TN TDOT Department of Transportation

HOT MIX ASPHALT

MIX DESIGN

SPECIFICATIONS

VERSION 18.0

Division of Materials and Tests *2018*

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Helpful Links

Specs, Circulars, Etc:	https://www.tn.gov/tdot/tdot-construction-division/transportation-construction-division-resources/transportation-construction-2015-standard-specifications.html
SOP:	https://www.tn.gov/tdot/materials-and-tests/standard-operating-procedures.html
Blank Forms:	https://www.tn.gov/tdot/materials-and-tests/field-operations/forms.html
Training Information:	https://www.tn.gov/tdot/materials-and-tests/field-operations/training.html

1) *Maximum Specific Gravity of Mix*

$$Gmm = \frac{Pmm}{\left(\frac{Ps}{Gse}+\frac{Pb}{Gb}\right)}$$

Gmm = Max Specific Gravity of mix
Gb = Gravity of asphalt cement
Pmm = Percent by mass of loose mix
Ps = Percent (%) Agg. Content
Gse = Effective specific gravity of Agg.
Pb = Asphalt content % by total mass of mix

2) Volume of Air Voids in Marshall's

$$Vtm\ (Va) = 100 \times \frac{(Gmm - Gmb)}{Gmm}$$

Va = Volume of air voids
Gmm = Max Specific Gravity of mix
Gmb = Bulk gravity of mix

3) Volume of Voids in Mineral Agg.

$$Vma(eff.) = 100 - \frac{(Gmb \times Ps)}{Gse}$$

Vma = Volume of voids in mineral Agg.
Ps = Percent (%) Agg. Content
Gse = Effective specific gravity of Agg.
Gmb = Bulk gravity of mix

4) Volume of Voids Filled with Asphalt

$$Vfa(eff.) = 100 \times \frac{(Vma - Va)}{Vma}$$

Vfa = Voids filled with AC
Va = Volume of air voids
Vma = Volume of voids in mineral Agg.

5) Effective Asphalt Content by % Mix Mass

$$Pbe = Pb - \left(\frac{Pba}{100}\right) \times Ps$$

Pbe = Eff. AC (% by mass of mix)
Pba = Absorbed AC (% by mass of Agg.)
Pb = % Asphalt Content
Ps = % Agg. Content

6) Absorbed Asphalt Content by % Agg.

$$Pba = 100 \times \frac{(Gse - Gsb)}{(Gsb - Gse)} \times Gb$$

Pba = Absorbed AC (% by mass of Agg.)
Gse = Effective specific gravity of Agg.
Gb = Gravity of asphalt cement
Gsb = Bulk Specific Gravity of Agg.

7) Effective Specific Gravity of Agg.

$$Gse = \frac{(Pmm - Pb)}{\left(\frac{Pmm}{Gmm}-\frac{Pb}{Gb}\right)}$$

Gse = Effective specific gravity of Agg.
Pb = Asphalt content % by total mass of mix
Gmm = Max Specific Gravity of mix
Gb = Gravity of AC
Pmm = % by mass of loose mix.

8) Blending of Agg. / Proportioning Agg.

$$P = Aa + Bb + Cc + \cdots$$

A,B,C,… = % of Agg.passing a given sieve
a,b,c,… = Proportions of Agg. A,B,C,…

9) RAP Blending Calculation

$$M(rap) = \frac{(P(rap) \times M(tot))}{(\ 100 - Pb(rap)\ )}$$

M(rap) = Mass of RAP
P(rap) = % of RAP in Mix
M(tot) = Total mass of Agg. in mix
Pb(rap) = % AC contributed by RAP

10) Mass of Virgin Asphalt Needed

$$M(acpb) = \left(\frac{M(tot)}{\left(\frac{100-Pb}{100}\right)}\right) - \left(\frac{\left(M(rap)\times Pb(rap)\right)}{100}\right) - M(tot)$$

M(acpb) = Mass of Virgin AC
M(rap) = Mass of RAP
Pb(rap) = % Asphalt Content in RAP
Pb = % Asphalt Content
M(tot) = Total mass of Agg. in mix

1

Supplemental Specifications

Table of Contents

S T A T E **O F** **T E N N E S S E E**

(Rev. 3-30-15)
(Rev. 11-16-15)
(Rev. 6-27-16)
(Rev. 12-2-16)
(Rev. 5-15-17)
(Rev. 11-6-17)

January 1, 2015

Supplemental Specifications - Section 100

of the

Standard Specifications for Road and Bridge Construction

January 1, 2015

Subsection 101.03 (pg. 10) 5-15-17; Add the following definition for Specialty Items:

"**Specialty Item.** Work items identified in the contract which are not bid normally associated with highway construction and require highly specialized knowledge, abilities, craftsmanship, or equipment not ordinarily available in the type of contracting organizations qualified and expected to bid on the contract in general, these items are to be limited to minor components of the overall contract."

Subsection 102.11 (pg. 18), 3-30-15; Add the following to the second paragraph:

"The Department may retain the Proposal Guaranty, not as a penalty, but as liquidated damages in the event a bidder does not have a license at the time of award."

Subsection 104.04 (pg. 27), 3-30-15; Add the following as the first full paragraph on page 27:

"If a holiday falls on Saturday or Sunday, do not close lanes or restrict traffic from the preceding Friday at 6 am to the following Monday at 6 am."

Subsection 105.03 (pg. 38), 12-2-16; Add the following to the end of the section:

"Products listed on the QPL which fail to comply with Departmental performance expectations shall be removed from the QPL. Products removed from the QPL shall be replaced with an equivalent product from the QPL. At the Departments discretion, an equitable adjustment may be made to the contract for invoice price deviations."

Subsection 105.03 (pg. 38), 6-27-16; Add the following to the end of the section:

"All products must be listed on the Qualified Products List (QPL) and perform as specified at the time of use regardless of Letting date. Any products removed from the QPL or that do not perform as specified, must be supplied or replaced at the Contractor's expense."

Subsection 105.06 (pg. 40), 3-30-15; Replace 2nd sentence of 1st paragraph with

"The contractor must attend a preconstruction conference arranged by the Engineer."

Subsection 105.10 (pg. 46), 5-15-17; Revise 2nd sentence of the first paragraph:

"Such inspection may extend to any part or to all of the Work and to the preparation, fabrication, or manufacture of materials to be used."

Subsection 105.11 (pg. 46), 5-15-17; Revise the 1st sentence:

"The Engineer or its representative will inspect all materials and each part or detail of the Work ."

Subsection 105.13 (pg. 48), 5-15-17; Remove the 2nd paragraph.

Subsection 105.15 (pg. 49), 5-15-17; Remove last paragraph:

Subsection 106.06 (pg. 61), 5-15-17; Revise the first paragraph of A. and subsection A.2:

"Provide a Type A Laboratory consisting of a building, room, or dedicated area having at least 120 square feet of floor area with a minimum width of 8 feet and a minimum height of 7 feet. Provide laboratory space that is floored, roofed, sealed inside, weather-tight, and furnished with electricity. Furnish the space with adequate work benches, cabinets, and drawers. Provide suitable heat and air conditioning, and equip the laboratory with a laboratory oven capable of maintaining a temperature of 230 °F ± 9 °F. Stove tops and hot plates may be used to determine moisture conditions of aggregates. Provide lights, electrical outlets, and adequate ventilation for the tests being performed.

When the determination of aggregate gradation is required, furnish the following equipment:

1. Scales of appropriate capacity and design to weigh the required samples. Scales are to be sensitive to within 0.2% of the sample to be weighed. Provide standard weights for scale calibration.

2. Screens of appropriate size and mesh to separate the samples into the required series of sizes. Woven wire cloth shall conform to AASHTO M 92. Screens for running gradations of coarse aggregates shall meet AASHTO T27.

3. A mechanical shaker approved by the Engineer and suitable for running both coarse and fine aggregate.

4. Facilities to perform wash tests according to AASHTO T 11 that include an adequate and suitable water supply."

Subsection 107.08 (pg. 69), 5-15-17; Add the following to the end of the third paragraph:

"All costs associated with any support activities including obtaining permission from landowners, permits, and compliance are to be included in the bid cost for the project."

Subsection 107.08 (pg. 71), 11-6-17; Add the following as section E:

"E. Migratory Birds

The following procedure will be automatically implemented by TDOT, unless FWS approves in writing deviations due to special circumstances, or for a specific variance.

Cliff swallow and barn swallow nests, eggs, or birds (young and adults) will not be disturbed between April 15 and July 31. From August 1 to April 14, nests can be removed or destroyed, and measures implemented to prevent future nest building at the site (i.e., closing off area using netting).

