall be cleaned from particles retained on the 4.75 mm (No. 4) sieve and included 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 3: 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 4: All tests, including reference tests, will be performed utilizing 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 5: 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 full 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.

2. Siphon 101.6 ±2.5 mm (4 ±0.1 in.) of working calcium chloride solution into the plastic cylinder. Pour the prepared test sample from the measuring can into the plastic cylinder, using the funnel to avoid spilling. 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.

3. Allow the wetted sample to stand undisturbed for 10 ±1 minutes. 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.

4. 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. Manually-operated Shaker 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 mm ±25 mm (9 ±1 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.

5. Set the cylinder upright on the work table and remove the stopper.

6. 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, since 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 6: 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.

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

   Note 7: 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.

8. 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.

   Note 8: 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.

   b. 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.

   c. 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.

d. If two Sand Equivalent (SE) samples are run on the same material and the second varies by more than ±4, based on the first cylinder result, additional tests shall be run.

e. 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 ±4, based on the average result, additional tests shall be run.

Calculations

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

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

For example: Sand Reading = 3.3 and Clay Reading = 8.0

$$SE = \frac{3.3}{8.0} \times 100 = 41.25\ or\ 41.3$$

Note 9: This example reflects the use of equipment made with English units. At this time, equipment made with metric units is not available.

2. 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.

3. In determining the average of the two or more samples, raise each calculated SE value to the next higher whole number before averaging. For example, calculated values of 41.3 and 42.8 would be reported as 42 and 43, respectively.

   Then average the two values:

$$\frac{42 + 43}{2} = 42.5$$

   If the average value is not a whole number, raise it to the next higher whole number – in this case: 43.

Report

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

Test Procedure AASHTO T 209 Continued

- **Use the procedure for Mixtures Containing Uncoated Porous Aggregate ("dryback" procedure) if the asphalt absorption (Pba) reported on the Mix Design is 1.2% or greater or if the mix design report indicates the "dryback" procedure was used for the mix design calculations. Use the results of the "dryback" procedure on all MDV and MAMD calculations.**

- **For each sublot of ACP produced, calculate the Pba and maintain a running average of 4 asphalt absorptions during ACP production. The Pba computation will be considered part of the required MDV testing. If the running average of four asphalt absorptions (Pba) is 1.2% or greater at any time during production and the procedure for Mixtures Containing Uncoated Porous Aggregate ("dryback" procedure) is not already being used, then use the "dryback" procedure on the remainder of the JMF production and apply to all MDV and MAMD calculations. A new lot will be started when the dryback procedure is initiated.**

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 ¾ 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 (77ºF) is 62.4.**

Oregon
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November 30, 2015

To: All Holders of the Manual of Field Test Procedure

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 Standardization of Pycnometer or Volumetric Flask section, delete the last sentence and replace with the following: The volumetric flask shall be standardized annually and when the calibration value is in question. The standardization will be based on the average of two separate weightings. The two weights must be within 0.3 grams for a validate average.**
- **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^{o}F +- 2^{o}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^{o}F +- 2^{o}F). Place the cover or a glass plate on the flask, and eliminate all air from the flask. The use of the temperature correction tables will not be allowed (The R Value under Calculation = 1.000).**

(See Next Page)

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

Scope

This procedure covers the determination of the maximum specific gravity (G_{mm}) of uncompacted hot mix asphalt (HMA) paving mixtures in accordance with AASHTO T 209-12. 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
- 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 a partial vacuum
- 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 4.0 kPa (30 mm Hg)
- Residual pressure manometer or vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (0.9°F)
- Bleeder valve to adjust vacuum
- Timer

Standardization of Pycnometer or Volumetric Flask

Use a pycnometer / volumetric flask that is standardized to accurately determine the mass of water, at 25 ±0.5°C (77 ±0.9°F), in the pycnometer / volumetric flask. The pycnometer / volumetric flask 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 T 168 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 and averaged. If the increments have a specific gravity difference greater than 0.014 the test must be re-run.

Table 1
Test Sample Size for G_{mm}

Nominal Maximum* Aggregate Size mm (in.)	Minimum Mass g
37.5 or greater (1 ½)	4000
19 to 25 (3/4 to1)	2500
12.5 or smaller (1/2)	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 (1/4 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, including the cover, to the nearest 0.1 g.

4. Place the sample in the container.

5. Determine and record the mass of the dry container, cover, 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 contents to a partial vacuum of 3.7 ±0.3 kPa (27.5 ±2.5 mm Hg) residual pressure for 15 ±2 minutes.

10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2 minute intervals. This agitation facilitates the removal of air.

11. Slowly open the release valve, turn off the vacuum pump, and remove the lid. When performing the pycnometer / volumetric flask method, complete steps 12B through 16B within 10±1 minutes.

Procedure – Bowl

12A. Fill the water bath to overflow level with water at 25 ±1°C (77 ±1.8°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 contents in water at 25 ±1°C (77 ±2°F) for 10 ±1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.

15A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.

16A. Refill the water bath to overflow level.

17A. Empty and re-submerge the bowl following Step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.

18A. Determine and record the submerged weight of the sample to the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 15A. Designate this submerged weight 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 contents so that the final temperature is within 25 ±1°C (77 ±2°F).

14B. Finish filling the pycnometer / volumetric flask with water that is 25 ±1°C (77 ±2°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 minutes 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 “ASSD.”

6. Calculate, as indicated below, G_{mm} using “A” and “ASSD,” and compare the two values.

Calculation

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

Bowl Procedure

$$G_{mm} = \frac{A}{A - C} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} - C}$$

(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

C = submerged weight of sample in water, g

Example:

A = 1432.7 g

A_{SSD} = 1434.2 g

C = 848.6 g

$$G_{mm} = \frac{1432.7\ g}{1432.7\ g - 848.6\ g} = 2.453 \qquad or \qquad G_{mm} = \frac{1432.7\ g}{1434.2\ g - 848.6\ g} = 2.447$$

Pycnometer / Volumetric Flask Procedure

$$G_{mm} = \frac{A}{A + D - E} \times R \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} + D - E} \times R$$

(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 = Mass of pycnometer / volumetric flask filled with water at 25°C (77°F), g, determined during the Standardization of Pycnometer / Volumetric Flask procedure

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

R = Factor from Table 2 to correct the density of water – use when a test temperature is outside 25 ±1°C (77 ±2°F)

Example (in which two increments of a large sample are averaged):

Increment 1	Increment 2
A = 2200.3 g	A = 1960.2 g
D = 7502.5 g	D = 7525.5 g
E = 8812.3 g	E = 8690.8 g
Temperature = 26.2°C	Temperature = 25.0°C

$$G_{mm_1} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.3\ g} \times 0.99968 = 2.470$$

$$G_{mm_2} = \frac{1960.2\ g}{1960.2\ g + 7525.5\ g - 8690.8\ g} \times 1.00000 = 2.466$$

Allowable variation is: 0.014

2.470 - 2.466 = 0.004, which is < 0.014, so they can be averaged.

Average

2.470 + 2.466 = 4.936 4.936 ÷ 2 = 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 in Metric units or 62.245 in English units.

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

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

or

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

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

Report

- Results on forms approved by the agency
- Sample ID
- G_{mm} to three decimal places
- Theoretical maximum density to1 kg/m^3 ($0.1\ lb/ft^3$)

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DATE: October 1, 2001

TO: All Holders of the Manual of Field Test Procedures File Code:

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- Addendum to step 5, 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.**
- **Procedure- Addendum to step 9, Use the following equation in lieu of the conversion curve to calculate the moisture content based on the dry weight of material. See form 3468.**
- **% Moisture based on Dry =** $$\frac{\%\,\text{Moisture Gauge Reading}}{100 - \%\,\text{Moisture Gauge Reading}} \text{ X } 100$$
- **Reporting- Report moisture to the nearest 0.1%.**

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 soils 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 potential for sparks or other ignition might 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")

Material

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

Note 1: Check the manufacturer's recommendations for maximum storage life and replacement, and storage requirements.

Procedure

1. With the moisture tester in a horizontal position place three scoops, approximately 24 g, of calcium carbide, into the body.
2. Place two steel balls into the body of the tester with the calcium carbide.
3. Obtain a sample of soil of the wet mass specified by the manufacturer, using the balance built into the unit, and place the soil into the cap of the tester.

   Note 2: This method shall not be used on granular material having particles large enough to affect the accuracy of the test. In general, no + 4.75 mm (No.4) material.

> ***Note 3:*** If the anticipated moisture content 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 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 turn the unit to vertical and gently tap to allow the soil to fall from the cap into the pressure vessel. Do not allow the steel balls to strike the bottom of the pressure vessel.
6. Return vessel to horizontal position. Create a circular motion that causes the steel balls to roll around the interior perimeter of the vessel. Do not allow the steel balls to hit the cap or the bottom of the pressure vessel. Continue this motion vigorously for 60 seconds then rest for 30 seconds. Repeat motion and resting cycles a minimum of three times or until no further reaction occurs.
7. Allow time for the dissipation of the heat generated by the chemical reaction.
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.
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

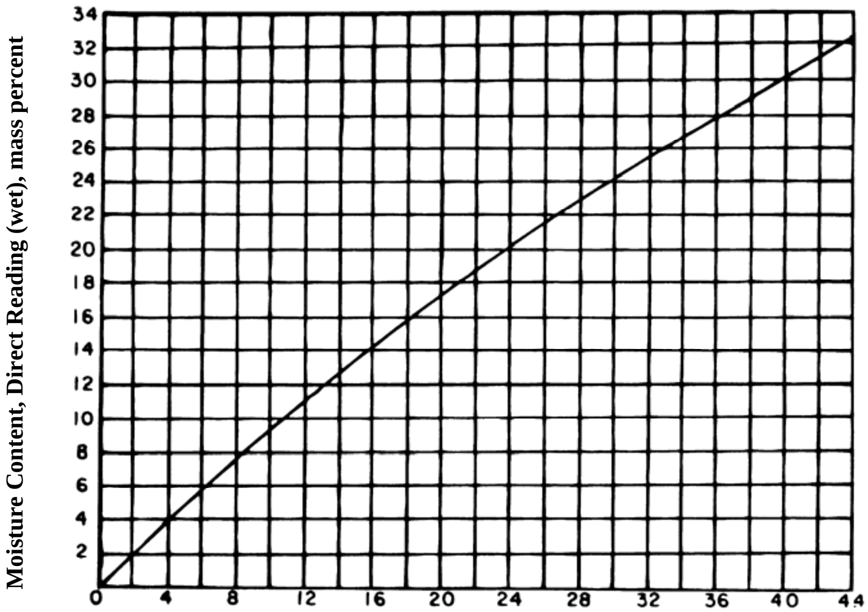
1. The tester determines moisture content based on the wet mass of the soil. Moisture content based on the dry mass of soil is obtained from a conversion chart or curve supplied with each tester. See Figure 1 for curve from AASHTO T 217.

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

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

Figure 1

Conversion Curve for Moisture Tester Reading



Moisture Content, Oven Dry, mass percent

Report

Results shall be reported on standard forms approved by the agency. Report moisture content to the nearest 1 percent.

Standard Practice for

Capping Cylindrical Concrete Specimens

AASHTO Designation: T 231-13
ASTM Designation: C 617-98 (2003)

AASHTO
THE VOICE OF TRANSPORTATION

1. SCOPE

1.1. This method covers apparatus, materials, and procedures for capping freshly molded concrete cylinders with neat cement and hardened cylinders and drilled concrete cores with high-strength gypsum plaster or sulfur mortar.

1.2. The values stated in SI units are the preferred standard.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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.* For specific precaution statements, see Sections 4.3 and 6.2.4.1.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:
- M 85, Portland Cement
- M 240M/M 240, Blended Hydraulic Cement
- T 22, Compressive Strength of Cylindrical Concrete Specimens
- T 106M/T 106, Compressive Strength of Hydraulic Cement Mortar (Using 50-mm or 2-in. Cube Specimens)

2.2. *ASTM Standards*:
- C 287, Standard Specification for Chemical-Resistant Sulfur Mortar
- C 472, Standard Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete
- ASTM *Manual of Aggregate and Concrete Testing*

2.3. *ANSI Standard*:
- B 46.1, Standard for Surface Texture, Surface Roughness, Waviness and Lay

3. SIGNIFICANCE AND USE

3.1. This practice describes procedures for providing plane surfaces on the end surfaces of freshly molded concrete cylinders, hardened cylinders, or drilled concrete cores when the end surfaces do not conform with the planeness and perpendicularity requirements of applicable standards.

4. CAPPING EQUIPMENT

4.1. *Capping Plates*—Neat cement caps and high-strength gypsum plaster caps shall be formed against a glass plate at least 6 mm (0.25 in.) thick or a machined metal plate at least 11 mm (0.45 in.) thick (Note 1), on a polished plate of granite or diabase at least 75 mm (3 in.) thick. Sulfur mortar caps shall be formed against similar metal or stone plates. In all cases, plates shall be at least 25 mm (1 in.) greater in diameter than the test specimen and the working surfaces shall not depart from a plane by more than 0.05 mm (0.002 in.) in 150 mm (6 in.). The surface roughness of newly finished metal plates shall not exceed that set forth in Table 4 of the American National Standard for Surface Texture (ANSI B46.1) or 0.003 mm (125 μ in.) for any type of surface and direction of lay. The surface when new shall be free of gouges, grooves, or indentations beyond those caused by the finishing operation. Metal plates that have been in use shall be free of gouges, grooves, or indentations greater than 0.25 mm (0.010 in.) deep or greater than 32 mm^2 (0.05 in.^2) in surface area. If a recess is machined into the metal plate, the thickness of the plate beneath the recessed area shall be at least 13 mm (0.5 in.). In no case shall the recess in the plate be deeper than 13 mm (0.5 in.).

Note 1—In vertical capping devices, use of two-piece metal capping plates is advantageous as this facilitates refinishing of the capping surface should it become necessary to do so. In such devices, the lower section is a solid plate and the upper section has a circular hole that forms the recess. The two sections are customarily fastened together with machine screws. It is advantageous to have the upper surface of the lower plate case hardened. A Rockwell hardness of HRC 48 is suggested.

4.2. *Alignment Devices*—Suitable alignment devices such as guide bars or bull's-eye levels shall be used in conjunction with capping plates to ensure that no single cap will depart from the perpendicularity of the cylindrical specimen by more than 0.5 degrees [approximately equivalent to 3.2 mm in 305 mm (0.125 in. in 12 in.)]. The same requirement is applicable to the relationship between the axis of the alignment device and the surface of a capping plate when guide bars are used. In addition, the location of each bar with respect to its plate must be such that no cap will be off-centered on a test specimen by more than 1.6 mm (0.06 in.).

4.3. *Melting Pots for Sulfur Mortars*—Pots used for melting sulfur mortars shall be equipped with automatic temperature controls and shall be made of metal or lined with a material that is nonreactive with molten sulfur.