Exceptions:
(1) If there are no eggs in the nests prior to April 15, TDOT will be allowed to destroy the nests and prevent further nest building at the site, by installing netting. Net openings shall be ½ inch or smaller after installation, and shall be installed securely and in such a manner that it will not pose a safety hazard. Absence of eggs prior to net installation must be documented by using appropriate means for determination, such as, but not limited to, site visits and photographs.
(2) If there are no birds (young or adult) left in any of the nests at a specific site prior to July 31, the nests can be removed or destroyed. Absence of birds must be documented by using appropriate means for determination, such as, but not limited to, site visits, photographs, and observations of no birds using the nests.

Osprey, Double Crested Cormorants, Great Horned Owls, Barn Owls, Black Vulture, and Eastern Phoebes:
If these avian species are encountered on a bridge project, TDOT Ecology should be contacted immediately for further assistance.

The Contractor will be assessed the amount of any and all fines and penalties assessed against and cost incurred by TDOT which are the result of the Contractor's failure to comply with this Special Provision. TDOT will not be responsible for any delays or costs due to the Contractor's failure to comply. Additional compensation or contract time due to noncompliance will not be granted.

All costs incurred with this specification will not be measured or paid for separately, but will be considered included in the contract unit prices bid for other items of the contract."

Subsection 108.01 (pg. 78) 5-15-17; Subletting of Contract, Add the following list of specialty items:

"Do not sublet, allow second tier sublet, sell, transfer, assign, or otherwise dispose of the Contract or any portion thereof or a right, title, or interest in the Contract without the Engineer's written consent. If the Engineer consents to subletting or second tier

subletting a portion of the Contract, the Contractor shall self-perform work amounting to not less than 30% of the total original Contract cost. For items designated in the Contract as "specialty items," the Contractor may sublet or second tier sublet this work and deduct the cost of such specialty items from the total original cost before computing the amount of the Work required to be self-performed by the Contractor with its own organization.

As stated above, unless there is a Special Provision 108A in the proposal, the following items are designated as Specialty Items:

Item 105-01 - Construction Stakes, Lines and Grades
Item 202-01.02 – Removal of Asbestos
Item 209 - EPSC Item 411-12.**Shoulder Scoring
Item 501-03.12 – Concrete Shoulder Rumble Strip
Item 602-03 - Steel Structures
Item 602-04 - Steel Structures
Item 602-10.13 / .14 - Navigational LightingItem 602-10.81 – Heat Straightening
Item 603-02 - Repainting Steel Structures
Item 603-05 - Containment and Disposal of Waste
Item 604-04.01 - Applied Texture Finish (New Structures),
Item 604-04.02 - Applied Texture Finish (Existing Structures)
Item 604-04.62 - Clean and Texture Finish Median Barrier
Item 604-05.31 - Bridge Deck Grooving (Mechanical)
Item 604.07 – Retaining Wall
Item 604-42.01 – Underwater Divers
Item 606-26.05 – Core Drilling for Piles (Abandoned)Item 617 - Bridge Deck Sealant
Item 624 – Retaining Wall Items
Item 625-01.08,10,11 – Inclinometer, Drilled Shaft Inspections
Item 640 - Weigh Station Items
Item 705 - Guardrail, Anchors, etc.
Item 706 - Guardrail Items
Item 707 - Fencing ItemsItem 712 - Traffic Control Items
Item 713 - Signing Items
Item 714 - Lighting Items
Item 716 - Pavement Marking Items
Item 720-03, 720-04, 720-05, 720-06, 720-07, 720-08, 720-09 – Railroad Highway Crossing
Item 721-01.06 – Irrigation System Repair
Item 721-10, 721-11.20, 721-11.30, 721-12 – Landscape and Irrigation Item 725 – ITS items
Item 730 - Traffic Signal Items
Item 7** - Utility Items
Item 750.01 – Mitigation Site
Item 801 - Seeding
Item 802 - Landscaping Items
Item 803-01 - Sodding
Item 805 - Erosion Control
Item 806 - Project Mowing"

Subsection 109.01 (pg. 98-100) 11-16-15; Measurement of Quantities, E. Weight; Remove the 12th paragraph and replace with the following:

"The scales shall be checked by an independent certified scale company. The check shall be performed on a semiannual basis; January through June and July through December. The results shall be maintained onsite and made available for review to Departmental personnel. If deficiencies are reported, all corrections shall be performed, documented, and verified prior to supplying material for TDOT projects."

Subsection 109.01 (pg. 98-99) 5-15-17; Measurement of Quantities, E. Weight, Modify the 6th paragraph to the following:

"Employ a Certified Public Weigher as defined in the Certified Public Weigher Law of 1981, Tennessee Code Annotated, Section 47-26-801, et seq., as amended. The Engineer will measure all applicable materials in accordance with the Certified Public Weigher Law and Department policy on scales approved by the Engineer. Provide weight (haul) tickets in accordance with Department policy and as directed by the Engineer. These requirements apply to entities located both inside and outside the state of Tennessee"

Subsection 109.01 (pg. 98-100) 5-15-17; Measurement of Quantities, E. Weight, Modify the 12th paragraph to the following:

"The scales shall be calibrated and certified by an independent certified scale company. The calibration and certification shall be performed on a semiannual basis; January through June and July through December. Scales shall be validated on a quarterly basis to ensure their continued accuracy. Validation shall be made by a verified known weight, or other scales that are approved by the Department or other State agency. A verified known weight shall be checked for continued accuracy each time the scales are calibrated. The results shall be maintained onsite and made available for review to Departmental personnel. If deficiencies are reported, all corrections shall be performed, documented, and verified prior to supplying material for TDOT projects."

Subsection 109.01 (pg. 98-100), 11-9-17; E. Weights, Revise subsection to the following:

"E. Weight

The term "ton" will mean the short ton consisting of 2,000 pounds avoirdupois.

~~The Engineer will measure cement by the ton.~~

Unless otherwise specified, the Engineer will accept certified weights for materials measured or proportioned by weight that are shipped by rail or truck transport, provided that only the actual weight of the material used is paid for.

For bituminous materials, net certified scale weights or weights based on certified volumes in the case of rail or truck transport shipments, unless otherwise specified, will be used as a basis of measurement, subject to correction when bituminous material has been lost, wasted, or otherwise not incorporated in the Work.

In all cases where measurement of materials is based on certified weights, provide the Engineer with certified weigh bills showing the net tons of materials received in each shipment. The

Engineer will not pay for materials in excess of the amounts represented by the certified weigh bills.

~~When~~ Certified Weigh Tickets ~~are required~~ for Asphalt Mixtures and Aggregate Materials ~~, the following~~ shall ~~be~~ list~~ed~~ on the ticket:

1. Date
2. Time
3. The ticket number
4. Gross weight of the loaded truck
5. Tare weight of the truck
6. Net weight of the material to be paid
7. Running Daily Total for the particular material
8. Truck number
9. Truck Legal limit

Employ a Certified Public Weigher as defined in the Certified Public Weigher Law of 1981, Tennessee Code Annotated, Section 47-26-801, et seq., as amended. The Engineer will measure all applicable materials in accordance with the Certified Public Weigher Law and Department policy on scales approved by the Engineer. Certified Weigher licenses shall be posted near the scale beam or weight indicator in full view at all times. Certified Weigher shall be the only person allowed to operate the scale or weigh recording equipment. Provide weight (haul) tickets in accordance with Department policy and as directed by the Engineer. These requirements apply to entities located both inside and outside the state of Tennessee.

Certified Weigher shall weigh each load with the maximum load not to exceed the legal limit established by law. The proposed haul route shall be known prior to deployment.

Provide a standard brand of platform truck scales with a sufficient rated capacity to weigh the maximum gross load to which they will be subjected. Do not use truck scales to measure weights in excess of the manufacturer's rated capacity. Clearly post the manufacturer's rated capacity on the scale manufacturer's plate and in the shelter provided for the weigher.

At the time of installation or modification of existing scales, test the scales before using to ensure they are within the allowable tolerances. Use a qualified scale technician to perform any alteration (e.g., electrical readout) or change in the rated capacity. Document all changes or alterations made by the scale technician and furnish a copy of the documentation to the Department.

House the recording mechanism of the scale in a suitable shelter furnished with adequate light, heat, chairs, tables, and storage drawers as needed for the convenience of the weigher. In addition, keep the scale platform and scale pit free of debris that could affect the accuracy of the scales.

Provide digital readout and scale printers as the primary weight indicator or as accessory equipment. The Department will inspect and approve all scale control and recording equipment.

Ensure the scale's accuracy within a tolerance of 0.5% ~~and with a minimum graduation value not greater than 100 pounds~~. Provide a straight approach at each end of the platform scale in the same plane as the platform and of sufficient length and width to ensure the level positioning of vehicles longer than the scale platform during weight determinations. Weigh each truck and trailer with no brakes set on any wheel. Locate the scale platform so that surface water will drain away from it and to allow for an adequate foundation of concrete or other approved materials. Construct the foundation of sufficient strength and durability to withstand repeated capacity loading without affecting the accuracy of the scales.