Caution—Melting pots equipped with peripheral heating will ensure against accidents during reheating of cooled sulfur mixtures that have a crusted-over surface. When using melting pots not so equipped, a buildup of pressure under the hardened surface crust on subsequent reheating may be avoided by use of a metal rod that contacts the bottom of the pot and projects above the surface of the fluid sulfur mix as it cools. The rod should be of sufficient size to conduct enough heat to the top on reheating to melt a ring around the rod first and thus avoid the development of pressure. A large metal ladle can be substituted for the rod.

Sulfur melting pots should be used under a hood to exhaust the fumes to outdoors. Heating over an open flame is dangerous because the flash point of sulfur is approximately 227°C (440°F) and the mixture can ignite due to overheating. Should the mixture start to burn, covering will snuff out the flame. The pot should be recharged with fresh material after the flame has been extinguished.

5. CAPPING MATERIALS

5.1. The strength of the capping material and the thickness of the caps shall conform to the requirements of Table 1.

Table 1—Compressive Strength and Maximum Thickness of Capping Materials

Cylinder Compressive Strength, MPa (psi)	Minimum Strength of Capping Material	Maximum Average Thickness of Cap	Maximum Thickness Any Part of Cap
3.5 to 50 MPa (500 to 7000 psi)	35 MPa (5000 psi) or cylinder strength, whichever is greater	6 mm (0.25 in.)	8 mm (0.31 in.)
greater than 50 MPa (7000 psi)	Compressive strength not less than cylinder strength, except as provided in Section 5.1.1.	3 mm (0.125 in.)	5 mm (0.20 in.)

5.1.1. If sulfur mortar, high strength gypsum plaster, and other materials except neat cement paste are to be used to test concrete with a strength greater than 50 MPa (7000 psi), the manufacturer or the user of the material must provide documentation:

- that the average strength of 15 cylinders capped with the materials is not less than 98 percent of the average strength of 15 companion cylinders capped with neat cement paste or 15 cylinders ground plane to within 0.05 mm (0.002 in.);
- that the standard deviation of the strengths of the capped cylinders is not greater than 1.57 times that of the standard deviation of the reference cylinders;
- that the cap thickness requirements were met in the qualification tests; and
- of the hardening time of the caps used in the qualification tests.

5.1.2. Additionally, the qualification test report must include the compressive strength of 50-mm (2-in.) cubes of the material qualified and of neat cement paste cubes, if used. Capping materials conforming to these requirements are permitted to be used for cylinders with strengths up to 20 percent greater than the concrete tested in these qualification tests. The manufacturer must requalify lots of material manufactured on an annual basis or whenever there is a change in the formulation of the raw materials. The user of the material must retain a copy of the qualification results, and the dates of manufacture of material qualified and of the material currently being used. (See Table 2.)

Table 2—Sample Report of Qualifications of a Capping Material

Note-Manufacturer: Testing Supplies Co.
Capping Material: Super Strong AAA-Sulfur mortar
Lot: 12a45 Date Tested: 11/3/98
Signed by:______________________________________(Testing Agency and Responsible Official)

Item	Capping Material	Control Cylinders	Ratio	Criteria	Pass/Fail
Concrete cylinder test data					
Type of capping material	Sulfur	Ground			
Average concrete strength, MPa (psi)	76.2 (11,061)	75.9 (11,008)	1.005	>0.98 Xc	Pass
Standard deviation MPa (psi)	2.59 (376)	1.72 (250)	1.504	≤1.57 C	Pass
Number of cylinders tested	15	15			
Cap age when cylinders tested	7 days	n/a			
Capping material test data					
Average cap thickness mm (in.)	2.8 (0.11)	n/a			
Compressive strength of 50-mm (2-in.) cubes, MPa (psi)	91 (12,195)				
Cube age when tested	7 days				
Maximum concrete strength qualified, MPa (psi)			1.2 av. str = 91.5 (13,273)[a]		

[a] Nominally a specified strength of 75 MPa (11 000 psi) and perhaps somewhat higher.

5.1.3. The compressive strength of capping materials shall be determined by testing 50-mm (2-in.) cubes following the procedure described in T 106M/T 106. Except for sulfur mortars, molding procedures shall be as in T 106M/T 106 unless other procedures are required to eliminate large entrapped air voids. See test methods for alternative compaction procedures. Cure cubes in the same environment for the same length of time as the materials used to cap specimens.

5.1.4. The strength of the capping material shall be determined on receipt of a new lot and at intervals not exceeding 3 months. If a given lot of the capping material fails to conform to the strength requirements, it shall not be used, and strength tests of the replacement material shall be made weekly until four consecutive determinations conform to specification requirements.

5.2. *Neat Hydraulic Cement Paste*:

5.2.1. Make the qualification test of the neat hydraulic cement paste prior to use for capping to establish the effects of water/cement ratio and age on compressive strength of 50-mm (2-in.) cubes (Note 2).

Note 2—The cements used generally conform to M 85 Types I, II, or III; however, M 240M/M 240 blended cements, calcium aluminate, or other hydraulic cements producing acceptable strength may be used.

5.2.2. Mix the neat cement paste to the desired consistency at a water/cement ratio equal to or less than that required to produce the required strength, generally 2 to 4 h before the paste is to be used (Note 3). Remix as necessary to maintain acceptable consistency (Note 4). Some retempering of the paste is acceptable if the required water/cement ratio is not exceeded. Optimum consistency is generally produced at water/cement ratios of 0.32 to 0.36 by mass for Type I and Type II cements and 0.35 to 0.39 by mass for Type III cements.

Note 3—Freshly mixed pastes tend to bleed, shrink, and make unacceptable caps. The 2- to 4-h period is generally appropriate for portland cements.

Note 4—The required consistency of the paste is determined by the appearance of the cap when it is stripped. Fluid paste results in streaks in the cap. Stiff paste results in thick caps.

5.3. *High-Strength Gypsum Cement Paste*:

5.3.1. No fillers or extenders may be added to neat high-strength gypsum cement paste subsequent to the manufacture of the cement (Note 5). Qualification tests shall be made to determine the effects of water/cement ratio and age on the compressive strength 50-mm (2-in.) cubes. Retarders may be used to extend working time, but their effects on required water/cement ratio and strength must be determined (Note 6.)

Note 5—Low-strength molding plaster, plaster of paris, or mixtures of plaster of paris and portland cement are unsuitable for capping.

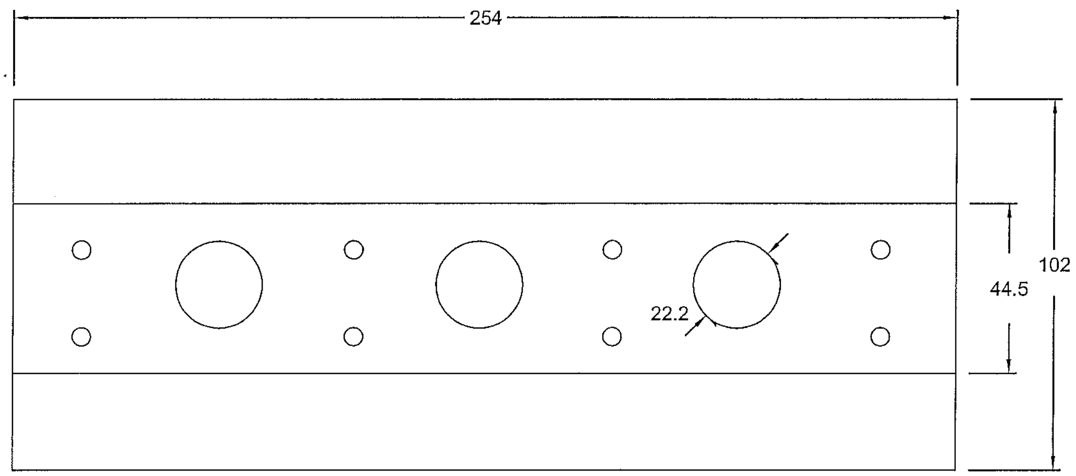
Note 6—The water/gypsum cement ratio should be between 0.26 and 0.30. Use of low water/cement ratios and vigorous mixing will usually permit development of 35 MPa (5000 psi) at ages of 1 to 2 h. Higher water/gypsum cement ratios extend working time, but reduce strength.

5.3.2. Mix the neat gypsum cement paste at the desired water/cement ratio and use it promptly because it sets rapidly.

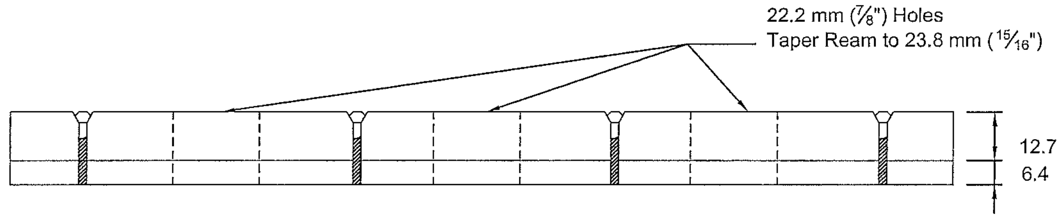
5.4. *Sulfur Mortar*:

5.4.1. Proprietary or laboratory prepared sulfur mortars are permitted if allowed to harden a minimum of 2 h before testing concrete with strength less than 35 MPa (5000 psi). For concrete strengths of 35 MPa (5000 psi) or greater, sulfur mortar caps must be allowed to harden at least 16 h before testing, unless a shorter time has been shown to be suitable as specified in Section 5.1.1.

5.4.2. *Determination of Compressive Strength*—Prepare test specimens using a cube mold and base plate conforming to the requirements of T 106M/T106 and a metal cover plate conforming in principle to the design shown in Figure 1 (Note 7). Bring the various parts of the apparatus to a temperature of 20 to 30°C (68 to 86°F), lightly coat the surfaces that will be in contact with the sulfur mortar with mineral oil and assemble near the melting pot. Bring the temperature of the molten sulfur mortar in the pot within a range of 129 to 143°C (265 to 290°F), stir thoroughly, and begin casting cubes. Using a ladle or other suitable pouring device, quickly fill each of the three compartments until the molten material reaches the top of the filling hole. Allow sufficient time for maximum shrinkage, due to cooling, and solidification to occur (approximately 15 min) and refill each hole with molten material (Note 8). After solidification is complete, remove the cubes from the mold without breaking off the knob formed by the filling hole in the cover plate. Remove oil, sharp edges, and fins from the cubes and check the planeness of the bearing surfaces in the manner described in T 106M/T 106. After storage at room temperature to the desired age, but not less than 2 h, test cubes in compression following the procedure described in T 106M/T 106 and calculate the compressive strength in MPa (psi).



Cover Plate - Plan View



Cover Plate - Front View

Dimensional Equivalents

mm	6.4	12.7	22.2	44.5	100	250
in.	$^1/_4$	$^1/_2$	$^7/_8$	$1^3/_4$	4	10

Notes: All dimensions shown in millimeters unless otherwise noted.

Figure 1—Sketch of Cover for 50-mm (2-in.) Cube Mold

Note 7—If desired, a plain phenol formaldehyde (bakelite) plate of 3-mm (0.125-in.) thickness, provided with three appropriately spaced filling holes, may be inserted between the cover plate and the mold to slow the rate of cooling of test specimens.

Note 8—The second filling helps to prevent the formation of a large void or shrinkage pipe in the body of a cube. However, such defects may occur no matter how much care is exercised, and it therefore is advisable to inspect the interior of tested sulfur mortar cubes for homogeneity whenever the strength values obtained are significantly lower than anticipated.

6. CAPPING PROCEDURES

6.1. *Freshly Molded Cylinders*—Use only neat portland cement pastes (Note 9) to cap freshly molded cylinders. Make caps as thin as practical. Do not apply the neat paste to the exposed end until the concrete has ceased settling in the molds, generally from 2 to 4 h after molding. During the molding of the cylinder, strike off the upper end even with or slightly below the plane of the rim of the mold. Mix the neat paste to a stiff consistency 2 to 4 h before it is to be used in order to allow the paste to go through its period of initial shrinkage. The strength of the paste will depend on the consistency, water/cement ratio, curing, brand, and type of cement. For Type I and Type II cement pastes, the optimum consistency is generally produced at a water/cement ratio of 0.32 to 0.36 by mass. For Type III cement, the water ratio should generally be between 0.35 to 0.39 by mass. The paste will stiffen during the 2- to 4-h waiting period and the use of retempering water is not recommended. However, if retempering water is used, the amount should not increase the water/cement ratio by more than 0.05 by mass. Remove free water and laitance from the top of the specimen immediately before capping. Form the cap by placing a conical mound of paste on the specimen and then gently pressing a freshly oiled capping plate on the conical mound until the plate contacts the rim of the mold. A very slight twisting motion may be required to extrude excess paste and minimize air voids in the paste. The capping plate must not rock during this operation. Carefully cover the capping plate and mold with a double layer of damp burlap and a polyethylene sheet to prevent drying. Removal of the capping plate after hardening may be accomplished by tapping the edge with a rawhide hammer in a direction parallel to the plane of the cap.

Note 9—Type I neat cement caps generally require at least 6 days to develop acceptable strength and Type III neat cement caps at least 2 days. Dry concrete specimens will absorb water from freshly mixed neat cement paste and produce unsatisfactory caps. Neat cement paste caps will shrink and crack on drying and therefore should be used only for specimens that are to be moist-cured continuously until time of testing.

6.2. *Hardened Concrete Specimens*:

6.2.1. *General*—Table 1 gives a differentiation on the thickness of capping materials based on the compressive strength of cylinders. If either or both ends of a specimen have coatings or deposits of oily or waxy materials that would interfere with the bond of the cap, remove such coatings or deposits. If necessary, the ends of a specimen may be slightly roughened with a steel file or wire brush to produce proper adhesion of the cap. If desired, capping plates may be coated with a thin layer of mineral oil or grease to prevent the capping material from adhering to the surface of the plate.

Form the caps as described in Section 6.1 using capping plates described in Section 4.1 to achieve the alignment required in Section 4.2 (Note 10). Generally capping plates may be removed within 45 min with gypsum cement pastes and after 12 h with neat cement paste, without visibly damaging the cap.

Note 10—A number of methods have been used to obtain the desired perpendicularity of the cap to the axis of the cylinder. A mound of paste can be placed on a capping plate and the specimen lowered into it. A bull's-eye level on the top of the cylinder helps obtain alignment. A mound of paste can be placed on top of the cylinder and a capping plate pressed into it, again using the bull's-eye level. A better system is to make a half-height mold with a vertical split so that it can be slipped over the hardened cylinder. A clamp is used to position the mold and to ensure the required cap thickness. The mound of paste can then be placed either on a capping plate or on top of the cylinder and pressed until the plate contacts the mold. As noted earlier, very stiff paste may require excessive force and produce thick or defective caps.

6.2.2. *End Condition*—The distance of any point on an uncapped end from a plane that passes through the highest point of the end surface and is perpendicular to the axis of the cylinder shall not exceed 3 mm (0.125 in.) (Note 11). If the end exceeds this limit, the end of the cylinder shall be cut, lapped, or ground prior to capping.

Note 11—This provision is to control the difference between the thickest and thinnest parts of a cap. The distance may be checked using a square with one blade touching the cylinder parallel to the cylinder axis and the other blade touching the highest point on the end of the cylinder. The distance between the blade of the square and the lowest point on the end of the cylinder is measured.

6.2.3. *Capping with High-Strength Gypsum Plaster*—Mix high-strength plaster for capping, using the same percent of mixing water as was used in making the qualification test described in Section 5.2.1 (Note 12).

Note 12—High-strength gypsum caps soften and deteriorate on contact with water and cannot be used on freshly mixed concrete or stored in a moist room for more than very brief periods up to 4 h.

6.2.4. *Capping with Sulfur Mortar*—Prepare sulfur mortar for use by heating to about 130°C (265°F), as periodically determined by an all-metal thermometer inserted near the center of the mass. Empty the pot and recharge with fresh material at frequent enough intervals to ensure that the oldest material in the pot has not been used more than five times (Note 13). Fresh sulfur mortar must be dry at the time it is placed in the pot as dampness may cause foaming. Keep water away from molten sulfur mortar for the same reason. The capping plate or device should be warmed slightly before use to slow the rate of hardening and permit the production of thin caps. Oil the capping plate lightly and stir the molten sulfur mortar immediately prior to pouring each cap. The ends of moist-cured specimens shall be dry enough at the time of capping to preclude the formation of steam or foam pockets under or in the cap larger than 6 mm (0.25 in.) in diameter. To ensure that the cap shall be bonded to the surface of the specimen, the end of the specimen shall not be oiled prior to application of the cap. When using a vertical device, pour the mortar onto the surface of the capping plate, lift the cylinder above the plate, and contact the cylinder sides with the guides; slide the cylinder down the guides onto the capping plate while keeping constant contact with the alignment guides. The cylinder end should continue to rest on the capping plate with cylinder sides in positive contact with the alignment guides until the mortar has hardened. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies. The sulfur mortar cap may be tapped or rubbed with a light metal implement. If a hollow sound is produced, an unsatisfactory mortar cap is indicated. See Section 25.16 of the ASTM *Manual of Aggregate and Concrete Testing.*

Note 13—Reuse of material must be restricted in order to minimize loss of strength and pourability occasioned by contamination of the mortar with oil, miscellaneous debris, and loss of sulfur through volatilization.

6.2.4.1. **Caution**—Hydrogen sulfide gas may be produced during capping when sulfur mortar is contaminated with organic materials such as paraffin or oil. The gas is colorless and has a notoriously bad odor of rotten eggs; however, the odor should not be relied upon as a warning sign, because the sensitivity to the odor disappears rapidly on exposure. High concentrations are lethal and less concentrated dosages may produce nausea, stomach ache, distress, dizziness, headache, or irritation of the eyes. For this and other reasons, it is desirable that the melting pot be located under a hood or near an exhaust fan and that the capping area be well ventilated.

6.2.5. *Daily Check*—During each day's capping operation, planeness of the caps on at least three specimens representing the start, middle, and end of the run shall be checked by means of a straightedge and feeler gauge, making a minimum of three measurements on different diameters to ensure that the surfaces of the caps do not depart from a plane by more than 0.05 mm (0.002 in.).

7. PROTECTION OF SPECIMENS AFTER CAPPING

7.1. Moist-cured specimens shall be maintained in a moist condition between the completion of capping and the time of testing by returning them to moist storage or wrapping them with a double layer of wet burlap. Specimens with gypsum plaster caps shall not be immersed in water and shall not be stored in a moist room for more than 4 h. If stored in a moist room, the plaster caps shall be protected against water dripping on their surfaces.

APPENDIX

(Nonmandatory Information)

X1. COMPOSITION AND DETERMINATION OF LOSS ON IGNITION OF SULFUR MORTAR CAPPING MATERIALS

X1.1. *Composition*:

X0.0.1. Loss on ignition, 48 to 70 percent. Residue after ignition, 30 to 52 percent.

X1.2. *Determination of Loss on Ignition*—Obtain samples from caps on concrete cylinders or from cast specimens similar to caps in size and thickness. Divide each cap-size specimen into eight approximately equal triangular sections, and secure test samples by breaking any two or four of the triangular sections into small pieces with the fingers. Using a balance capable of determining mass to an accuracy of 0.01 g, measure out 20 to 25 g of fragmented material in a previously ignited, cooled, and tared Coors No. 3, high-form porcelain crucible. Place the crucible on a ring approximately 50 mm (2 in.) above a Terrel-type bunsen burner and adjust the flame so that the sulfur burns slowly without spattering (Note X1). (See Section 4.) When the sulfur has been completely consumed, adjust the burner for high heat and ignite the residue for 30 min. Cool the crucible and residue in a desiccator and determine the mass. Continue to ignite, cool, and determine the mass of the crucible until a constant mass is obtained. Calculate the percentage of loss on ignition, C, as follows (Note X2):

$$C = \frac{A}{B} \times 100 \tag{X1.1}$$

where:

A = original mass of sample less mass of the residue after ignition; and

B = original mass of sample.

Note X1—Where the filler is known or found to be composed of carbonate minerals, the ignition test shall be made at a carefully controlled temperature in the range from 600 to 650°C (1110 to 1200°F), to prevent calcination of the mineral. Small amounts of plasticizer and carbon filler will be included in the reported value for loss on ignition using the simple test herein described.

Note X2—A referee procedure for the determination of the percent of sulfur contained in sulfur mortar may be found in ASTM C 287.

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October 31, 2014

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 248**

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 may be reduced using either Method A or Method B. 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 either Method A or Method B.

  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 AGGREGATES TO TESTING SIZE
FOP FOR AASHTO T 248

Scope

This procedure covers the reduction of samples to the appropriate size for testing in accordance with AASHTO T 248-14. 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
- Canvas or plastic sheet, approximately 2 by 3 m (6 by 9 ft)

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 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.

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

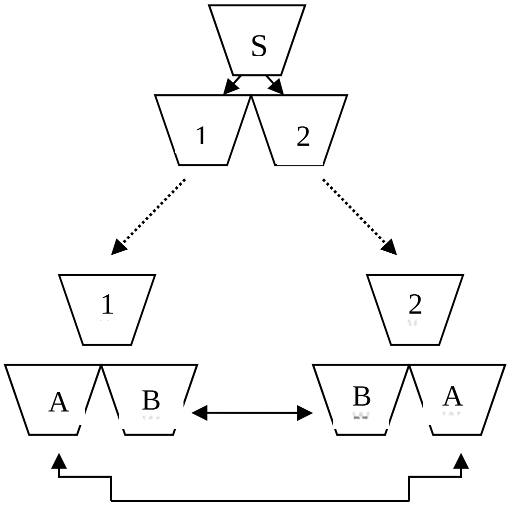
Method A – Mechanical Splitter

1. Place the sample in the hopper or pan and uniformly distribute it from edge to edge so that approximately equal amounts flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the pans below.

2. Reduce the sample from one of the two pans as many times as necessary to reduce the sample to meet the minimum size specified for the intended test. The portion of the material collected in the other pan may be reserved for reduction in size for other tests.

3. As a check for effective reduction, 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. In lieu of the check for effective reduction, use the method illustrated in Figure 1.

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.

Calculation

$$\frac{Smaller\ Mass}{Larger\ Mass} = Ratio \qquad (1 - ratio) \times 100 = \%\ Difference$$

Splitter check: 5127 g total sample mass

Splitter pan #1: 2583 g

Splitter pan #2: 2544 g

$$\frac{2544\ \text{g}}{2583\ \text{g}} = 0.985 \qquad (1 - 0.985) \times 100 = 1.5\%$$

Procedure

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 canvas or plastic sheet:

1. Place the sample on the sheet.

2. Mix the material thoroughly a minimum of four times by pulling each corner of the sheet 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 sheet 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 sheet 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 sheet.

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 <u>two diagonally opposite</u> quarters.

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 255-00 and AASHTO T 265-15. 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 principle 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, controlled:
  - Forced draft oven
  - Ventilated oven
  - Convection oven
- Heat source, uncontrolled:
  - Infrared heater/heat lamp, hot plate, fry pan, or any other device/method that will dry the sample without altering the material being dried
  - Microwave oven (900 watts minimum)

- Utensils such as spoons

- Hot pads or gloves

Sample Preparation

In accordance with the FOP for AASHTO T 2 obtain a representative sample in its existing condition.

For aggregates the representative 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)
4.75 (No. 4)	500 (1.1)
9.5 (3/8)	1500 (3.3)
12.5 (1/2)	2000 (4)
19.0 (3/4)	3000 (7)
25.0 (1)	4000 (9)
37.5 (1 1/2)	6000 (13)
50 (2)	8000 (18)
63 (2 1/2)	10,000 (22)
75 (3)	13,000 (29)
90 (3 1/2)	16,000 (35)
100 (4)	25,000 (55)
150 (6)	50,000 (110)

* 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 representative 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
0.425 (No. 40)	10
4.75 (No. 4)	100
12.5 (1/2)	300
25.0 (1)	500
50 (2)	1000

Immediately seal or cover 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.

    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.

3. Determine and record the total mass of the container and wet sample.

4. Determine and record the wet mass of the sample 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 apparatus:
    a. For aggregate –
        i. Controlled heat source (oven): at 110 ±5°C (230 ±9°F).
        ii. Uncontrolled heat source (Hot plate, infrared heater, etc.): Stir frequently to avoid localized overheating.
    b. For soil – controlled heat source (oven): at 110 ±5°C (230 ±9°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, etc.): 10 minutes
        iii. Uncontrolled heat source (Microwave oven): 2 minutes

Caution: Some minerals in the sample may cause the aggregate to overheat, 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:

    a. For Aggregate – less than a 0.10 percent change after additional drying time.

    b. For Soil – no change after additional drying time. A sample dried overnight (15 hours minimum) is sufficient in most cases.

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 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 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, etc.	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:

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

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 g - 1232.1 g = 1405.1 g

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

Mass, M_n, of dry sample: 2634.1 g - 1232.1 g = 1402.0 g

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

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

Mass of container and dry sample after third drying cycle: 2633.0 g
Mass, M_n, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

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

0.08 percent is less than 0.10 percent, so constant mass has been reached for an aggregate, but continue drying for soil.

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

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

Report

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

Oregon
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November 30, 2015

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".**
- **Under Section Maximum Dry Density and Optimum Moisture Content Determination, delete step 3 and replace with the following: The one-point must fall either between or on the highest and lowest curves in the family. If it does not, then a full curve must be developed or the guidelines for Selecting a Single Curve (Appendix B) may be utilized if applicable.**
- **See Appendix A for Family of Curves Development and Appendix B for guidelines on Selecting a Single Curve, located at the end of AASHTO T 272.**

FAMILY OF CURVES – ONE-POINT METHOD
FOP FOR AASHTO T 272

Scope

This procedure provides for a rapid determination of the maximum density and optimum moisture content of a soil sample, utilizing a family of curves and a one-point determination in accordance with AASHTO T 272-15. This procedure is related to the FOP for AASHTO T 99/T 180.

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. 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 in the FOP for AASHTO T 99/T 180.

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 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.

Procedure

See the FOP for AASHTO T 99/T 180.

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 = 1.9323 kg (4.26 lb)

   Measured volume of the mold = 0.0009469 m^3 (0.03344 ft^3)

$$Wet\ Density = \frac{1.9323\ kg}{0.0009469\ m^3} = 2041\ kg/m^3$$

$$Wet\ Density = \frac{4.26\ lb}{0.03344\ ft^3} = 127.4\ lb/ft^3$$

2. Calculate the dry density as follows.

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

Where:

ρ_d = Dry density, kg/m^3 (lb/ft^3)
ρ_w = Wet density, kg/m^3 (lb/ft^3)
w = Moisture content, as a percentage

Example:

ρ_w = 2041 kg/m^3 (127.56 lb/ft^3)
w = 11.4%

$$\rho_d = \left(\frac{2041\, kg/m^3}{11.4 + 100}\right) \times 100 = 1832\ kg/m^3 \quad \rho_d = \left(\frac{127.4\, lb/ft^3}{11.4 + 100}\right) \times 100 = 114.4\ lb/ft^3$$

or

$$\rho_d = \left(\frac{2041\, kg/m^3}{\frac{11.4}{100} + 1}\right) = 1832\ kg/m^3 \quad \rho_d = \left(\frac{127.4\, lb/ft^3}{\frac{11.4}{100} + 1}\right) = 114.4\, lb/ft^3$$

Maximum Dry Density and Optimum Moisture Content Determination

1. If the moisture-density one-point falls on one of the curves in the existing family of curves, the maximum dry density and optimum moisture content defined by that curve shall be used.

2. If the moisture-density one-point falls within the family of curves but not on an existing curve, a new curve shall be drawn through the plotted single point, parallel and in character with the nearest existing curve in the family of curves. The maximum dry density and optimum moisture content as defined by the new curve shall be used.