Check the scales as often as necessary to ensure their continued accuracy. If the scales cannot be checked within the time frame set by Department policy, the Engineer may give tentative approval, based on check truckloads weighed on other scales that are approved by the Department or other State agency. The scales shall be calibrated and certified by an independent certified scale company. The calibration and certification shall be performed on a semiannual basis; January through June and July through December. Scales shall be validated on a quarterly basis to ensure their continued accuracy. Validation shall be made by a verified known weight, or other scales that are approved by the Department of other State agency. A verified known weight shall be checked for continued accuracy each time the scales are calibrated. The results shall be maintained onsite and made available for review to Departmental personnel. If deficiencies are reported, all corrections shall be performed, documented, and verified prior to supplying material for TDOT projects.

Weigh tickets shall be certified either manually or electronically. If certified manually, the Certified Weigher shall sign his official registered signature and place his seal on the original ticket. The ticket shall be filled out in ink and delivered to the project site with the material.

~~Trucks used to haul material being paid for by weight shall be weighed empty at such times as the Engineer directs, and each truck shall bear a plainly legible identification mark.~~

For materials directly paid for by the ton, ~~T~~the Engineer will be furnished a daily recap of all materials delivered to the project. The daily recap sheet must list the ticket number, type of material by item number, and a quantity of materials for each load hauled. Any discrepancy between the certified weigh bills and the daily recap will be reviewed along with the contractor's initialed copy of weigh bills.

Due to possible variations in the specific gravity of aggregates, the tonnage used may vary from the proposal quantities and the Department will not make adjustments in the Contract unit price because of such variations.

The truck tare to be used in the weighing operation shall be the weight of the empty truck determined with full tank(s) of fuel and the operator seated in the cab. A daily weight shall be recorded at the beginning of each work day prior to use of truck. If preferred, a new tare may be determined for each load. When a new tare is obtained for each load, the requirement for full tank(s) of fuel shall be waived.

All weight of trucks shall be recorded to the nearest 20 pounds.

The cost of providing facilities and equipment for the accurate weighing, proportioning, or measuring of materials is incidental to the associated pay items in the Contract."

Subsection 109.02 (pg. 100-101), 11-9-17; Replace the last paragraph:

"Document on the Prompt Payment Certification Form the actual amount paid to all subcontractors, ~~ny certified Disadvantaged Business Enterprise (DBE) or certified Small Business Enterprise (SBE)~~ during the estimate period for which the certification is being made. Ensure all Disadvantaged Business Enterprise (DBE) or certified Small Business Enterprise (SBE) are listed and classified on the form, including DBE or SBE off-site haulers and DBE or SBE material suppliers"

Subsection 109.04 (pg. 106), 3-30-15; Replace C. Force Account, 4. Equipment, c. with:

"Idle or standby cost will not be paid for more than 8 hours in a day or 40 hours in a week".

S T A T E **O F** **T E N N E S S E E**
(Rev. 11-16-15) January 1, 2015
(Rev. 6-27-16)
(Rev. 12-2-16)
(Rev. 5-15-17)

Supplemental Specifications - Section 300

of the

Standard Specifications for Road and Bridge Construction

January 1, 2015

Subsection 303.01 (pg. 220) 5-15-17; add the following sentence as the last sentence of the 2nd paragraph:

"Mineral aggregates base shall be Type A or Type B, whichever is shown on the Plans and called for in the bid schedule. Reclaimed Concrete Aggregate (RCA) may be used as an alternate for Type A or Type B base material."

Subsection 303.02 (pg. 220-221) 5-15-17; add the following sentence to the last sentence of the 1st paragraph:

"Depending upon whether the Plans require Type A or Type B base, provide mineral aggregate meeting 903.05. For Type A base, use aggregate of Grading D. For Type B base, the Contractor may use aggregate of Grading C or D. For RCA, use grading specified in 903.05-C."

Subsection 303.07 (pg. 222-223) 5-15-17; modify the 1st sentence of the 1st paragraph to the following:

"Construct Mineral Aggregate Base, Type A, ~~or~~ Type B, or RCA in one or more layers, to the compacted thickness shown on the Plans."

Subsection 303.08 (pg. 223-224) 5-15-17; add the last sentence to the last paragraph of subsection A:

"For Mineral Aggregate Base, Type A, use the stationary plant method. For Mineral Aggregate Base, Type B, requiring the blending of two or more materials, use either the stationary plant method or the road mix method (mechanical mixer), except as provided for in **903.05**. For Mineral Aggregate Base, Type B, requiring additive, use either stationary plant mixing or road mixing. When using RCA as a replacement for Mineral Aggregate Base, Type A or Type B, use the intended method of mixing for the material listed above."

Subsection 303.10 (pg. 225-227) 5-15-17; add subsection c.:

"**2. Density Requirements**

a. **Type A Base.** The average density of each lot of Type A base, unless otherwise specified, shall be within 100% of maximum density as determined according to AASHTO T 99, Method D, with no individual test less than 97% of maximum density.

b. **Type B Base.** The average density of each lot of Type B base, unless otherwise specified, shall be not less than 97% of maximum density as determined according to AASHTO T 99, Method D, with no individual test being less than 95% of maximum density.

c. **RCA Base.** The average density of each lot of RCA base, unless otherwise specified, shall be not less than 100% of maximum density as determined according to AASHTO T 99, Method D, with no individual test less than 97% of maximum density. The moisture content shall be within ±3% of the optimum moisture content as determined by an independent laboratory analysis. Mixing of the material with water shall be completed per Section 303.08."

Subsection 303.14 (pg. 228) 5-15-17; revise the first sentence of A.:

"**A. Mineral Aggregate for Mineral Aggregate Base, Type A or Type B, or RCA**

The Department will measure Mineral Aggregate for Mineral Aggregate Base, Type A, ~~or~~ Type B, or RCA, by the ton, in accordance with **109**."

Subsection 307.03 (pg. 246) 11-16-15; Modify Table 307.03-3:

B. Recycled Asphalt Pavement for Bituminous Plant Mix Base, Table 307.03-3

Table 307.03-3: Mixtures Using RAP

Mix Type	% RAP (Non-processed)[1]	Maximum % RAP (Processed)[2]	Maximum % RAP Processed & Fractionated[3]	Maximum Particle Size (inches)
307-ACRL	0	00	-	-
307-AS	0	00	15	-
307-A	15	20	35	1-1/2
307-B	15	30	35	1-1/2
307-BM	15	30	35	3/4
307-BM2	15	30	35	3/4
307-C	15	30	35	3/8
307-CW	15	30	35	1/2
307-CS	0	15	25	5/16

[1] "Non-processed" refers to RAP that has not been crushed and screened or otherwise sized prior to its use.

[2] "Processed" refers to RAP that has been crushed and screened

or otherwise sized such that the maximum recycled material particle size is less than that listed in Table 307.03-3 prior to entering the dryer drum.

(3) "Fractionated" refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes (e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

(4) RAP for 307-AS must be processed in a manner such that the minimum particle size is no smaller than 3/4" prior to solvent extraction. For RAP containing gravel as coarse aggregate, the maximum allowable RAP content shall be 10%.

2. Recycled Asphalt Shingles (RAS) RAS may be included to a maximum of 3% of the total weight of the mixture.

Subsection 307.03 (pg. 246) 5-15-17; Modify Table 307.03-3:

B. Recycled Asphalt Pavement for Bituminous Plant Mix Base, Table 307.03-3

Table 307.03-3: Mixtures Using RAP

Mix Type	% RAP (Non-processed)(1)	Maximum % RAP (Processed)(2)	Maximum % RAP Processed & Fractionated (3)	Maximum Particle Size (inches)
307-ACRL	0	00	-	-
307-AS	10	1000	1015	-
307-A	15	20	35	1-1/2
307-B	15	30	35	1-1/2
307-BM	15	30	35	3/4
307-BM2	15	30	35	3/4
307-C	15	30	35	3/8
307-CW	15	30	35	1/2
307-CS	0	15	25	5/16

(1) "Non-processed" refers to RAP that has not been crushed and screened or otherwise sized prior to its use.

(2) "Processed" refers to RAP that has been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that listed in Table 307.03-3 prior to entering the dryer drum.

(3) "Fractionated" refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes

(e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

~~(4) RAP for 307-AS must be processed in a manner such that the minimum particle size is no smaller than 3/4" prior to solvent extraction. For RAP containing gravel as coarse aggregate, the maximum allowable RAP content shall be 10%.~~

Subsection 307.03 (pg. 250) 6-27-16; C. revise the last paragraph to the following:

"Mix an approved antistrip agent with the asphalt cement at the dosage as specified in **921.06.B**."

Subsection 307.06 (pg. 250) 12-2-16; add the following as the second paragraph:

"Do not place AS/ACRL which cannot be covered by the next course of pavement within the same construction season."

Subsection 313.03 (pg. 273) 11-16-15; B. Bituminous Treated Permeable Base, add the following sentence to the end of the paragraph:

"Recycled Asphalt Pavement (RAP) meeting the requirements of 307.03.B may be incorporated into asphalt treated permeable base up to 15% by weight of aggregate. RAP must be processed in a manner such that the minimum particle size is no smaller than ¾" prior to solvent extraction. Treated permeable base mixtures containing RAP shall contain at least 65% virgin asphalt binder. For RAP containing gravel as a coarse aggregate, the maximum allowable RAP content shall be 10%"

Subsection 313.03 (pg. 273) 5-15-17; B. Bituminous Treated Permeable Base, revise the sentence added on 11-16-15 to the following sentence:

"Recycled Asphalt Pavement (RAP) meeting the requirements of 307.03.B may be incorporated into asphalt treated permeable base up to 10~~5~~% by weight of aggregate. ~~RAP must be processed in a manner such that the minimum particle size is no smaller than ¾" prior to solvent extraction.~~ Treated permeable base mixtures containing RAP shall contain at least 65% virgin asphalt binder. For RAP containing gravel as a coarse aggregate, the maximum allowable RAP content shall be 10%.

Mix an approved antistrip agent with the asphalt cement at the dosage as specified in **921.06.B.**"

Subsection 313.10 (pg. 276) 5-15-17; Basis of Payment, add the sentence as the third paragraph:

"The cost of antistrip additive used in Bituminous Plant Mix (Hot Mix) will be included in the price of Treated Permeable Base."

S T A T E **O F** **T E N N E S S E E**
(Rev. 5-18-15) January 1, 2015
(Rev. 7-13-15)
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(Rev. 11-6-17)

Supplemental Specifications - Section 400

of the

Standard Specifications for Road and Bridge Construction

January 1, 2015

Subsection 402.03 (pg. 282) 5-27-16; revise 0.2 to 0.05 in the range as shown in the 2nd paragraph:

> "The distributor shall be designed, equipped, maintained, and operated so that bituminous material at even heat may be applied uniformly on variable surface widths at readily determined and controlled rates from 0.05 to 0.5 gallons per square yard, with uniform pressure, and with an allowable variation from any specified rate of plus or minus 0.02 gallons per square yard."

Subsection 403.02 (pg. 285-286) 12-2-16; Bituminous Materials, remove trackless tack information from specifications and reference the QPL for approved Emulsified Trackless Tacks, remove trackless tacks from Table 403.02-1:

> "Emulsified Asphalt, SS-1, SS-1h, CSS-1, CSS-1h, TST-1P, CQS-1h, CQS-1hp……904.03 or Approved Emulsified Trackless Tack from the QPL.

Table 403.02-1: Tack Coat Application Temperatures

Material	Temperature Range
SS-1, SS-1h, CSS-1, TST-1P, CQS-1h, CQS-1hp and CSS-1h	60 to 140 °F

Subsection 403.02 (pg. 285-286) 11-16-15; Bituminous Materials, update the reference to 904.03, add TTT-3 to Table 403.02-1:

"Emulsified Asphalt, SS-1, SS-1h, CSS-1, CSS-1h, TST-1P, CQS-1h, CQS-1hp, TTT-1, TTT-2, TTT-3 ……..904.03"

Table 403.02-1: Tack Coat Application Temperatures

Material	Temperature Range
SS-1, SS-1h, CSS-1, TST-1P, CQS-1h, CQS-1hp and CSS-1h	60 to 140 °F
TTT-1	160 to 180 °F
TTT-2	120 to 160 °F
TTT-3	100 to 180 °F

Subsection 403.05 (pg. 286) 11-16-15; A. Emulsified Asphalt, Add the following paragraph at the end of the subsection:

"Take a minimum of 3 cores throughout the length of the project for informational tack coat shear testing. Include the underlying layer. Not required for mats less than one inch thick."

Subsection 403.05 (pg. 287) 11-16-15;) B. Test Strip, modify the 2nd paragraph to update the rate as 0.08 and 0.12:

"If placing the bituminous material upon a milled surface, apply the tack material at a rate of between 0.08 and 0.12 gallons of applied emulsion per square yard."

Subsection 403.05 (pg. 287) 6-27-16; revise the last sentence of the 2nd paragraph:

"If placing the bituminous material upon a milled surface, apply the tack material at a rate of between 0.08 and 0.12 gallons applied emulsion per square yard."

Subsection 403.05 (pg. 287), 11-6-17; Revise the 1st sentence of the 1st paragraph:

"When the Contract requires bituminous material for fog sealing of shoulders, provide emulsified asphalt meeting **403.02** or an item from QPL 40A ~~meeting **403.02**~~**."**

Subsection 404 (pg. 289-293) 1-6-17; Remove the entire subsection. All specifications regarding Double Bituminous Surface Treatment has been incorporated into subsection 405. All references shall be updated to subsection 405.

Subsection 405 (pg. 294-298) 1-6-17; replace subsection 405 with the following:

"405.01 Description

This work consists of constructing a bituminous seal coat consisting of one or more applications each of bituminous material and cover aggregate.

MATERIALS

405.02 Materials

Provide materials as specified in:

Mineral Aggregate, Size Nos. 7, 8, 78, 89..... 903.13
Mineral Aggregate……..... 903.14
Emulsified Asphalt, CRS-2p 904.03

Apply seal coat at a temperature range of 60 to 140 °F.

EQUIPMENT

405.03 Equipment

Provide a power broom or other mechanical sweeping equipment, equipment for heating bituminous material, a pressure distributor meeting the requirements of 402.03, pneumatic-tire and steel-wheel rollers, self-propelled mechanical aggregate spreading equipment that can be adjusted so as to spread accurately at the specified rate, and such other equipment and small tools as may be required to perform the work in a satisfactory manner.

CONSTRUCTION REQUIREMENTS

405.04 Limitations

Only apply bituminous material:

1. When the designated surface is dry, firm, and properly cured;

2. Between April 15 and October 1; and, unless otherwise directed,

3. When the ambient temperature in the shade and away from artificial heat is 70°F or more.

405.05 Preparing the Designated Surface

Before placing seal coat, clean all surfaces to be sealed by sweeping with a motorized broom to remove any loose material. Clean depressions and cracks not reached by the power broom using hand brooms or pressurized air.

Cover any utility installations to prevent adherence of the bituminous mixture. Suitable covering includes plywood disks, sand, craft paper, roofing felt or other approved methods. Remove the protective coverings before opening the road to traffic. The cost for these adjustments shall be included in the bid price for other items.

The Plans will indicate whether the surface is to be constructed on a treated or untreated subbase, a granular base, an asphalt base, or on an existing surface. The surface of the base or sub-base upon which the construction is to be placed shall meet the requirements of the applicable Section of Part 3, Bases and Subgrade Treatments, of these Specifications.

Condition existing surface, if called for on the Plans, as specified in 407.10. Condition existing mineral aggregate base as specified in 310.

Construct and maintain Prime Coat or Tack Coat, if shown on the Plans, as specified in 402 or 403, respectively.

405.06 Application

A. Applying Bituminous Material:

Have all equipment calibrated prior to starting work. The TDOT inspector shall be present during calibration to determine aggregate spread rate and distributor rates. Distributor trucks shall have proper calibration of spray equipment. Spray nozzles should be clean, properly angled, and appropriately sized for the desired application rate. Stop work if the distributor is not applying material properly, such as gaps in application or streaking.

Place a 500 ft. test strip for the bituminous seal coat at the beginning of the project to assure proper coverage and proper equipment calibration. The test section is to verify break time of emulsion and chip retention. The test strip shall be able to carry normal traffic within 3 hours. If normal traffic cannot be carried, the emulsion shall be adjusted and another test strip is required.

At least 14 working days before the scheduled start of construction of any bituminous seal coat, submit a sample of aggregate intended for use for the determination of the appropriate application rates of bituminous material and aggregate. Apply emulsified asphalt by pressure distributor at a uniform rate in accordance with Table 405.06-1 below. The exact rate will be established by the Engineer.

Table 405.06-1: Application Rates for Bituminous Material

Aggregate Size (per 903.22)	Aggregate Spread Rate (lb/yd^2)	Emulsion Shot Rate (gal/yd^2)
7	25 – 30	0.30 – 0.45
78	22 – 28	0.28 – 0.38
8	20 – 25	0.20 – 0.35
89	17 – 23	0.17 – 0.28

Before beginning each spread, place building paper across the roadway surface with the forward edge exactly coinciding with the end of the preceding covered spread. Start distributors on the paper, the width of which shall allow the full force of all nozzles to be in effect before the forward edge of the paper is reached. If required by the Engineer, also stop the spread on building paper. Remove the paper immediately after its use, and dispose of properly. Immediately correct all defects in application.