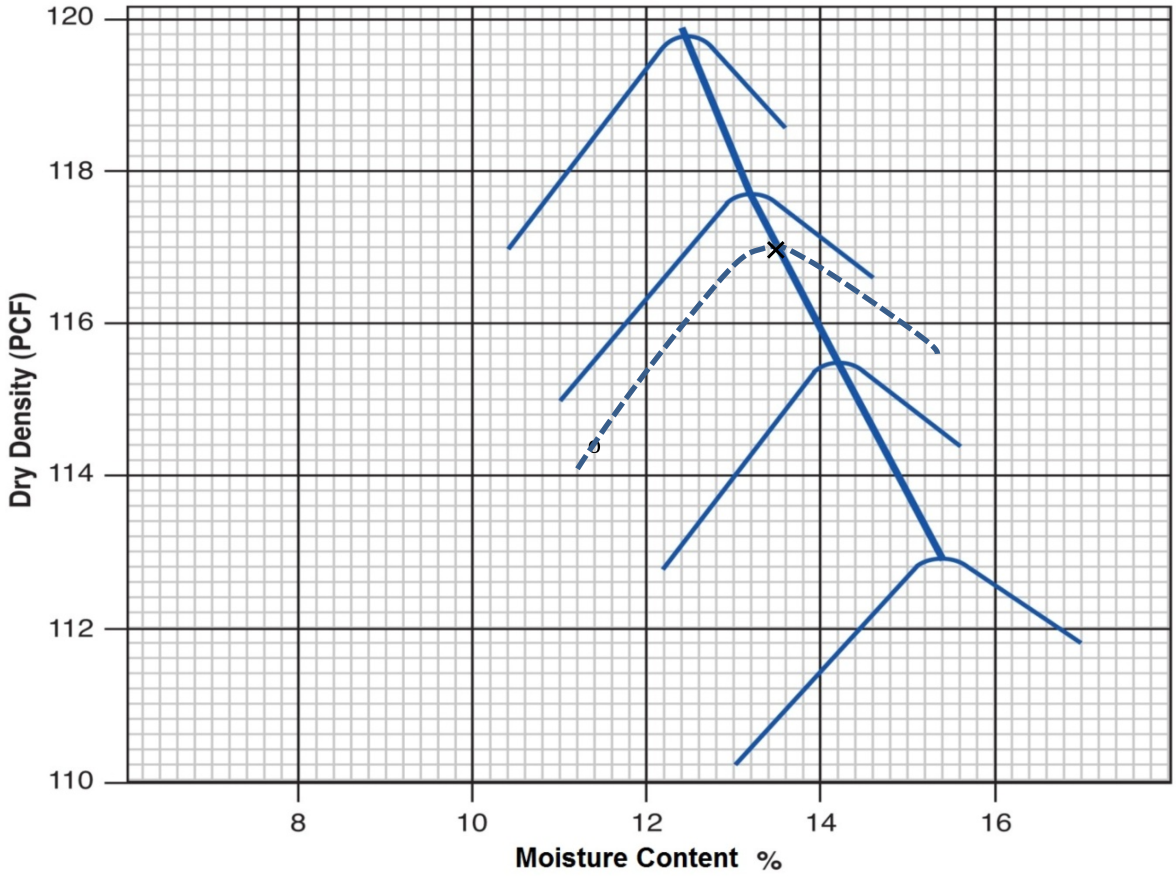
3. The one-point must fall either between or on the highest or lowest curves in the family. If it does not, then a full curve must be developed.

4. 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.

5. If the family of curves is such that the new curve through a one-point is not well defined or is in any way questionable, a full moisture-density relationship shall be made for the soil to correctly define the new curve and verify the applicability of the family of curves.

Note 1: 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



Example:

A moisture-density procedure (FOP for AASHTO T 99/T 180) was performed. A dry density of 114.4 lb/ft^3 and a corresponding moisture content of 11.4 percent were determined. This point was plotted on the appropriate family between two previously developed curves.

The "dashed" curve beginning at the moisture-density one-point was sketched between the two existing curves. A maximum dry density of 117.0 lb/ft^3 and a corresponding optimum moisture content of 13.5 percent were estimated.

Report

- Results on forms approved by the agency
- Sample ID
- Maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the closest 0.1 percent

FAMILY OF CURVES – DEVELOPMENT APPENDIX "A" FOP FOR AASHTO T 272

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/ft^3 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 maybe used, if the difference between curves is less than 2.0 lbs/ft^3.

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/ft^3 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/ft^3 increments draw moisture-density relationships using slopes similar to those of the original moisture-density relationships.

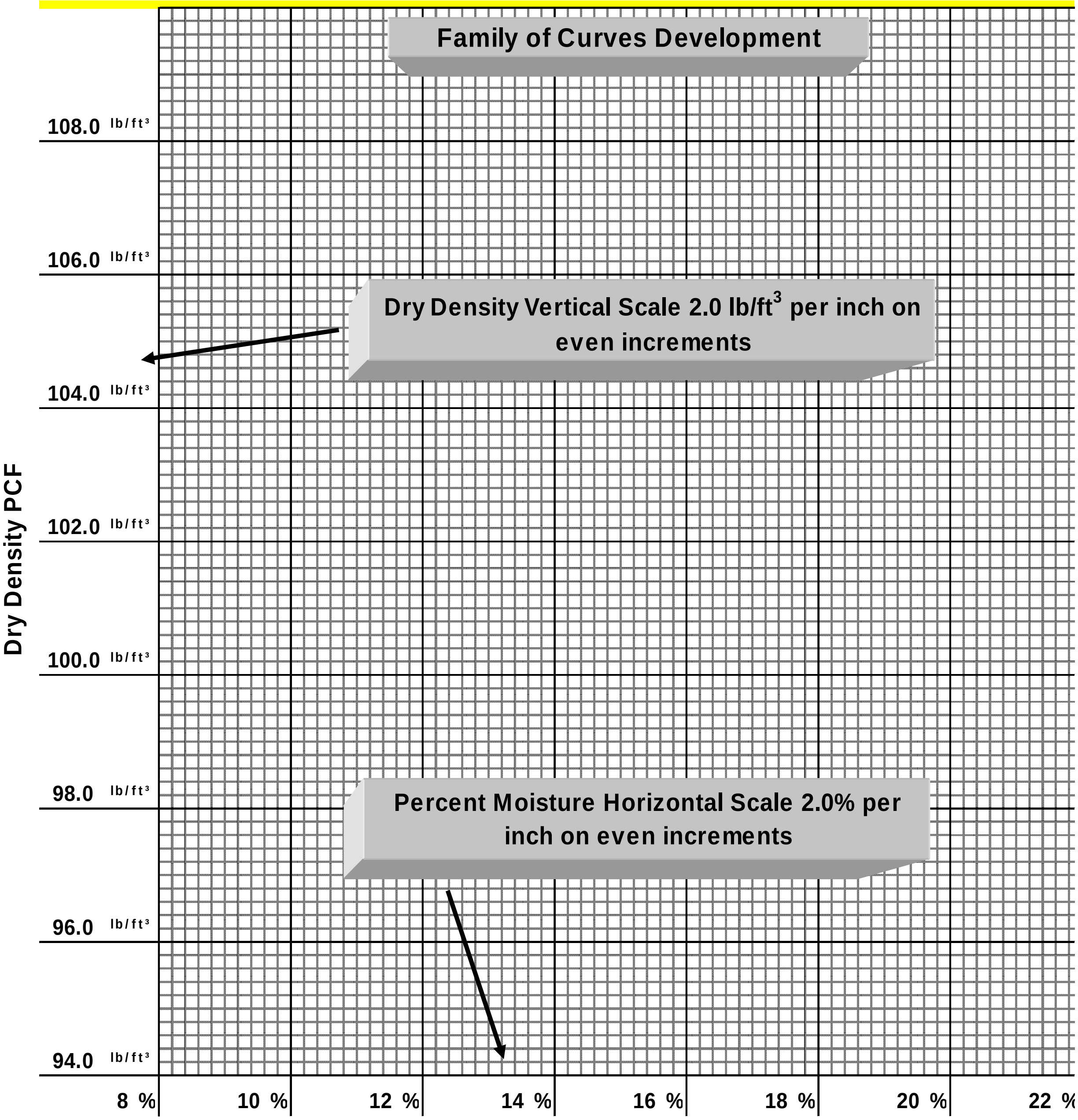
EXAMPLE OF FAMILY DEVELOPMENT:

STEP 1:

- **Sort and only retain curves developed by the same procedure (e.g. T 99 method A.**

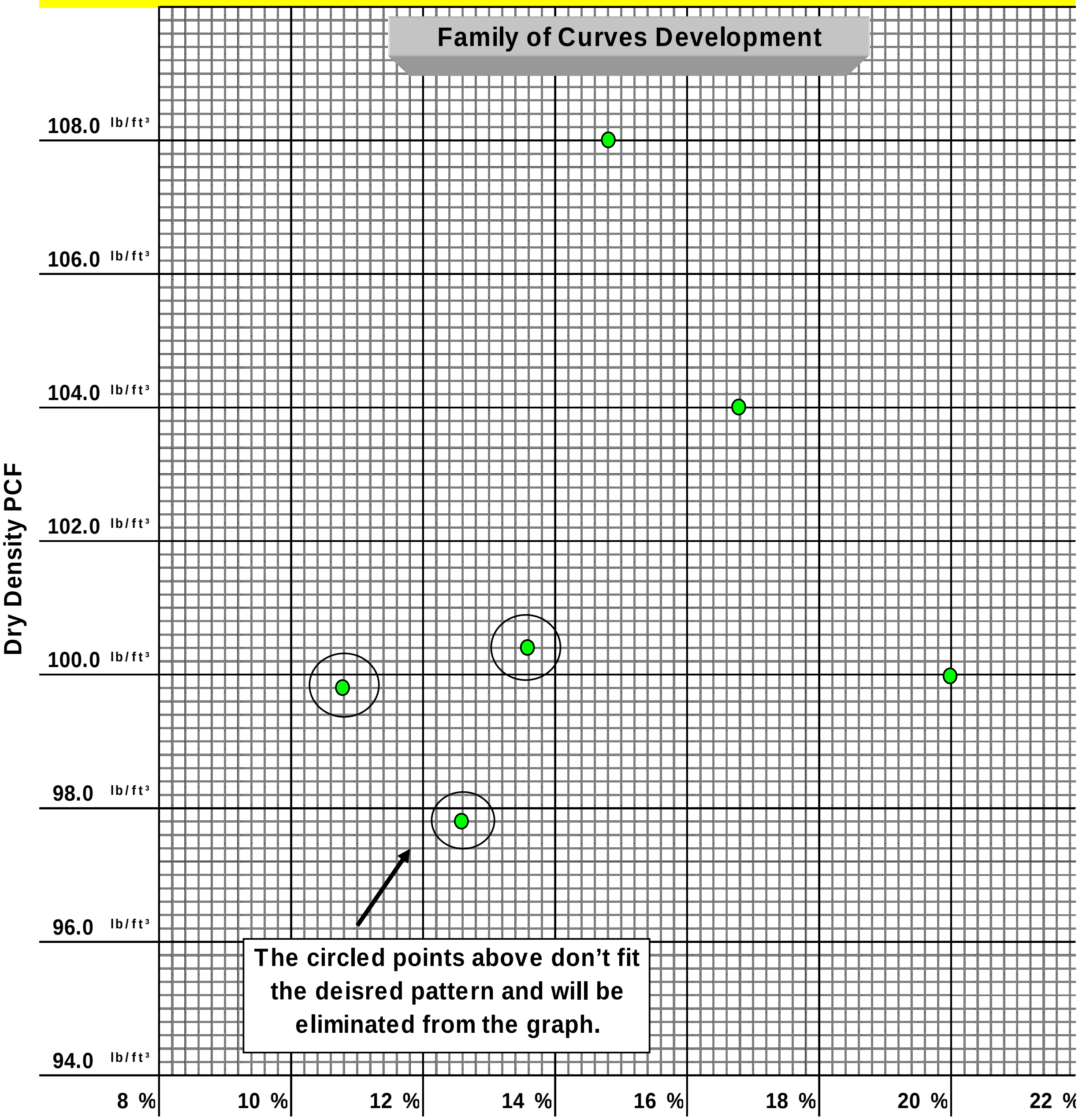
STEP 2 & 3:

- **Establish and label an appropriate dry density scale on the vertical axis and a percent moisture scale on the horizontal axis.**

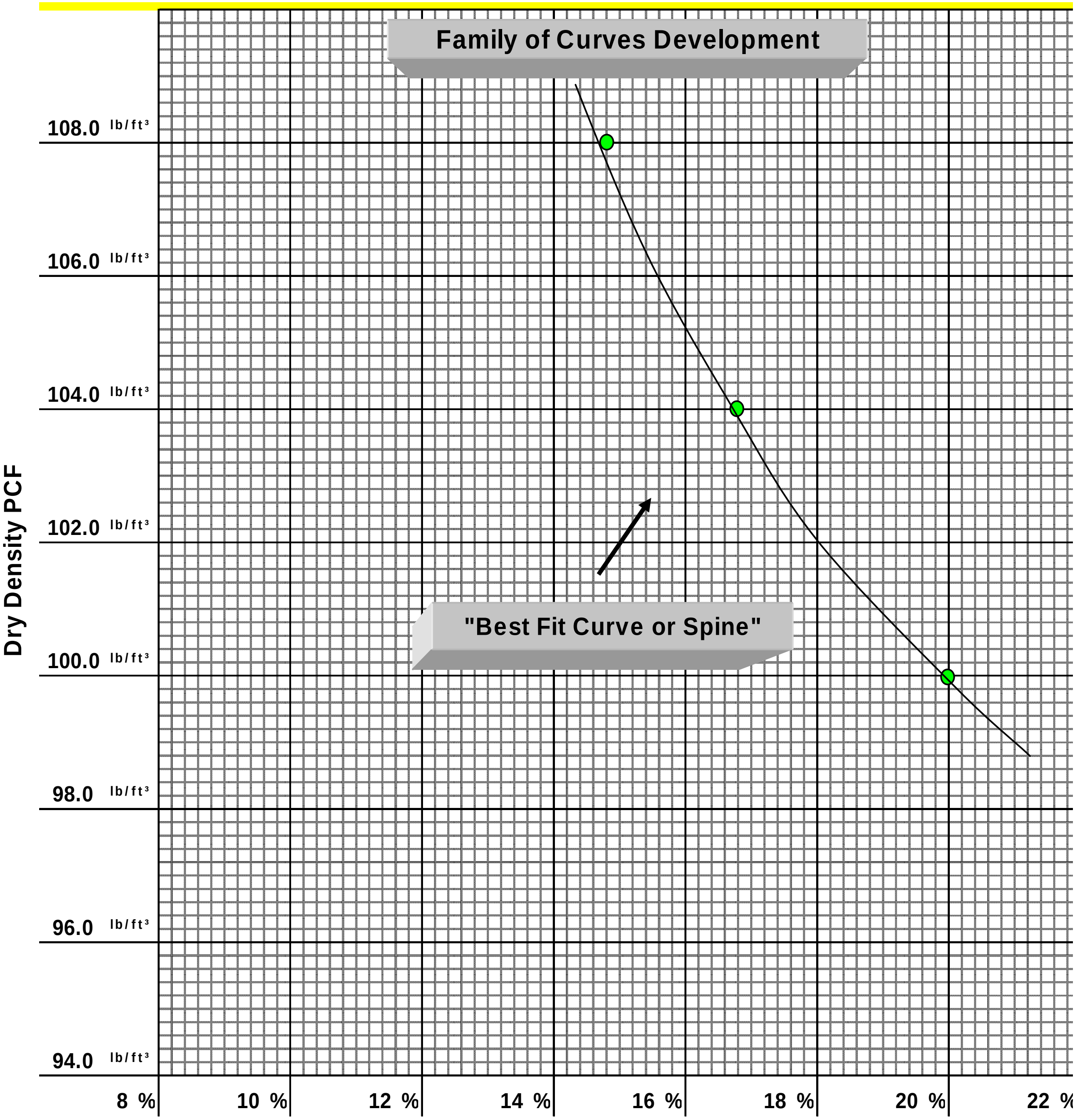


Step 4:

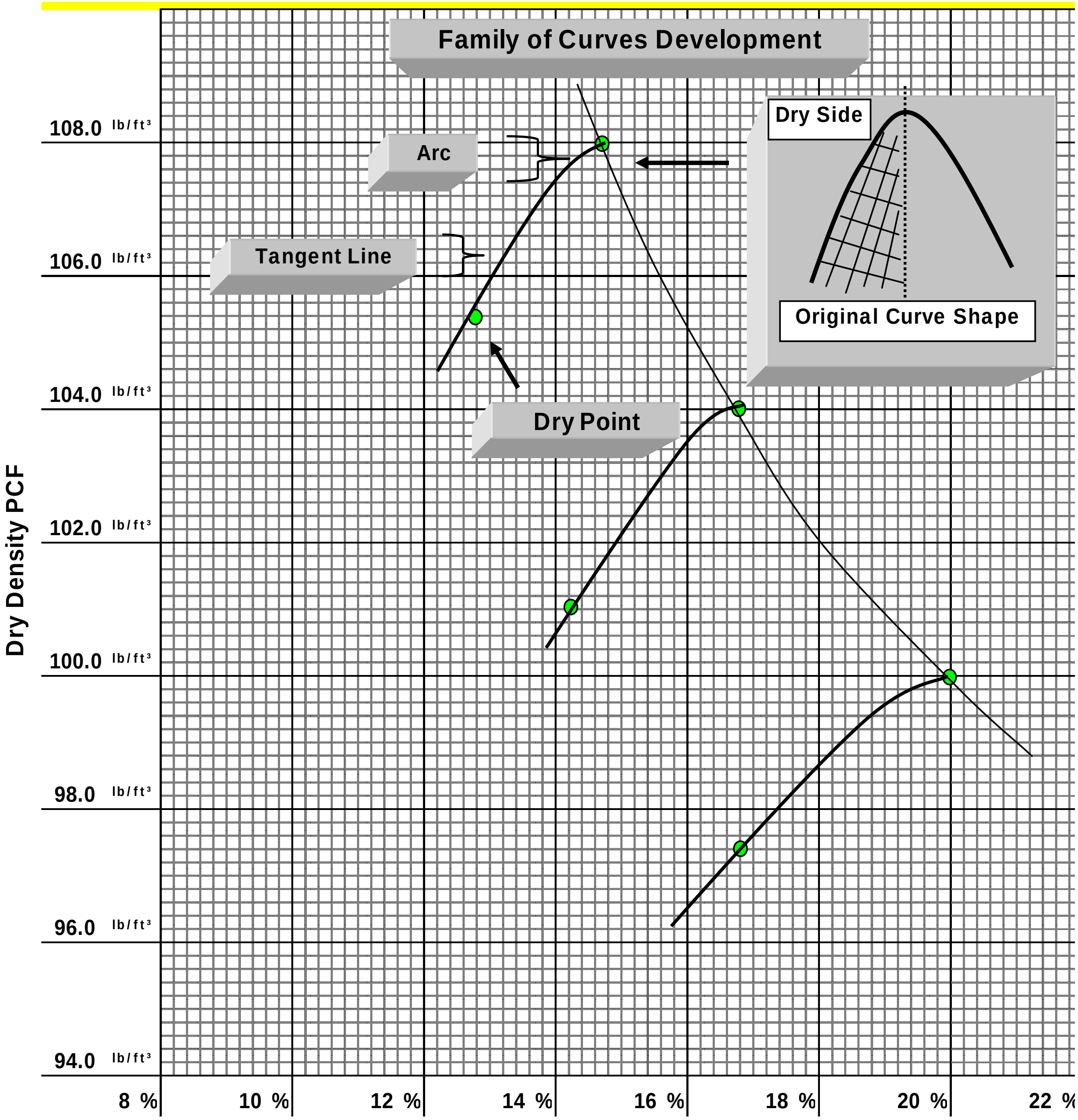
- **Plot only the points representing the maximum dry density and optimum moisture from the candidate curves.**



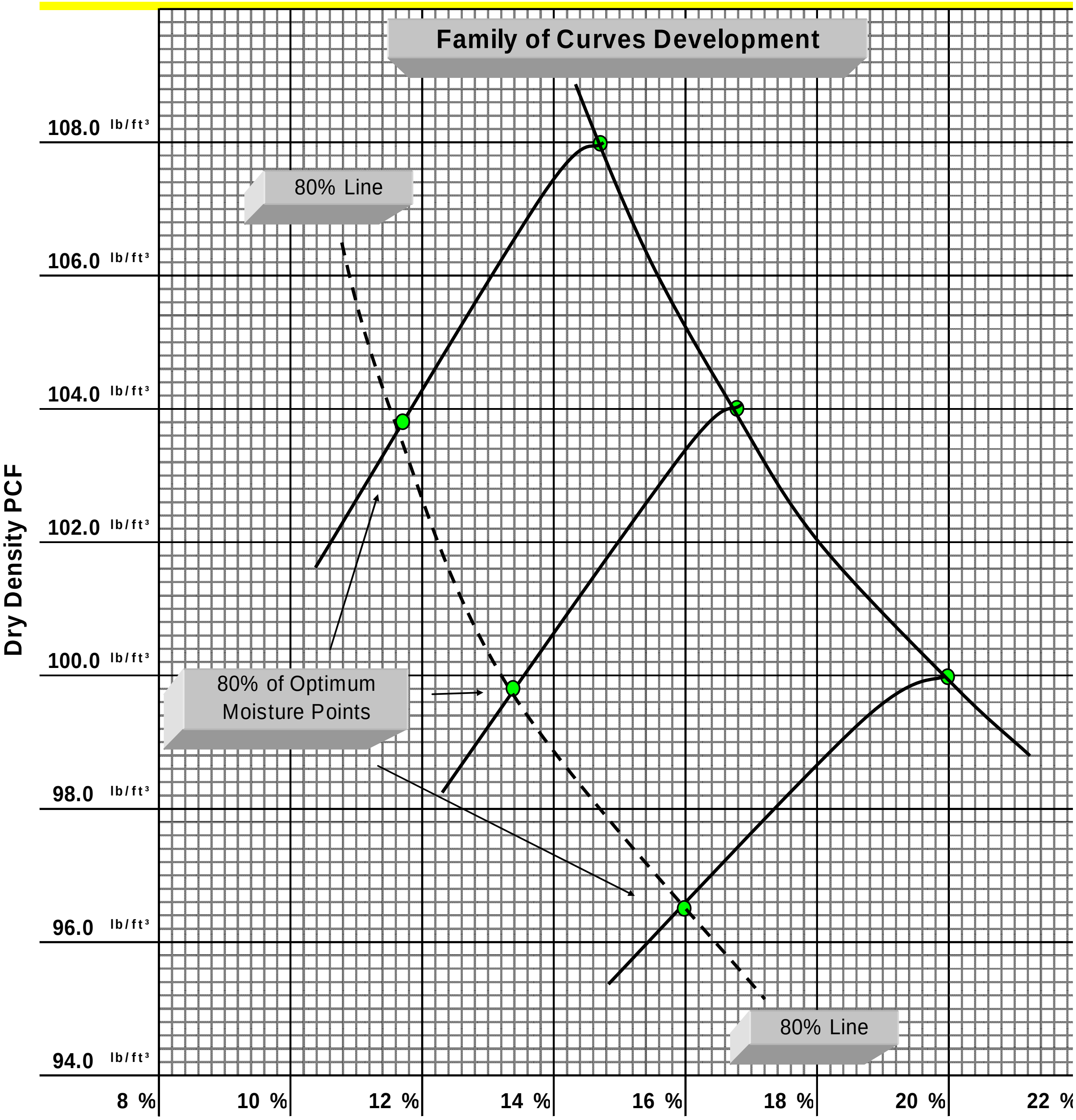
Step 5: Draw a smooth "best fit" curve through the points creating a curve that is slightly concave up and to the left.



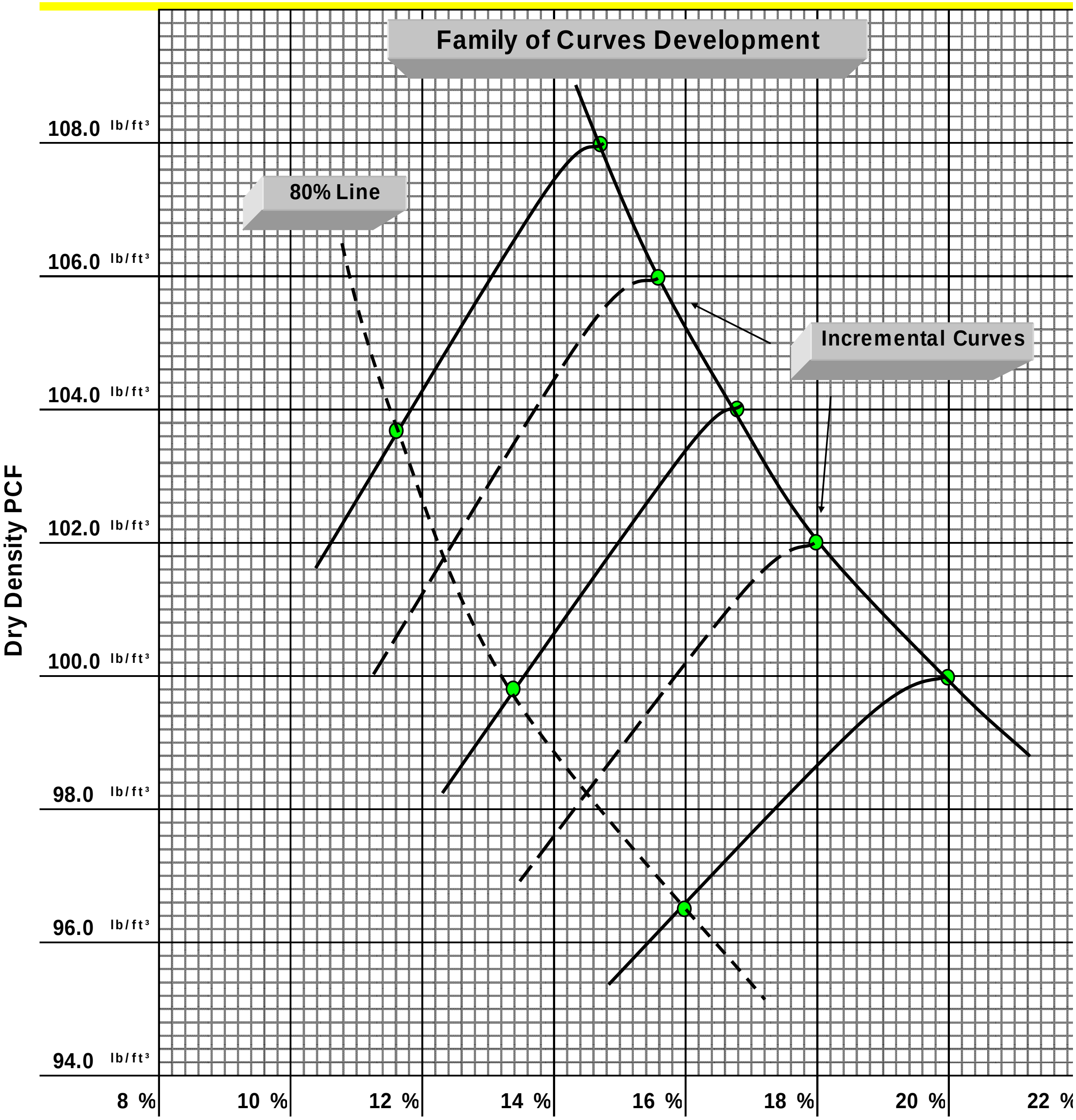
Step 6: Mark each maximum density-optimum moisture point with a dry side arc of sufficient length to meet the dry side leg. Plot a point on the "dry side" and connect the arc with the point using a tangent line.



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.



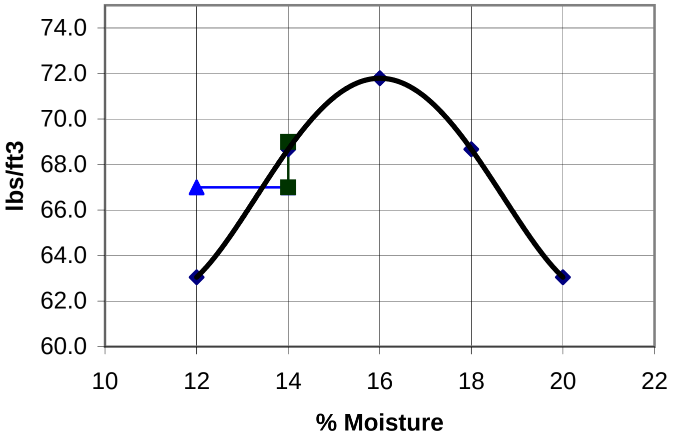
Report

- Include original curve data with family.
- Include Gsb & Absorption information of retained material, if available.

Appendix "B" Guidelines for Selecting a Single Curve

1) Select all curves where the One Point plots within 2 lbs/ft^3 and 2.0% of the curve.

   a) Plot the One Point on a curve.
   b) Extend a line vertically 2 lbs/ft^3 in length form the One Point towards the curve.
   c) Extend a line Horizonally 2.0% in length form the One Point towards the curve.

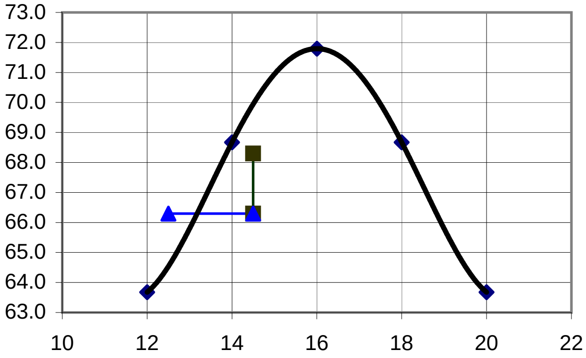


Example Shown: The One Point is 67 lbs/ft^3 @ 14% moisture. Therefore the horizontal extension is 12% (-2%) and the vertical extension is to 69 lbs/ft3 (+2lbs/ft^3).

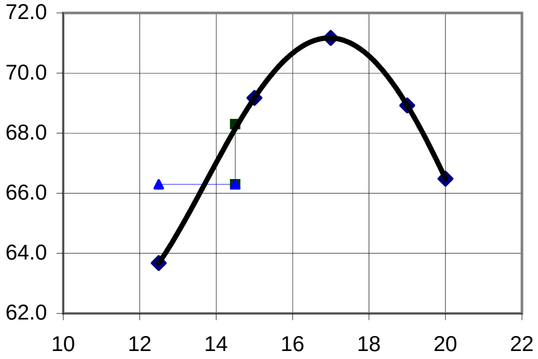
2) Retain only those curves where the One Point has a lower moisture content than the Optimum Moisture of the curve being used for comparison.
3) Review the remaining curves and select the curve which best fits in order of the following parameters:
   a) One Point closest to the curve line. a) Highest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

EXAMPLE

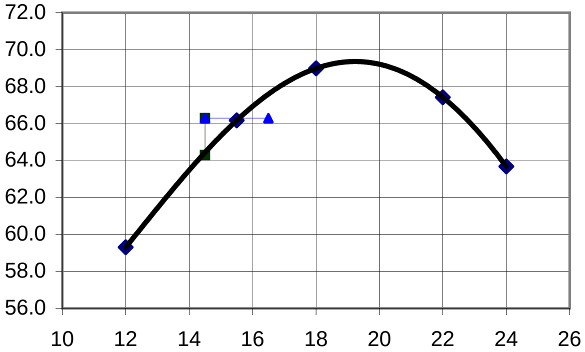
curve #1



curve #2



Curve #3



One Point = 66.3 lbs/ft^3 @ 14.5% moisture

1) Only two curves meet requirement 1.
2) Both curves 2 & # have higher Optimum moistures than the One Point. Meeting
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

Revised (Oct. 2008)

Test Procedure AASHTO T 283 Continued

3. **Of the remaining 2 specimens; select the specimen with the lowest air voids and designate it “Wet”. The remaining specimen is designated “Dry”**

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

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October 31, 2013

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 6.2, only 6" specimens are allowed for this step.**
- **Section 6.4, Do not perform the 2-hr cooling and 16-hr loose mix curing required by this section. After mixing place mixture in the specified pans and follow the steps in Section 6.5.**
- **Section 6.5, Compact each specimen to the required air void range.**
- **Section 6.6, Delete requirement for storage of 24 +/- 3 hours at room temperature. Instead, allow the compacted specimens to completely cool to room temperature (no longer than 24 hours). Then proceed to Section 9.**

Preparation of Field-Mixed, Lab compacted Specimens

- **Section 7.2, only 6" specimens are allowed for this step.**
- **Section 7.5, Delete requirement for storing specimens at 24 +/- 3 hours at room temperature. Instead allow compacted specimens too completely cool to room temperature (no longer than 24 hours). Then proceed to Section 9.**

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"**

(See Next Page)

Standard Method of Test for

Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage

AASHTO Designation: T 283-07

1. SCOPE

1.1. This method covers preparation of specimens and the measurement of the change of diametral tensile strength resulting from the effects of water saturation and accelerated water conditioning, with a freeze-thaw cycle, of compacted HMA. The results may be used to predict long-term stripping susceptibility of the HMA and evaluate liquid anti-stripping additives that are added to the asphalt binder or pulverulent solids, such as hydrated lime or portland cement, which are added to the mineral aggregate.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard may involve hazardous materials, operations, and equipment. 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 DOCUMENTS

2.1. *AASHTO Standards*:

- T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
- T 167, Compressive Strength of Hot Mix Asphalt
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures
- T 245, Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
- T 247, Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
- T 328, Reducing Samples of Hot Mix Asphalt to Testing Size

2.2. *ASTM Standards*:

- D 979, Sampling Bituminous Paving Mixtures
- D 2041, Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
- D 3387, Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)

- D 3549, Thickness or Height of Compacted Bituminous Paving Mixture Specimens

3. SIGNIFICANCE AND USE

3.1. As noted in the scope, this method is intended to evaluate the effects of saturation and accelerated water conditioning, with a freeze-thaw cycle, of compacted HMA. This method can be used to test: (a) HMA in conjunction with mixture design testing (lab-mixed, lab-compacted); (b) HMA produced at mixing plants (field-mixed, lab-compacted); and (c) HMA cores obtained from completed pavements of any age (field-mixed, field-compacted).

3.2. Numerical indices of retained indirect-tensile properties are obtained by comparing the properties of laboratory specimens subjected to moisture and freeze-thaw conditioning with the similar properties of dry specimens.

4. SUMMARY OF METHOD

4.1. Test specimens for each set of mix conditions, such as those prepared with untreated asphalt binder, asphalt binder treated with anti-stripping agent, or aggregate treated with lime, are prepared. Each set of specimens is divided into subsets. One subset is tested in dry condition for indirect-tensile strength. The other subset is subjected to vacuum saturation and a freeze cycle, followed by a warm-water soaking cycle, before being tested for indirect-tensile strength. Numerical indices of retained indirect-tensile strength properties are calculated from the test data obtained by the two subsets: dry and conditioned.

5. APPARATUS

5.1. Equipment for preparing and compacting specimens from one of the following: T 245, T 247, T 312, or ASTM D 3387.

5.2. Equipment for determining the theoretical maximum specific gravity (G_{mm}) of the HMA from T 209 or ASTM D 2041.

5.3. Balance and water bath from T 166.

5.4. Water bath capable of maintaining a temperature of 60 ± 1°C (140 ± 1.82°F).

5.5. Freezer maintained at −18 ± 3°C (0 ± 5°F).

5.6. A supply of plastic film for wrapping specimens; heavy-duty, leak-proof plastic bags to enclose the saturated specimens; and masking tape.

5.7. 10-mL graduated cylinder.

5.8. Pans having a surface area of 48,400 to 129,000 mm^2 (75 to 200 in.^{2}) in the bottom and a depth of approximately 25 mm (1 in.).

5.9. Forced-draft oven, thermostatically controlled, capable of maintaining any desired temperature setting from room temperature to 176°C (350°F) within ±3°C (±5°F).

5.10. Loading jack and ring dynamometer from T 245, or a mechanical or hydraulic testing machine from T 167, to provide a range of accurately controllable rates of vertical deformation, including 50 mm/min (2 in./min).

5.11. Steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 100 mm (4 in.) in diameter, the loading strips shall be 12.7 mm (0.5 in.) wide, and for specimens 150 mm (6 in.) in diameter, the loading strips shall be 19.05 mm (0.75 in.) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the loading strips shall be rounded to the appropriate radius of curvature by grinding.

6. PREPARATION OF LABORATORY-MIXED, LABORATORY-COMPACTED SPECIMENS

6.1. Make at least six specimens for each test, half to be tested dry and the other half to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle (Note 1).

Note 1—It is recommended that two additional specimens for the set be prepared. These specimens can then be used to establish compaction procedures as given in Section 6.5 or 7.4 and the vacuum saturation technique as given in Section 10.3.

6.2. Specimens 100 mm (4 in.) in diameter by 63.5 ± 2.5 mm (2.5 ± 0.1 in.) thick, or 150 mm (6 in.) in diameter by 95 ± 5 mm (3.75 ± 0.20 in.) thick are used. Specimens 150 mm (6 in.) in diameter by 95 ± 5 mm (3.75 ± 0.20 in.) thick should be used if aggregate larger than 25 mm (1 in.) is present in the mixture.

6.3. Prepare mixtures in batches large enough to make at least three specimens or, alternatively, prepare a batch large enough to just make one specimen at a time. If preparing a multi-specimen batch, split the batch into single-specimen quantities before placing in the oven.

6.4. After mixing, the mixture shall be placed in a pan having a surface area of 48,400 to 129,000 mm^2 (75 to 200 in.^2) in the bottom and a depth of approximately 25 mm (1 in.) and cooled at room temperature for 2 ± 0.5 h. Then, the mixture shall be placed in a 60 ± 3°C (140 ± 5°F) oven for 16 ± 1 h for curing. The pans should be placed on spacers to allow air circulation under the pan if the shelves are not perforated.

6.5. After curing, place the mixture in an oven for 2 hours ± 10 minutes at the compaction temperature ±3°C (5°F) prior to compaction. Compact the specimens according to one of the following methods: T 245, T 247, T 312, or ASTM D 3387. The mixture shall be compacted to 7.0 ± 0.5 percent air voids. This level of voids can be obtained by adjusting the number of blows in T 245; adjusting foot pressure, number of tamps, leveling load, or some combination in T 247; or adjusting the number of revolutions in T 312 or ASTM D 3387. The exact procedure must be determined experimentally for each mixture before compacting the specimens for each set (Note 2).

Note 2—Due to the elevated void content and potential instability of the specimens, ensure each specimen is adequately cool and stable prior to removal from the mold.

6.6. After removal from the molds, the specimens shall be stored for 24 ± 3 h at room temperature.

7. PREPARATION OF FIELD-MIXED, LABORATORY-COMPACTED SPECIMENS

7.1. Make at least six specimens for each test, half to be tested dry and the other half to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle (Note 1).

7.2. Specimens 100 mm (4 in.) in diameter by 63.5 ± 2.5 mm (2.5 ± 0.1 in.) thick, or 150 mm (6 in.) in diameter by 95 ± 5 mm (3.75 ± 0.20 in.) thick are used. Specimens 150 mm (6 in.) in diameter by 95 ± 5 mm (3.75 ± 0.20 in.) thick should be used if aggregate larger than 25 mm (1 in.) is present in the mixture.

7.3. Field-mixed asphalt mixtures shall be sampled in accordance with ASTM D 979.

7.4. No loose-mix curing as described in Section 6.4 shall be performed on the field-mixed samples. After sampling, divide the sample to obtain the desired size in accordance with T 328. Next, place the mixture in an oven until it reaches the compaction temperature ±3°C (5°F). Then, compact the specimen according to one of the following methods: T 245, T 247, T 312, or ASTM D 3387. The mixture shall be compacted to 7.0 ± 0.5 percent air voids. This level of voids can be obtained by adjusting the number of blows in T 245; adjusting foot pressure, number of tamps, leveling load, or some combination in T 247; or adjusting the number of revolutions in T 312 or ASTM D 3387. The exact procedure must be determined experimentally for each mixture before compacting the specimens for each set (Note 2).

7.5. After removal from the molds, the specimens shall be stored for 24 ± 3 h at room temperature.

8. PREPARATION OF FIELD-MIXED, FIELD-COMPACTED SPECIMENS (CORES)

8.1. Select locations on the completed pavement to be sampled, and obtain cores. When testing pavement layers with a thickness less than or equal to 63.5 mm (2.5 in.), use 100 mm (4 in.) diameter cores. Otherwise, use either 100 mm (4 in.) or 150 mm (6 in.) diameter cores. The number of cores shall be at least six for each set of mix conditions.

8.2. Separate the core layers as necessary by sawing them or by other suitable means, and store the layers to be tested at room temperature until they are dry.

8.3. No loose-mix curing (Section 6.4) or compacted-mix curing (Section 6.6) shall be performed on the field-mixed, field-compacted specimens (cores).

9. EVALUATION AND GROUPING OF SPECIMENS

9.1. After curing or heating mixture samples for the theoretical maximum specific gravity (G_{mm}) test as described in Sections 6.4 and 6.5, or Section 7.4 as appropriate, determine the G_{mm} of those samples by T 209 or ASTM D 2041.

9.2. Determine each specimen thickness (t) in accordance with ASTM D 3549.

9.3. Record each specimen diameter (D) as defined in Section 6.2, 7.2, or 8.1, as appropriate.

9.4. Determine each bulk specific gravity (G_{mb}) by Method A of T 166. Express the volume (E) of the specimens, or the saturated, surface-dry mass minus the mass in water, in cubic centimeters.

9.5. Calculate the percentage of air voids (P_a) in accordance with T 269.

9.6. Separate the specimens into two subsets, of at least three specimens each, so that the average air voids of the two subsets are approximately equal.

For those specimens to be subjected to vacuum saturation, a freeze cycle, and a warm-water soaking cycle, calculate the volume of air voids (V_a) in cubic centimeters using the following equation:

$$V_a = \frac{P_a E}{100} \qquad (1)$$

where:

V_a = volume of air voids, cm^3;

P_a = air voids, percent; and

E = volume of the specimen, cm^3.

Note 3—A data sheet that is convenient for use with this test method is shown as Table 1.

10. PRECONDITIONING OF TEST SPECIMENS

10.1. One subset will be tested dry, and the other will be partially vacuum-saturated, subjected to freezing, and soaked in warm water before testing.

10.2. The dry subset will be stored at room temperature as described in Section 6.6 or 7.5, as appropriate. At the end of the curing period from Section 6.6 or 7.5, as appropriate, the specimens shall be wrapped with plastic or placed in a heavy-duty, leak-proof plastic bag. The specimens shall then be placed in a 25 ± 0.5°C (77 ± 1°F) water bath for 2 h ± 10 min with a minimum 25 mm (1 in.) of water above their surface. Then, test the specimens as described in Section 11.

10.3. The other subset shall be conditioned as follows:

10.3.1. Place the specimen in the vacuum container supported a minimum of 25 mm (1 in.) above the container bottom by a perforated spacer. Fill the container with potable water at room temperature so that the specimens have at least 25 mm (1 in.) of water above their surface. Apply a vacuum of 13 to 67 kPa absolute pressure (10 to 26 in. Hg partial pressure) for a short time (approximately 5 to 10 minutes). Remove the vacuum and leave the specimen submerged in water for a short time (approximately 5 to 10 minutes).

10.3.2. Determine the mass of the saturated, surface-dry specimen after partial vacuum saturation (B') by Method A of T 166.

10.3.3. Calculate the volume of absorbed water (J') in cubic centimeters by use of the following equation:

$$J' = B' - A \qquad (2)$$

where:

J' = volume of absorbed water, cm^3;

B' = mass of the saturated, surface-dry specimen after partial vacuum saturation, g; and

A = mass of the dry specimen in air, g (Section 9.4).

10.3.4. Determine the degree of saturation (S') by comparing the volume of absorbed water (J') with the volume of air voids (V_a) from Section 9.6 using the following equation:

$$S' = \frac{100J'}{V_a} \tag{3}$$

where:

S' = degree of saturation, percent.

10.3.5. If the degree of saturation is between 70 and 80 percent, proceed to Section 10.3.7.

10.3.6. If the degree of saturation is less than 70 percent, repeat the procedure beginning with Section 10.3.1 using more vacuum and/or time. If the degree of saturation is more than 80 percent, the specimen has been damaged and must be discarded. In this case, repeat the procedure on the next specimen beginning with Section 10.3.1 using less vacuum and/or time.

10.3.7. Cover each of the vacuum-saturated specimens tightly with a plastic film (Saran Wrap® brand or equivalent). Place each wrapped specimen in a plastic bag containing 10 ± 0. 5 mL of water and seal the bag. Place the plastic bags containing the specimens in a freezer at a temperature of –18 ± 3°C (0 ± 5°F) for a minimum of 16 hours. Remove the specimens from the freezer.

10.3.8. Place the specimens in a bath containing potable water at 60 ± 1°C (140 ± 2°F) for 24 ± 1 h. The specimens should have a minimum of 25 mm (1 in.) of water above their surface. As soon as possible after placement in the water bath, remove the plastic bag and film from each specimen.

10.3.9. After 24 ± 1 h in the 60 ± 1°C (140 ± 2°F) water bath, remove the specimens, and place them in a water bath at 25 ± 0.5°C (77 ± 1°F) for 2 h ± 10 min. The specimens should have a minimum of 25 mm (1 in.) of water above their surface. It may be necessary to add ice to the water bath to prevent the water temperature from rising above 25°C (77°F). Not more than 15 minutes should be required for the water bath to reach 25 ± 0.5°C (77 ± 1°F). Remove the specimens from the water bath, and test them as described in Section 11.