The length of spread of bituminous material shall not exceed that which trucks loaded with cover material can immediately cover.

The spread of bituminous material shall not extend more than 6 inches wider than the width covered by the cover material. Do not allow the bituminous material to chill or otherwise impair retention of the cover material.

Do not allow traffic on the bituminous material until it has been covered with mineral aggregate.

Treat areas that are inaccessible to the distributor with either hand sprays or pouring pots as directed by the Engineer.

B. Application of Double Bituminous Surface Treatment:

First Application

Apply the first application of emulsified asphalt using pressure distributors at a uniform rate established by the Engineer within the range of 0.30 to 0.38 gallons per square yard. Apply each spread of bituminous material so as not to be more than 6 inches wider than the width covered by the immediate spread of cover aggregate. Each width of spread shall not be less than half the surface to be treated.

Before beginning each spread, place building paper across the roadway surface with the forward edge exactly coinciding with the end of the preceding covered spread. Start distributors on the paper, the width of which shall allow the full force of all nozzles to be in effect before the forward edge of the paper is reached. If required by the Engineer, also stop the spread on building paper. Remove the paper immediately after its use, and dispose of properly. Immediately correct all defects in application.

Treat areas that are inaccessible to the distributor with hand sprays or pouring pots as directed by the Engineer.

If treating less than the full width of the roadway, do not spread the aggregate on the inside 6 inches of either the first or second application until the adjacent lane has been treated. Immediately following each application, uniformly cover the applied bituminous material with Size No. 7 mineral aggregate that is reasonably free of surface moisture.

Spread the aggregate at a rate between 24 and 30 pounds per square yard, as established by the Engineer, using a self-propelled mechanical spreader; except on short projects of 1/2 mile in length or less, self-propelled mechanical spreading equipment will not be required. Back the truck on the aggregate being spread, without driving on or over uncovered bituminous material.

The length of bituminous material spread shall not exceed that which trucks loaded with cover material can immediately cover.

Second Application

Apply the second application of emulsified asphalt in the same manner as the first application, at a uniform rate established by the Engineer within the range of 0.20 and 0.35 gallons per square yard.

Spread mineral aggregate, Size No. 8, in the same manner as the first spread at a rate established by the Engineer within the range of 16 to 28 pounds per square yard.

Immediately after each spread of cover aggregate, broom to achieve uniform coverage. Use a power source, which is independent of the drive train that propels the equipment, to power the revolving brooms of mechanical sweeping equipment. Place additional aggregate by hand on thin or bare areas.

405.07 Spreading and Rolling Aggregate

A. Spreading

Immediately after bituminous material has been applied, no more than two minutes, spread and embed the mineral aggregate cover in the bituminous material. Spread the aggregate as close to the application of bituminous material as is practicable, and cover each distributor load applied immediately. Aggregates shall be moistened and visually damp at the time of placement.

Spread the aggregate in accordance with the rates specified in Table 405.06-1. The exact rate will be established by the Engineer. Back the truck on the aggregate being spread, without driving on or over uncovered bituminous material. If treating less than the full width of roadway, do not spread the aggregate on the inside 6 inches of the bituminous spread until the adjacent lane is treated. Immediately after spreading the aggregate, perform hand-brooming to achieve uniform coverage. Place additional aggregate by hand on thin or bare areas.

The speed of the spreader shall be such that the aggregates are not rolling over, and starting and stopping of the spreader is minimized. Use of previously used (swept) aggregates is not permitted.

B. Rolling – Bituminous Seal Coat

Immediately after distributing the aggregate, roll the entire surface by moving in a longitudinal direction, beginning at the outer edges and progressing toward the center of the roadway, with each trip of the roller overlapping the previous trip by half the width of the rear wheel. Perform initial rolling with a self-propelled pneumatic tire roller, and follow with steel-wheel rolling. The amount and sequence of rolling shall be as directed by the Engineer. Complete the initial rolling of the aggregate within 1 hour after applying the bituminous material.

Use power brooms to correct irregularities by sweeping the aggregates from areas of thick or heavy distribution to areas of thin or light distribution. Then continue rolling using both steel-wheel and pneumatic rollers until the aggregate is thoroughly embedded in the bituminous material. The Engineer may require additional rolling at a later date. Redistribute excess or loose aggregate that was thrown out of place.

Slow moving traffic may use the section or roadway upon which the aggregate has been spread.

Rolling and Curing – Double Bituminous Seal Coat

Immediately after spreading and brooming the cover aggregate, roll the entire surface, beginning at the edges and progressing to the center. Begin rolling within 30 minutes after spreading the aggregate. Perform initial rolling with a self-propelled pneumatic tire roller, and follow with steel-wheel rolling. The amount and sequence of rolling shall be as directed by the Engineer.

Allow the first application of bituminous material and aggregate to cure for as long as deemed necessary by the Engineer before beginning the second application. Immediately before the second application of bituminous material, roll the surface with a steel-wheel roller.

For the second application of bituminous material and cover aggregate, repeat the same rolling and curing procedures as required for the first application.

The Contractor may allow slow-moving traffic to use sections of the roadway where the bituminous material has been covered with mineral aggregate.

405.08 Shoulders

Restore shoulders that have been disturbed by the Contractor's construction operations at no cost to the Department. Remove all objectionable material placed on the shoulders by the Contractor as directed by the Engineer.

Construct shoulders, when specified, as provided for under **208**.

405.09 Maintenance and Protection

Maintain in a satisfactory condition each completed section of seal coat until the entire Project is complete. Maintenance shall include making repairs where failures occur, and maintaining the seal coat in a smooth uniform condition; and brooming, dragging, and rolling when required.

After the final application, maintain the work in a satisfactory condition for at least 10 calendar days. If all other requirements of the Contract have been fulfilled, the Department will not charge working time during the 10-day maintenance period against the Contract time.

For final cleanup, sweep up all excessive quantities of loose, dislodged cover aggregate that may have collected along the edge of the completed seal coat, and dispose of this material as directed by the Engineer.

405.10 Method of Measurement

The Department will measure Mineral Aggregate and Bituminous Material by the ton in accordance with **109**. The Department may use net certified weights as a basis of measurement for mineral aggregate, subject to correction for aggregate that is lost, wasted, or otherwise not incorporated into the Work.

405.11 Basis of Payment

The Department will pay for accepted quantities of Bituminous Seal Coat, complete in place, at the contract prices as follows:

Item	*Pay Unit*
Bituminous Material	Ton
Mineral Aggregate	Ton

The Department will measure and pay for the work required to prepare the designated surface, as provided for under **405.05**, in accordance with the applicable Section or Subsection under which the work is performed."

Subsection 407.02 (pg. 300-301) 12-2-16; Replace the 4th paragraph:

"If anti-stripping additive, other than hydrated lime, meeting 921.06.B.1 is required, use approved in-line blending equipment, as specified in 407.04.A.6, to add it at the mixing plant or inject it at the asphalt terminal. Manufacture's documentation that asphalt binders will continue to meet requirements listed in subsection **904** after the anti-stripping additive is added shall be provided

by the contractor with the mix design submittal. For mix designs submitted more than six months in advance, the documentation shall be resubmitted prior to use of the mix design with updated test results."

Subsection 407.02 (pg. 300) 11-16-15; Materials, add the following at the end of the fourth paragraph:

"If anti-stripping additive, other than hydrated lime, meeting **921.06.B.1** is required, use approved in-line blending equipment, as specified in **407.04.A.6**, to add it at the mixing plant or inject it at the asphalt terminal. Provide manufacture's documentation ensuring asphalt binders will continue to meet requirements listed in Subsection **904** after anti-stripping additives are added."

Subsection 407.06 (pg. 327), 5-18-15; - A. Pavers. Replace the entire first paragraph with the following:

"Bituminous pavers shall be self-contained, power-propelled units provided with an activated screed, equipped to be heated, and capable of spreading and finishing courses of bituminous plant mix material in lane widths applicable to the specified typical section and thickness shown on the Plans. All screed extensions shall be full assembly extensions, including activated and heated screeds. Pavers shall include throw-back blades, reverse augers, or equivalent to place mix beneath the auger gearbox. Auger extensions shall be incorporated in a manner such that the maximum distance from the augers to the end plate shall be 18 inches. Screed extensions may extend beyond the 18-inch maximum from auger extensions only when extending for short-term temporary deviations in pavement width such as driveways. Do not use strike-off boxes, with the exception of sections with continuously varying width."

Subsection 407.11 (pg. 332) 12-2-16; Add the following to the paragraph below Table 407.11-1:

"Minimum temperature for OGFC mixes shall be 280º."

Subsection 407.15, C. Test Strips. (pg. 340-341) 11-16-15; Add the following paragraph after the 7th paragraph of the subsection:

"Take an additional 3 cores after placement of the surface layer on the tack coat test strip described in subsection **403.05.B**. Include the underlying pavement layer for shear testing. These cores will be for informational testing only. Not required for mats less than one inch thick"

Subsection 407.15 (pg. 341) 6-27-16; remove the 2nd sentence of the 8th paragraph:

"Take cores on the test strip at ten randomly selected locations as designated by the Engineer. Provide these cores to the Department for use in calibrating the nuclear gauge and to verify that the average density of the test strip meets the density requirements of the specifications. The Department will report all densities using the corrected nuclear gauge readings. Correction factors are specific to the nuclear gauges used during the test strip construction. If a different nuclear gauge needs to be used for acceptance, it will be necessary to cut new cores from the ongoing pavement construction to calibrate the new gauge."

Subsection 407.15 (pg. 341) 12-2-16; remove "randomly selected" from 1st sentence of the 8th paragraph as follows:

"Take cores on the test strip at ten locations as designated by the Engineer."

Subsection 407.15 A. 3. c. (pg. 337-338) 5-15-17; update 10,000 square yards to 1,000 tons:

"c. Projects containing less than 1,000 tons or bituminous pavement."

Subsection 407.20 A. (pg. 345), 11-6-17; Revise the second paragraph as follows:

"The Department will pay for liquid anti-strip additive and hydrated lime anti-strip additive based on certified documentation ~~invoices~~ of material costs not to exceed $15 per gallon and $90 per ton, respectively."

Subsection 407.20 (pg. 346) 5-18-15; Basis of Payment; B. Acceptance of Mixture; Modify the last paragraph to revise 500 tons to 1000 tons:

"When the total plan quantity of any mix is less than 1000 tons, the Department will accept the mix on the basis of visual inspection and Contractor Quality Control certification. The Department may run extraction, gradation analysis, or other tests deemed necessary for acceptance purposes."

Subsection 407.20 (pg. 348) 11-16-15; Table 407.20 – 2, make the following changes:

Table 407.20-2: Acceptance Schedule of Payment
(Asphalt Plant Mix Characteristics)

Characteristics	Pay Factor	Average Arithmetic Deviation of the Lot Acceptance Test from the JMF	
		1 Test	2 Tests or more
Asphalt Cement Content [1] (Extraction or ignition oven)	1.00	0.00-0.30	0.00-0.25
	0.95	0.31-0.35	0.26-0.30
	0.90	0.36-0.40	0.31-0.35
	0.80 [2]	over 0.40	over 0.35
Gradation 3/8 inch sieve and larger	1.00	0.00-6.50	0.00-5.70
	0.95	6.51-7.08	5.71-6.20
	0.90	7.09-7.66	6.21-6.69
	0.80 [2]	over 7.66	over 6.69
Gradation No. 4 sieve [3]	1.00	0.00-4.62	0.00-4.00
	0.95	4.63-5.20	4.01-4.50
	0.90	5.21-5.77	4.51-5.00
	0.80 [2]	over 5.77	over 5.00

Subsection 407.20 (pg. 350) 11-16-15; B. 5. Acceptance for Mix Density on the Roadway, Replace the entire 2nd paragraph with the following:

"For density testing purposes, the Department will divide the pavement into lots of 1,000 tons. Five density tests will be performed in each lot and the average results compared with the requirements specified in Tables 407.15-1 to 407.15-4. At the beginning of a project or at any

time it is deemed advisable, the Department may consider smaller lots to evaluate compaction methods or for other reasons as approved or directed by the Engineer."

Subsection 411.03 (pg. 363) 11-16-15; 2. Recycled Asphalt Shingles (RAS), change 5% to 3% in the 1st sentence of the 1st paragraph.

"Recycled Asphalt Shingles (RAS) may be included to a maximum of 3% of the total weight of mixture."

Subsection 411.03 B. Anti-strip Additive (pg. 365) 6-27-16; revise the 2nd paragraph:

"Mix an approved anti-strip agent with the asphalt cement at the dosage as specified in **921.06.B**."

Subsection 414.02 (pg. 369) 11-16-15; Materials, add the following paragraph to the end of the subsection:

"Ensure that no deleterious material is introduced into aggregate stockpiled at project site."

Subsection 414.02 (pg. 369) 11-6-17; Revise the last sentence:

"For a slurry seal, use a Type CQS-1h emulsified asphalt. For micro-surfacing use a type CQS-1hp or CSS-1hp emulsified asphalt."

S T A T E **O F** **T E N N E S S E E**

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Supplemental Specifications - Section 900

of the

Standard Specifications for Road and Bridge Construction

January 1, 2015

Subsection 903.01 - Table 903.01-1 (pg. 920), 5-18-15; Replace Note (1) with the following:

"[(1)]If the fine aggregate is manufactured from crushed stone and if material finer than the No. 200 sieve consists of the dust of fracture, essentially free from clay or shale, this limit may be increased to 5%.

Subsection 903.01 - Table 903.01-1, Table 903.01-2 (pg. 921), 5-15-17; replace Tables 903.01-1 and 903.01-2 with the following Tables:

Table 903.01-1: Limits of Deleterious Substances in Fine Aggregate for Concrete

Substance	Maximum Permissible Limits Percent by Weight
Clay Lumps	0.5
Coal and Lignite	0.5
Material Passing the No. 200 Sieve [(1)(3)]	3.0
Other deleterious substances (such as shale, alkali, mica, coated/grains, soft and flaky particles) [(1) (2)]	3.0

(1) If the fine aggregate is manufactured from crushed stone and if material finer than the No. 200 sieve consists of the dust of fracture, essentially free from clay or shale, this limit may be increased to 10%.

(2) Determine other organic impurities according to AASHTO T 267.

(3) If the fine aggregate is manufactured from crushed gravel and if material finer than the No. 200 sieve consists of the dust of fracture, essentially free from clay or shale, this limit may be increased to 3.5%.

Table 903.01-2: Gradation Requirements for Fine Aggregate

Sieve Size	Total Percent Passing by Weight
3/8 inch	100
No. 4	95-100
No. 16	50-90
No. 50	5-35
No. 100	0-20
No. 200 (1)	0-3

(1) If the fine aggregate is manufactured from crushed stone and if material finer than the No. 200 sieve consists of the dust of fracture, essentially free from clay or shale, this limit may be increased to 10%.

Subsection 903.03 (pg. 922) 5-15-17; Coarse Aggregate for Concrete, add the following as the 4th paragraph:

"Coarse aggregate in two-lift composite pavements shall consist of Size No. 467 in the lower lift, graded as specified in 903.22. Coarse aggregate in the upper lift shall be Size No. 57 or 67 graded as specified in 903.22 and shall meet 903.24 riding surface requirements."

Subsection 903.03 (pg. 922-923) 11-16-15; Coarse Aggregate for Concrete, modify the 4th and 5th paragraphs, update Table 903.03-1: Coarse Aggregate Sizes to the following:

"Coarse aggregate in Portland cement concrete bridge decks and overlays on interstates and four or more lane highways consisting of Size No. 57 shall meet 903.24.

The coarse aggregates for travel lanes and bridge decks shall be crushed and consist of stone, slag, gravel, quartzite, gneiss, or combination thereof with an absorption of plus 4 material not to exceed 5%. Do not use uncrushed gravel, pea gravel, or any other uncrushed particles. Crushed gravel, if used, shall consist of siliceous washed particles after processing, of which at least 70% by count of the material retained on the No. 4 sieve contains a minimum of two fractured faces. One face shall be fractured for the approximate average diameter or thickness of the particle."

Table 903.03-1

Application	Coarse Aggregate Size (1)
Structural concrete	No. 57
Self-Consolidating concrete	Maximum-No.67
Prestressed concrete	No. 57 or 67
Precast concrete	Any size fraction
Concrete curbing placed by machine-extrusion methods	No. 7, 57, 67, or 78

Cement treated permeable base [2]	No. 57

[1] Gradation shall conform to **903.22**.

[2] Aggregate shall meet the quality requirements specified below.

Subsection 903.03-2 (pg. 924) 5-15-17; Revise Table 903.03-2: Limits of Deleterious Substances in Coarse Aggregate for Concrete, update Material passing No. 200 Sieve and Footnote 2:

Table 903.03-2: Limits of Deleterious Substances in Coarse Aggregate for Concrete

Substance	Maximum Percent by Weight
Soft or non-durable fragments (fragments that are structurally weak such as shale, soft sandstone, limonite concretions, gypsum, weathered schist, or cemented gravel), and organic impurities as determined by AASHTO T 267 [1]	3
Coal and lignite [1]	1
Clay lumps [1]	0.25
Material passing the No. 200 sieve [1] [2]	1.5
Thin or elongated pieces (length greater than 5 times average thickness)	10
Other local deleterious substances [1]	1

[1] The sum of the percentages of these materials (i.e., soft or non-durable fragments, coal and lignite, clay lumps, material passing the No. 200 sieve, and other local deleterious substances) shall not exceed 5.0.