11. TESTING

11.1. Determine the indirect-tensile strength of dry and conditioned specimens at 25 ± 0.5°C (77 ± 1°F).

11.2. Remove the specimen from 25 ± 0.5°C (77 ± 1°F) water bath, and determine the thickness (t′) by ASTM D 3549. Place it between the steel loading strips and then place the specimen and loading strips between the two bearing plates in the testing machine. Care must be taken so that the load will be applied along the diameter of the specimen. Apply the load to the specimen, by means of the constant rate of movement of the testing machine head, at 50 mm/min (2 in./min).

11.3 Record the maximum compressive strength noted on the testing machine, and continue loading until a vertical crack appears. Remove the specimen from the machine, and pull it apart at the crack. Inspect the interior surface for evidence of cracked or broken aggregate; visually estimate the approximate degree of moisture damage on a scale from "0" to "5" (with "5" being the most stripped), and record the observations in Table 1.

Table 1— Moisture Damage Laboratory Data Sheet (Nonmandatory Information)

Project ________________________________

Additive ____________________ Dosage ________

Compaction Method ________________ Effort ________

Date Tested ____________ By ____________

Sample identification									
Diameter, mm (in.)	D								
Thickness, mm (in.)	t								
Dry Mass in Air, g	A								
SSD Mass, g	B								
Mass in Water, g	C								
Volume (B–C), cc	E								
Bulk specific Gravity (A/E)	G_{mb}								
Maximum Specific Gravity	G_{mm}								
% Air Voids $[100(G_{mm}-G_{mb})/G_{mm}]$	P_a								
Volume of Air Voids ($P_aE/100$), cm^3	V_a								
Load, N (lbf)	P								
Saturated min. @	kPa (psi) or	mm Hg (in. Hg)							
Thickness, mm (in.)	t'								
SSD Mass, g	B'								
Volume of Absorbed Water ($B'-A$), cm^3	J'								
% Saturation ($100J'/V_a$)	S'								
Load, N (lbf)	P'								
Dry Strength $[2000P/\pi tD\ (2P/\pi tD)]$, kPa (psi)	S_1								
Wet Strength $[2000P'/\ \pi t'D\ (2P/\pi t'D)]$, kPa (psi)	S_2								
Visual Moisture Damage (0 to 5 rating)									
Cracked/Broken Aggregate?									
TSR (S_2/S_1)									

12. CALCULATIONS

12.1. Calculate the tensile strength as follows:

SI Units:

$$S_t = \frac{2000\,P}{\pi\,t\,D} \tag{4}$$

where:

S_t = tensile strength, kPa

P = maximum load, N

t = specimen thickness, mm

D = specimen diameter, mm

U.S. Customary units:

$$S_t = \frac{2P}{\pi t D} \qquad (5)$$

where:

S_t = tensile strength, psi;

P = maximum load, lbf;

t = specimen thickness, in.; and

D = specimen diameter, in.

12.2. Express the numerical index of resistance of HMA to the detrimental effect of water as the ratio of the original strength that is retained after the moisture and freeze-thaw conditioning. Calculate the tensile strength ratio to two decimal places as follows:

$$\text{Tensile Strength Ratio (TSR)} = \frac{S_2}{S_1} \qquad (6)$$

where:

S_1 = average tensile strength of the dry subset, kPa (psi); and

S_2 = average tensile strength of the conditioned subset, kPa (psi).

---

13. REPORT

13.1. Report the following information:

13.1.1. Number of specimens in each subset;

13.1.2. Average air voids of each subset;

13.1.3. Tensile strength of each specimen in each subset;

13.1.4. Tensile strength ratio;

13.1.5. Results of visually estimated moisture damage observed when the specimen fractures; and

13.1.6. Results of observations of cracked or broken aggregate.

Test Procedure AASHTO T 308 Continued

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

$$\text{Mid} = \left\{ \frac{\text{Mi}}{1 + \left(\frac{\%\ \text{M}}{100} \right)} \right\}$$

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

$$\text{Pb} = \left(\frac{\text{Mid - Mf}}{\text{Mid}} \right) \text{X } 100 \text{ - Cf}$$

Where: Mf = Final mass of aggregate remaining after ignition.
Mid= Initial "Dry" mass of mixture prior to ignition.
Cf = Correction Factor

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

$$\text{Pb} = \left(\frac{\text{Mi - Mf}}{\text{Mi}} \right) \text{X } 100 \text{ - Cf}$$

Where: Mi = Initial Oven "Dried" mass of mixture prior to ignition.
Mf = Final mass of aggregate remaining after ignition.
Cf = Correction Factor

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October 31, 2008

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 Apparatus, Method A and Method B – An ignition furnace using Infra-Red elements is allowed. An Infra-Red furnace is not required to maintain a 578°C temperature.**
- **When using the Infra-Red furnace, for Methods A and B for step 1 the 538°C does not apply.**
- **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 for a minimum of 30 minutes 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.**
- **Delete Correction Factors Section. Perform calibration of Ignition Furnace according to ODOT TM 323.**
- **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 HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD
FOP FOR AASHTO T 308

Scope

This procedure covers the determination of asphalt binder content of hot mix asphalt (HMA) by ignition of the binder in accordance with AASHTO T 308-10.

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 HMA. When using recycled HMA, check with the agency for specific correction procedures.

Binder in the HMA is ignited in a furnace. Asphalt binder content is calculated as the percentage difference between the initial mass of the HMA 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.

There are two methods – A and B. The apparatus for the two methods are the same except that the furnace for Method A has 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 at 578°C (1072°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 baskets 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 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.

Note 2: The furnace shall be designed to permit the operator to change the ending mass loss percentage from 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 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 pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

Sampling

1. Obtain samples of HMA in accordance with the FOP for AASHTO T 168.

2. Reduce HMA 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 3: 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 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 (3/4)	2000	2500
12.5 (1/2)	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°C (1000°F) or to the temperature determined in the “Correction Factor” section, Step 9 of this method. Manually record the furnace temperature (set point) prior to 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 to the nearest 0.1 g of the sample basket assembly.

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 to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).

6. Record the correction factor or input into the furnace controller for the specific HMA.

7. Input the initial mass of the sample (M_i) into the ignition furnace controller. Verify that the correct mass has been entered.

   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.

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. 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 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 binder content.

9. 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.

10. 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.

11. 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).

12. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as Mf.

13. Use the asphalt binder content percentage from the printed ticket. Subtract the moisture content from the printed ticket asphalt binder content and report the difference as the corrected asphalt binder content.

$$P_b = BC - MC - C_f \text{ (if not input in the furnace controller)}$$

where:

P_b = the corrected asphalt binder content as a percent by mass of the HMA

BC = asphalt binder content shown on printed ticket

MC = moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0)

C_f = correction factor as a percent by mass of the HMA sample

14. Asphalt binder content percentage can also be calculated using the formula from "Method B" Step 16.

Procedure – Method B (External Balance)

1. Preheat the ignition furnace to 538°C (1000°F) or to the temperature determined in the "Correction Factor" section, Step 9 of this method. Manually record the furnace temperature (set point) prior to 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 total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).

6. Record the correction factor for the specific HMA.

7. 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 HMA sample in the furnace for 45 minutes or the length of time determined in the "Correction Factors" section.

8. 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).

9. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

10. Place the sample basket assembly back into the furnace.

11. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.

12. 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.).

13. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

14. 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 after ignition.

Note 6: 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.

15. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as Mf.

16. 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 HMA sample

M_f = the final mass of aggregate remaining after ignition

M_i = the initial mass of the HMA sample prior to ignition

MC= moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0).

C_f = correction factor as a percent by mass of the HMA 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

$$\frac{2222.9\ g - 2222.7\ g}{2222.9\ g} \times 100 = 0.009\%$$

Not greater than 0.01 percent, so $\mathbf{M_f}$ **=** 2222.7 g

$$P_b = \frac{2361.2\ g - 2222.7\ g}{2361.2\ g} \times 100 - 0.42\% - 0.04\% = 5.41\%$$

$\mathbf{P_b}$= 5.41%

Gradation

1. Empty contents of the basket(s) into a flat pan, 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

- Results on forms approved by the agency
- Sample ID
- Method of test (A or B)
- Corrected asphalt binder content, P_b, per agency standard
- Correction factor, C_f , to 0.01 percent
- Temperature compensation factor (if applicable)
- Total percent loss
- Sample mass
- Moisture content to 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

(Mandatory Information)

Asphalt Binder and Aggregate

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.

Historical data or scientific studies may be used to determine the correction factor(s) in lieu of using this testing procedure if the testing agency provides reference to the studies/data. 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 T 2.

2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO T 40.

   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 prior to 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 prior to 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 of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven 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 HMA.

9. If the asphalt binder correction factor exceeds 1.00 percent, the test temperature must be lowered to 482 ±5°C (900 ±8°F) and new samples must be burned. The temperature for determining the asphalt binder content of HMA 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 HMA 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	-0.2	
4.75 (No. 4)	51.5	53.6	55.9	-2.1/-4.4	-3.2	
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	-2.2	
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	-0.2	**-0.2**
4.75 (No. 4)	51.5	55.6	57.9	-4.1/-6.4	-5.2	**-5.2**
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	-2.2	**-2.2**
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 309-11.

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

Apparatus

- Container — The container shall be made of non-absorptive material and large enough to provide at least 75 mm (3 in.) of concrete in all directions around the sensor; concrete cover must also be a least three times the nominal maximum size of the coarse aggregate.
- Temperature measuring device — The temperature measuring device shall be calibrated and capable of measuring the temperature of the freshly mixed concrete to ±0.5°C (±1°F) throughout the temperature range likely to be encountered. Partial immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.
- Reference temperature measuring device — The reference temperature measuring device shall be a thermometric device readable to 0.2°C (0.5°F) that has been verified and calibrated. The calibration certificate or report indicating conformance to the requirements of ASTM E 77 shall be available for inspection.

Calibration of Temperature Measuring Device

Each temperature measuring device shall be verified for accuracy annually and whenever there is a question of accuracy. Calibration shall be performed by comparing readings on the temperature measuring device with another calibrated instrument 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 temperature measuring device 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.

Concrete containing aggregate of a nominal maximum size greater than 75 mm (3 in.) may require up to 20 minutes for the transfer of heat from the aggregate to the mortar after batching.

Procedure

1. Dampen the sample container.
2. Obtain the sample in accordance with the FOP for WAQTC TM 2.
3. Place sensor of the temperature measuring device 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 temperature measuring device at the surface of the concrete so that air cannot reach the sensor.
5. Leave the sensor of the temperature measuring device 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
- Measured temperature of the freshly mixed concrete to the nearest 0.5°C (1°F)

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Oregon

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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 310-13. 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/scraper 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, unless the gauge is corrected for trench wall effect.

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 probe depth, and shall be aligned such that insertion of the probe 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. Insert the probe in the hole and lower the source rod 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. 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 requirements. 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 + 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 + 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, WSDOT's TM 606, or WFLHD's Humphres.

See appropriate agency policies for use of density standards.

Calculation

Wet density readings from gauge: 1963 kg/m^3 (121.6 lb/ft^3)
1993 kg/m^3 (123.4 lb/ft^3)

Avg: 1978 kg/m^3 (122.5 lb/ft^3)

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:

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

Where:

ρ_d = Dry density, kg/m^3 (lb/ft^3)
ρ_w = Wet density, kg/m^3 (lb/ft^3)
w = Moisture content from the FOP's for AASHTO T 255 / T 265, as a percentage

$$\rho_d = \left(\frac{1978\, kg/m^3 \ or\ 122.5\ lb/ft^3}{15.9+100}\right) \times 100 \quad \rho_d = \left(\frac{1978\, kg/m^3 \ or\ 122.5\ lb/ft^3}{\frac{15.9}{100}+1}\right)$$

Corrected for moisture Dry Density: 1707 kg/m^3 (105.7 lb/ft^3)

Calculate percent compaction as follows:

$$\%\ \text{Compaction} = \frac{\rho_d}{Agency\ density\ standard} \times 100$$

Report

- Results 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 0.1 lb/ft^3.
- Moisture content as a percent, by mass, of dry soil mass to 0.1 percent.
- Dry density to 0.1 lb/ft^3.
- Density standard to 0.1 lb/ft^3.
- Percent compaction.
- Name and signature of operator.

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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 ±9ºC (15ºF) reference and replace with ±10ºC (25ºF).**
- **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 329-15.

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 ±14°C (325 ±25°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 10-260°C (50-500°F).

Sample

The test sample shall be obtained in accordance with the FOP for AASHTO T 168, 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 a minimum of 105°C (221°F), but do not exceed the Job Mix Formula (JMF) mixing temperature. If the mixing temperature is not supplied, a temperature of 163 ±14ºC (325 ±25ºF) is to be used.

   Note 1: For repeatability between laboratories, the preferred practice is to dry the sample at no less than 9° C (15° F) below the JMF mixing temperature.

2. Determine and record the mass of the sample container, including release media, to the nearest 0.1 g.

   Note 2: 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 min intervals until further drying does not alter the mass by more than 0.05 percent.

8. Cool the sample container and test sample to ±9°C (±15°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.

   Note 3: Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

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 4: 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:

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

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 g – 232.6 g = 1129.2 g

Mass of container and possibly dry sample after second drying cycle: 1360.4 g

Mass, M_n, of possibly dry sample: 1360.4 g – 232.6 g = 1127.8 g

$$\frac{1129.2\ g - 1127.8\ g}{1129.2\ g} \times 100 = 0.12\%$$

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 g – 232.6 g = 1127.3 g

$$\frac{1127.8\ g - 1127.3\ g}{1127.8\ g} \times 100 = 0.04\%$$

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.

$$Moisture\ Content = \frac{M_i - M_f}{M_f} \times 100$$

Where: M_i = initial, moist mass

M_f = final, dry mass

Example:

M_i = 1134.9 g
M_f = 1127.3 g

$$Moisture\ Content = \frac{1134.9\ g - 1127.3\ g}{1127.3\ g} \times 100 = 0.674, \text{say } 0.67\%$$

Report

- Results on forms approved by the agency
- Sample ID
- Moisture content to 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 fracture. The percentage of conforming particles, by mass, is calculated for comparison to the specifications.

Apparatus

- Balance or scale: Capacity sufficient for the principle 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 AASHTO M 92.

- Splitter: Meeting the requirements of FOP for AASHTO T 248.

Terminology

1. 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.

2. 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 T 2 and T 248.

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 T 248, 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 T 248.

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 3: 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 large enough to permit careful inspection of each particle. To verify that a particle meets the fracture criteria, hold the aggregate particle so that the face is viewed directly.

2. To aid in making the fracture determination, separate the sample into three categories:

   - fractured particles meeting the criteria
   - particles not meeting the criteria
   - questionable or borderline particles

3. Determine the dry mass of particles in each category to the nearest 0.1 g.

4. Resort the questionable particles when more than 15 percent is present. Continue sorting until there is less than 15 percent in the questionable category.

Calculation

Calculate the mass percentage of questionable fractured particles to the nearest 1 percent using the following formula:

$$\%Q = \frac{Q}{F + Q + N} \times 100$$

where:
%Q = Percent of questionable fractured particles
F = Mass of fractured particles
Q = Mass of questionable or borderline particles
N = Mass of unfractured particles

Example:

F = 632.6 g, Q = 97.6 g, N = 352.6 g
% Q =

$$\frac{97.6\ g}{632.6\ g + 97.6\ g + 352.6\ g} \times 100 = 9.0\% \qquad \%\text{Q} = \mathbf{9}\%$$

Calculate the mass percentage of fractured faces to the nearest 1 percent using the following formula:

$$\text{P} = \frac{\frac{Q}{2} + F}{F + Q + N} \times 100$$

where:
P = Percent of fracture
F = Mass of fractured particles
Q = Mass of questionable particles
N = Mass of unfractured particles

Example:

F = 632.6 g, Q = 97.6 g, N = 352.6 g

$$\text{P} = \frac{\frac{97.6\ g}{2} + 632.6\ \text{g}}{632.6\ g + 97.6\ g + 352.6\ g} \times 100 \qquad \mathbf{P = 63}\%$$

Report

- Results on forms approved by the agency
- Fracture to the nearest 1 percent.

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November 30, 2015

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 1, a filler material is defined as material passing the No. 8 or finer sieve and be from the aggregate source used to produce the Job Mix Formula.**
- **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 USING THE NUCLEAR MOISTURE-DENSITY GAUGE
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 355-15. 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 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 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) 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, 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. Use filler material to fill surface voids. 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.

2. Place the gauge on the test site. Using a crayon (not spray paint), mark the outline or footprint of the gauge. Extend the probe to the backscatter position.

3. Take a one-minute test and record the wet density reading.

4. Rotate the gauge 90 degrees centered over the original footprint. Mark the outline or footprint of the gauge.

5. Take another one-minute test and record the wet density reading.

6. 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.

7. The density reported for each test site shall be the average of the two individual one-minute wet density readings.

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.

Example:

Reading #1: 141.5 lb/ft^3

Reading #2: 140.1 lb/ft^3 Are the two readings within the tolerance? (YES)

Reading average: 140.8 lb/ft^3

Core correction : +2.1 lb/ft^3

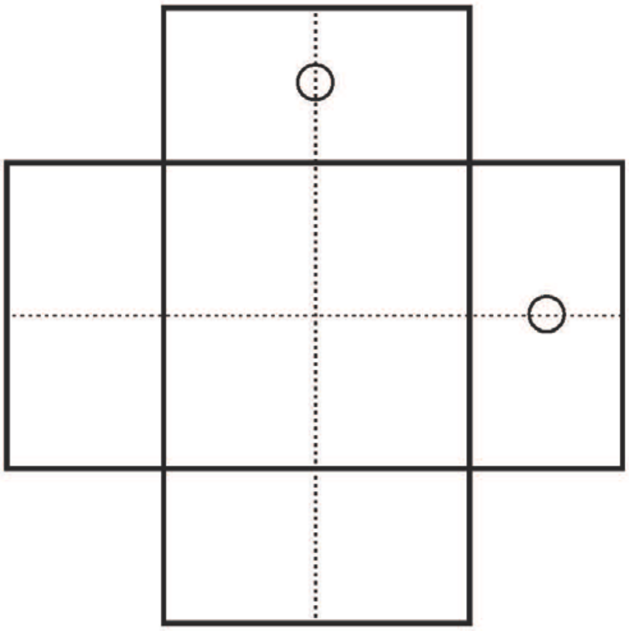
Corrected reading: 142.9 lb/ft^3

From the FOP for AASHTO T 209:

G_{mm} = 2.466

Maximum Laboratory Dry Density = 153.5 lb/ft^3

$$\frac{Corrected\ Reading}{Maximum\ Density} \times 100 = \%\ compaction \qquad \frac{142.9\ lb/ft^3}{153.5\ lb/ft^3} \times 100 = 93.1\%$$



Footprint of the gauge test site

Report

- Results 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 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 HMA and can be compared with the nuclear density gauge readings. Comparing the core value to the corresponding gauge values, a correlation can be established.

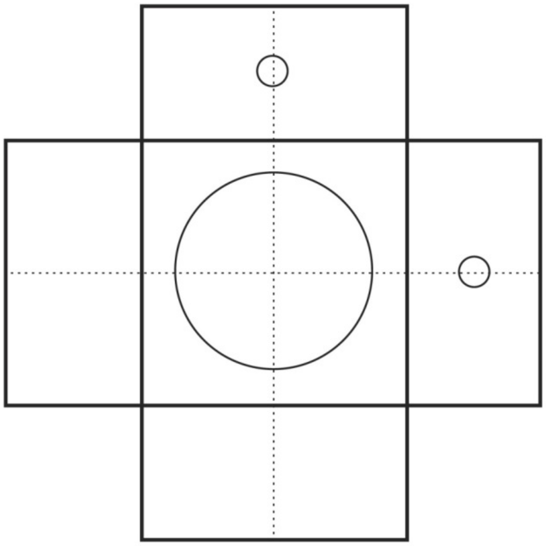
The correlation can then be used to adjust the gauge readings to the in-place density of the cores. The core correlation is gauge specific and must be determined without traffic allowed on the pavement between nuclear density gauge readings and obtaining the core. When using multiple nuclear density gauges each gauge should be correlated to the core locations prior to 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 prior to 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.



Footprint of the gauge test site. Core location in the center of the footprint.

3. Determine the density of the cores by the FOP for AASHTO T 166, Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface Dry Specimens.

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 and at the probe depth 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.

Core Correlation Example:

English

	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	139.8lb/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	0.01

Average Difference: +2.1 lb/ft^3

$$\sqrt{\frac{\sum x^2}{n-1}}$$

Where:

$\sum$ = Sum
x = Difference from the average Difference
n-1 = number of data sets minus 1

Example: 10 – 1 = 9

$$\sqrt{\frac{2.5}{9}} = 0.53$$

The Sum of X^2 = 2.5 and the number of data sets = 9 for a computed standard deviation of 0.53. This is within the allowable 2.5 therefore no cores are eliminated, use the average difference from all ten cores.

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November 30, 2015

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 A (Quartermaster) and Type B (Riffle) are 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 HOT MIX ASPHALT (HMA) TO TESTING SIZE FOP FOR AASHTO R 47

Scope

This procedure covers sample reduction of Hot Mix Asphalt (HMA) to testing size in accordance with AASHTO R 47-14. 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 HMA samples from the quartering device, cleaning surfaces used for splitting, etc.

- Square-tipped, flat-bottom scoop, shovel or trowel for mixing HMA prior to quartering.

- Miscellaneous equipment including hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, and cans.

- Sheeting: Non-stick heavy paper, heat-resistant plastic, 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 A (Quartermaster): having four equal-width chutes discharging into four appropriately sized sample receptacles. Splitter is to be equipped with a receiving hopper that will hold the sample until the release lever is activated with four sample receptacles of sufficient capacity to accommodate the reduced portion of the HMA sample from the mechanical splitter. Refer to AASHTO R 47, Figures 1 through 3, for configuration and required dimensions of the mechanical splitter.

- 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% 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 HMA through the chutes without segregation or loss of material. Sample receptacles of sufficient width and capacity to receive the reduced portions of HMA from the riffle 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 HMA by an amount allowing complete separation of the quartered sample. Height of the sides must exceed the thickness of the flattened cone of HMA.

- Non-stick mixing surface that is hard, heat-resistant, clean, level, and large enough to permit HMA samples to be mixed without contamination or loss of material.

Sampling

Obtain samples according to the FOP for AASHTO T 168.

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 HMA may be performed by a combination of the following methods, as approved by the agency. The methods for reduction are:

- Mechanical Splitter Method
    - Type A (Quartermaster)
    - Type B (Riffle Splitter)
- Quartering Method
    - Full Quartering
    - By Apex
- Incremental Method

Procedure

Mechanical Splitter Type A (Quartermaster)

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will contact HMA.

2. Close and secure hopper gates.

3. Place the four sample receptacles in the splitter so that there is no loss of material.

4. Remove the sample from the agency-approved container(s) and place in the mechanical splitter hopper. Avoid segregation, loss of HMA or the accidental addition of foreign material.

5. Release the handle, allowing the HMA to drop through the divider chutes and discharge into the four receptacles.

6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.

7. Close and secure the hopper gates.

8. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.

9. Combine the material contained in the receptacles from opposite corners and repeat the splitting process until an appropriate sample size is obtained.

10. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Mechanical Splitter Type B (Riffle)

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed 110ºC (230ºF).

2. Clean the splitter and apply a light coating of approved release agent to the surfaces that will come in contact with HMA (hopper or straight-edged pan, chutes, receptacles).

3. Place two empty receptacles under the splitter.

4. Carefully empty the HMA 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.

5. Discharge the HMA at a uniform rate, allowing it to flow freely through the chutes.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
7. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.
8. Using one of the two receptacles containing HMA, repeat the reduction process until the HMA contained in one of the two receptacles is the appropriate size for the required test.
9. After each split, remember to clean the splitter hopper and chute surfaces if needed.
10. Retain and properly identify the remaining unused HMA sample for further testing if required by the agency.

Quartering Method

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed the mix temperature.
2. If needed, apply a light coating of release agent to quartering template.
3. 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.
4. 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.
5. 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.
6. Divide the flattened cone into four equal quarters using the quartering template. Press the template down until it is in complete contact with the surface on which the sample has been placed, assuring complete separation.

   Note 1: Straightedges may be used in lieu of the quartering device to completely separate the material in approximately equal quarters.

7. Reduce the sample by quartering the sample completely or by removing the sample from the apex.

8. Full Quartering

   8a. Remove two diagonally opposite quarters, including all of the fine material.

   8b. Remove the quartering template and combine the remaining quarters, again forming a conical pile.

   8c. Repeat steps 4, 5, 6, 8a, and 8b until a sample of the required size has been obtained. The final sample must consist of the two remaining diagonally opposite quarters.

   8d. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

9. By Apex

   9a. Using a straightedge, slice through a quarter of the HMA from the center point to the outer edge of the quarter.

   9b. Pull or drag the material from the quarter with two straight edges or hold one edge of the straightedge in contact with quartering device.

   9c. Remove an equal portion from the opposite quarter and combine these increments to create the required sample size.

   9d. Continue using the apex method with the unused portion of the HMA until samples have been obtained for all required tests.

   9e. Retain and properly identify the remaining unused portion of the HMA 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 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. 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.

5. Pull the sheeting so at least ¼ of the length of the loaf is off the edge of the counter. Allow this material to drop into a container to be saved. As an alternate, using a straightedge, slice off approximately ¼ of the length of the loaf and place in a container to be saved.

6. Pull material off the edge of the counter and drop into an appropriate size sample pan or container for the test to be performed. Continue removing material from the loaf until the proper size sample has been acquired. As an alternate, using a straightedge, slice off an appropriate size sample from the length of the loaf and place in a sample pan or container.

7. Repeat step 6 until all the samples for testing have been obtained.

   Note2: 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. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Oregon
Kate Brown, Governor

Department of Transportation
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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 66-15. 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.

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 hot mix asphalt (HMA) plant 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 prior to dilution.

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 sublot 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.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

Test Procedure AASHTO R 67 Continued

Under the Layer Separation Section 6, delete 6.1 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.**

Oregon
Kate Brown, Governor

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November 30, 2015

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 3, change or modify as follows:

- **Section 3.2, Core Drill Bit, the core barrel shall have an inside diameter of (6 ± 0.25 in.).**
- **Section 3.3, 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 3.4, Retrieval Device – Removal with a screw driver(s) or similar device shall not be allowed.**

Under the Filling Core Holes Section 4.8, delete and replace with the following:

> **The Hole made 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 that the final surface is level with the surrounding surface.**

(See Next Page)

Standard Practice for

Sampling Asphalt Mixtures after Compaction (Obtaining Cores)

AASHTO Designation: R 67-15[1]

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Practice for

Sampling Asphalt Mixtures after Compaction (Obtaining Cores)

AASHTO Designation: R 67-15[1]

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. SIGNIFICANCE

2.1. Samples obtained in accordance with the procedure may be used for measuring asphalt mixture thickness, density, and other testing.

3. APPARATUS

3.1. *Core Drilling Machine*—A power-driven wet-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 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.

3.2. *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.

3.3. *Separation Equipment*—A saw or other method(s) that provides a clean, smooth plane representing the layer to be tested without damaging the specimen.

3.4. *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.

3.5. *Cooling Agent*—Such as water, ice, dry ice, or liquid nitrogen.

4. PROCEDURE

4.1. Freshly compacted asphalt mixtures shall be allowed sufficient time to cool prior to coring in order to prevent damage to the core.

4.1.1. 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.

4.2. 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.

4.3. Position the coring machine above the selected location. Engage power and water or air source to coring machine. Slowly advance bit until contact with the compacted asphalt mixture surface.

4.4. Keep the core bit perpendicular to the compacted asphalt mixture surface, applying constant pressure during the process.

Note 2—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 bit to bind or distort the core.

4.5. Continue the coring operation to the desired depth.

4.6. After drilling, use a retrieval device to obtain the core without damaging or distorting the sample.

Note 3—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.

4.7. Clearly label the core with a sample marking tool.

4.8. 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.

5. TRANSPORTING SAMPLES

5.1. Transport cores in a manner that prevents damage from jarring, rolling, or impact with any object.

5.2. Prevent cores from freezing or from excessive heat during transport.

Note 4—In extreme ambient temperature conditions, an insulated container should be used during transport.

5.3. If the core is damaged in transport to a point it cannot be utilized for its intended purpose, the core will not be used.

6. LAYER SEPARATION

6.1. Using appropriate separation equipment, separate two or more pavement courses, lifts, or layers along the designated lift line.

Note 5—Lift lines are often more visible by rolling the core on a flat surface.

7. REPORT

7.1. *The report shall include the following*:

7.1.1. Date the cores were obtained.

7.1.2. Paving date.

7.1.3. Coring location.

7.1.4. The lift/layer being evaluated.

7.1.5. Material type.

7.1.6. Average thickness if required.

APPENDIX

(Nonmandatory Information)

X1. THICKNESS DETERMINATION

X1.1. Measure the thickness of the designated lift to the nearest 0.01 ft, $^1/_8$ in., or 3 mm. Calculate an average of three or more measurements taken around the lift.

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[1] This full standard was first published in 2015.