[2] For crushed aggregate, if all the material finer than the No. 200 sieve, as determined in accordance with AASHTO T 11, consists of the dust of fracture, essentially free of clay or shale, this limit may be increased to 2.0.

Subsection 903.05 – B. Type B Aggregate (pg. 927), 5-18-15; Replace the 1st paragraph of subsection 3. With the following:

> **"3.** Do not use material having clay content greater than 12%, as determined by hydrometer analysis performed in accordance with AASHTO T 88. Material may be used having a clay content exceeding 12% if a plasticity index-fines product does not exceed 3 when calculated by the following formula"

Subsection 903.05 – Aggregate for Mineral Aggregate Base and Surface Courses (pg. 928) 5-15-17; add section C to the bottom:

> **C. Reclaimed Concrete Aggregate.** Provide material comprised of concrete reclaimed from the demolition of a concrete structure or pavement. Reclaimed Concrete Aggregate may only be used

as a mineral aggregate base course, subbase or shoulder course. The material shall be free of any materials classified as Solid or Hazardous Waste, especially asbestos, lead and mercury, with test results submitted by the contractor to the Project Supervisor. These test results shall be certified and notarized. The percentage of wear as determined in accordance with AASHTO T 96 shall not exceed 50. Deleterious substances shall be kept to a minimum, and may not be higher than the amounts listed on Table 903.05-3.

Table 903.05-3: Deleterious Materials

Material	Maximum Permissible Limits Percent by Weight
Brick	5
Bituminous Concrete Materials	5
Weathered Rock	2
Wood	0.1
Metals	0.1

The gradations of the coarse and fine fractions of aggregate shall be such that, when combined in proper proportions, the resultant mixture will fall within the grading specified in Table 903.05-4.

Table 903.05-4: RCA Grading Tolerances

Sieve Size	Total Percent Passing per Weight
1 ½ inch	100
1 inch	85-100
¾ inch	60-95
3/8 inch	50-80
No. 4	40-65
No. 16	20-40
No. 100	5-18

Subsection 903.05 – Aggregate for Mineral Aggregate Base and Surface Courses (pg. 925) 5-15-17; add reference to subsection **903.05 C.** in the second paragraph of subsection A.:

"**903.05 Aggregate for Mineral Aggregate Base and Surface Courses**

Provide crushed stone, crushed slag, crushed or uncrushed gravel, or crushed or uncrushed chert that may be blended with crushed recycled concrete or screened reclaimed asphalt pavement (RAP), together with material such as manufactured sand or other fine materials that are either naturally contained or added as needed to conform to these Specifications.

Provide aggregate of Types A and B, as specified below.

A. Type A Aggregate

Provide hard, durable particles or fragments of stone, slag, gravel, or chert, and other finely divided mineral matter.

The Contractor may use recycled concrete aggregate per 903.05 C. or reclaimed asphalt pavement~~,~~ ~~–~~at a maximum rate of 25% by weight~~,~~ for Type A aggregate, provided the combined aggregate blend meets all the requirements specified below. Crush and screen the recycled concrete and asphalt to produce a uniform

stockpile before blending it with the virgin material. Keep the recycled stockpiles free of bricks, steel, wood, and all other deleterious materials. "

Subsection 903.05 – Aggregate for Mineral Aggregate Base and Surface Courses (pg. 925-926) 5-15-17; add reference to subsection **903.05 C.** in the second paragraph of subsection B.:

"For Provide crushed or uncrushed gravel, crushed or uncrushed chert, crushed stone or crushed slag, and other finely divided particles.

The Contractor may use recycled concrete aggregate per 903.05 C. or reclaimed asphalt pavement~~,~~ at a maximum rate of 30% by weight~~,~~ for Type B aggregate, provided the combined aggregate blend meets all the requirements specified below. Crush and screen recycled concrete and asphalt to produce a uniform stockpile before blending it with the virgin material. Keep the recycled stockpiles free of bricks, steel, wood, and all other deleterious materials."

Subsection 903.06 - C. Combined Aggregate Grading (pg. 930) 11-16-15; add the following sentence at the end of the first paragraph:

"For mixtures including recycled asphalt pavement, RAP, and/or recycled asphalt shingles, RAS, stockpiles will not be considered as contributing to the required minimum of three stockpile sizes."

Subsection 903.11 - Aggregate for Asphaltic Concrete Surface Coarses (Hot Mix) (pg. 934) 11-16-15; add the following sentence at the end of the first paragraph:

"For mixtures including recycled asphalt pavement, RAP, and/or recycled asphalt shingles, RAS, stockpiles will not be considered as contributing to the required minimum of three stockpile sizes."

Subsection 903.11 (pg. 934) 11-16-15; A. Coarse Aggregate (retained on a No. 4 sieve), revise the 1st paragraph and subsection 3:

"Provide aggregate, consisting of crushed stone, crushed slag, crushed gravel, crushed granite, crushed quartzite, crushed gneiss, or natural combinations of these materials.",

"3. Combined aggregate shall consist of siliceous particles processed from washed material, of which at least 70% by count of the material retained on the No. 4 sieve shall have a minimum of two fractured faces, one of which must be fractured for the approximate average diameter or thickness of the particle. Do not add pea gravel or uncrushed particles. The absorption of the crushed aggregate retained on the No. 4 sieve shall not exceed 5% when tested in accordance with AASHTO T 85."

Subsection 903.11 - A. Coarse Aggregate (retained on a No. 4 sieve) (pg. 934), 5-18-15; revise subsection 2. as follows:

"2. Material retained on the No. 4 sieve shall contain a maximum of 10% elongated pieces (length greater than five times the average thickness)"

Subsection 903.11 C.3. (pg. 938), 6-27-16; revise the 1st paragraph of subsection C.3 to the following:

"**3. Grading OGFC.** A minimum of 75% of the aggregate shall meet the requirements specified in 903.24 for Surface Mixtures (Non-Skid Aggregates). The coarse aggregate shall have at least 90% crushed aggregate with two fractured faces and 100% with one fractured face as determined in accordance with ASTM D5821. The coarse aggregate shall have a LA Abrasion value of less than 40% and a maximum absorption of 3.0%."

Subsection 903.11 (pg. 938), 12-2-16; Add the following to C. as subsection 5.:

"**5. Grading C, CS, CW.** The mixture shall meet all requirements of **903.06.** When using Grading C, CS, or CW as a final riding surface for traffic lanes and the design ADT is greater than 1000, a minimum of 75% of the aggregate shall meet the requirements specified in **903.24** for Surface Mixtures (Polish-Resistant Aggregate) for the appropriate levels."

Subsection 903.12 (pg. 938) 11-16-15; A. Aggregate for Slurry Seal, revise the 1st paragraph a A. as shown; delete the 2nd paragraph:

"The aggregate shall be crushed slag, crushed granite, or crushed stone (crushed stone as specified in 903.24), meeting the requirements of ASTM D692, except the gradation shall be as specified in Table 903.12-1. The aggregate shall have a minimum sand equivalent, as determined in accordance with AASHTO T 176, of 45.

Subsection 903.12 (pg. 939) 11-16-15; B. Aggregate for Micro-Surface: modify the first paragraph, delete the second paragraph:

"The aggregate shall be crushed slag, crushed granite, or crushed stone (crushed stone as specified in **903.24**) meeting the gradation limits specified in Table 903.12-2 and the physical properties of ASTM D692, except the percent of fractured pieces shall be 100. The aggregate shall have a minimum sand equivalent, as determined in accordance with AASHTO T 176, of 65. Polish-resistant aggregates will not be required for leveling courses, provided they will be covered with riding surface mixtures.

Subsection 903.12 (pg. 939) 5-15-17; B. Aggregate for Micro-Surface: Add the following as the 2nd paragraph:

"If blending aggregates from more than one source, use automated proportioning and blending equipment which has individual bins for each aggregate source used to produce a stockpile meeting the job mix formula gradation. Proportion and blending equipment shall be calibrated at the beginning of production. All aggregate sources shall meet the requirements of **Table 903.24-1**. Do not blend aggregates with a front end loader. Proportion the aggregate to produce a uniform gradation meeting the requirements specified in Table 903.12-2. The contractor shall provide a Type A laboratory as defined by **106.06** capable of verifying gradation at the location where blending occurs."

Subsection 903.13 (pg. 940), 12-2-16; modify the last sentence of the 1st paragraph:

"Provide aggregate consisting of crushed stone, crushed slag, or crushed gravel, meeting the quality requirements of ASTM D692, except that at least 50% by count of crushed gravel aggregates shall have at least one fractured face. Crushed slag aggregate retained on the No. 4

sieve shall contain no more than 20% by weight of glassy particles. Provide aggregates meeting the requirements of **903.24 except, if ADT is less than 1000**."

Subsection 903.15 (pg. 941), 5-15-17; revise the 3rd paragraph:

"The Contractor may use recycled concrete aggregate per 903.05 C. or reclaimed asphalt pavement (RAP), at a maximum rate of 25% by weight~~,~~ provided the combined aggregate blend meets all the requirements specified above. If blending, crush and screen the recycled concrete and/or asphalt to produce a uniform stockpile before blending it with the virgin material. Keep the reclaimed asphalt pavement stockpiles free of bricks, steel, wood, and all other deleterious materials. The virgin and reclaimed pavement blend shall meet the quality requirements specified in Table **903.05-1**."

Subsection 903.24 (pg. 946), 5-18-15; Modify the 1st paragraph to the following:

"Provide coarse aggregate consisting of crushed gravel, crushed granite, crushed slag, crushed quartzite, crushed gneiss, or crushed sandstone. Other crushed aggregate may be used provided it has the chemical, physical, and performance characteristics specified in Table 903.24-1."

Subsection 904.01 (pg. 948) 11-16-15; Asphalt Cements, add the following between the 4th and 5th paragraphs:

"Polyphosphoric acid may be used as a modified not exceeding 0.5% by weight of asphalt binder and may only be used when the primary modifier is one of the styrene-based products listed above."

Subsection 904.01 (pg. 948) 11-6-17; Asphalt Cements, modify the fourth paragraph with the following:

"To modify the asphalt, properly blend one or more modifier(s) consisting of styrene butadiene (SB), styrene butadiene styrene (SBS), or styrene butadiene rubber (SBR), or Ground Tire Rubber (GTR) to a PG 64-22 or PG 67-22 base asphalt.

GTR used to modify asphalt shall meet the requirements of 921.17. Blending of GTR into asphalt cement shall occur only at the asphalt terminal. "

Subsection 904.01 (pg. 948), 11-6-17; Asphalt Cements, add the following paragraph as the next to last paragraph:

"In addition to the above, asphalt cement modified with GTR shall meet the following requirement. The temperature difference determined by the Separation Test shall not exceed 15 °F. The separation test shall consist of taking the difference in softening point, as determined by the Ring and Ball Test (AASHTO T53), between the top and bottom thirds of a specimen prepared per ASTM D7173."

Subsection 904.01 (pg. 949), 12-2-16; Modify Table 904.01-1:

"**Table 904.01-1: Requirements for Asphalt Cement**

Property*	PG 64-22, PG 67-22	PG 70-22	PG 76-22	PG 82-22
Non-recoverable creep compliance at 3.2kPa, Jnr(3.2), kPa^{-1} at 64°C, Max	4.5	1.0	0.5	0.5
% Difference in Non-Recoverable Creep Compliance, Jnr(diff) at 64°C, %, Max	75	75**	n/a	n/a

* Tested in accordance with AASHTO T350.
** Shall be waived if Jnr(3.2) is equal to or less than 0.5

PG76-22 and PG82-22 grade asphalts shall meet the requirements for Indication of Elastic response as defined in Appendix X1 of AASHTO M332. PG70-22 grade asphalts shall have a minimum percent recovery at 3.2 kPa of 29%."

Subsection 904.01 (pg. 948-950) 5-18-15; revise the 1st paragraph to add the word cement, add sentence to the end of the 2nd paragraph, add "cement high-temperature grade properties to the 4th paragraph, remove the grades of asphalts and add asphalt cements to the 5th paragraph, update Table 904-01-1 to remove "Ring and Ball" and" Elastic Recovery", add "Non-recoverable creep compliance" requirements to Table 904-01-1, add footnote to Table, add a 6th paragraph, remove A. Test Procedures and Table 904.01-2, remove Materials Certification header, remove 8th paragraph, and revise the 9th paragraph:

"Only obtain asphalt cement for use on Department projects from Certified Asphalt Cement Suppliers that have an approved Quality Control Plan in accordance with the Department's Standard Operating Procedures.

Asphalt cement shall conform to AASHTO M 320 and Department procedures. Direct Tension testing is not required.

Instead of PG 64-22, the Contractor may use asphalt cement graded to PG 67-22. PG 67-22 shall conform to the requirements of AASHTO M 320 when the applicable tests are conducted at 67 °C and -12 °C, and the dynamic shear of the rolling thin film, pressure aged vessel sample is tested at 26.5 °C.

To modify the asphalt cement high-temperature grade properties, properly blend styrene butadiene (SB), styrene butadiene styrene (SBS), or styrene butadiene rubber (SBR) to a PG 64-22 or PG 67-22 base asphalt.

In addition to the above requirements, asphalt cements shall meet the requirements specified in Table 904.01-1.

Table 904.01-1: Requirements for Asphalt Cement

Property*	**PG 64-22, PG 67-22**	**PG 70-22**	**PG 76-22**	**PG 82-22**
Non-recoverable creep compliance at 3.2kPa, Jnr(3.2), kPa^{-1} at 64°C, Max	4.5	1.0	0.5	0.5
% Difference in Non-Recoverable Creep Compliance, Jnr(diff) at 64°C, %, Max	75	75	75	75

* Tested in accordance with AASHTO T350.

All modified grades shall meet the requirements for Indication of Elastic response as defined in Appendix X1 of AASHTO M332.

Furnish a certification to the Engineer on each project stating that the asphalt cement provided meets the Department's specification. Ensure that quality control and compliance testing are completed in accordance with the asphalt supplier's approved quality control plan and Department procedures.

In addition, the asphalt cement supplier shall provide a temperature-viscosity curve for PG 64-22 and PG 67-22 asphalt cements with a recommended mixing temperature range. In order to develop a temperature-viscosity curve, it may be necessary to run the viscosity test at a higher temperature, based on the softening point of the modified asphalt cement."

Subsection 904.01(pg. 949), 6-27-16; Modify Table 904.01-1:

Table 904.01-1: Requirements for Asphalt Cement

Property	PG64-22 PG67-22	PG70-22	PG76-22	PG82-22
Non-recoverable creep compliance at 3.2kPa, Jnr(3.2), kPa^{-1} at 64°C, Max	4.5	1.0	0.5	0.5
% Difference in Non-Recoverable Creep Compliance, Jnr(diff) at 64°C, %, Max	75	75	75	n/a

Subsection 904.01 B. (pg. 949) 11-6-17; Asphaltic Cements, B. Materials Certification, add the following as the last sentence of the first paragraph:

"Furnish a certification to the Engineer on each project stating that the asphalt cement provided meets the Department's specification. Ensure that quality control and compliance testing are completed in accordance with the asphalt supplier's approved quality control plan and Department procedures. Identify on the certification, the type(s) of modifier used."

Subsection 904.03 (pg. 951) 11-16-15; Emulsified Asphalts, Add "TTT-3" to 904.03-1 with the following requirements:

Saybolt-Furol Viscosity @ 77 °F, seconds	10-100
Particle Charge	Positive
Sieve Test, %	0.1 Max
Residue by	Distillation(1)
Residue, %	50 Min
Demulsibility, %	65 Min
Penetration	40-90

[1]-Distill at 350°F

Subsection 904.03 (pg. 954), 12-2-16; Revise Table 904.03-1(c) to remove TTT-1, TTT-2, and TTT-3:

Table 904.03-1(c): Test Requirements for Emulsified Asphalt

Practices	**AASHTO Test Method**	**CRS-2P**	**RS-2**	**RS-1**
Saybolt-Furol Viscosity @ 77 °F, seconds	T59	n/a	n/a	20-100
Saybolt-Furol Viscosity @ 122 °F, seconds	T59	100-400	75-400	n/a
Storage Stability Test, 24- h, %	T59	1 Max	1 Max	1 Max
5-day Settlement, %	T59	n/a	n/a	n/a
Particle Charge	T59	Positive	n/a	n/a
Sieve Test, %	T59	0.1 Max	0.1 Max	0.1 Max
Residue by	T59	*Evaporation*	Distillation	Distillation
Residue, %	T59	65 Min	63 Min	55 Min
Demulsibility, %	T59	40 Min	60 Min	60 Min
Distillate, %	T59	n/a	n/a	n/a
Oil Test, %	T59	n/a	n/a	n/a
Stone Coating	T59	n/a	n/a	n/a
Float Test, seconds	T50	n/a	n/a	n/a
Penetration	T49	75-175	100-200	100-200
Elastic Recovery, % (2)	T301	50 Min	n/a	n/a

Practices	AASHTO Test Method	CRS-2P	RS-2	RS-1
Ductility @ 77 °F, cm	T51	40 Min	40 Min	40 Min
Ductility @ 40 °F, cm	T51	n/a	n/a	n/a
R&B Softening Point, °F	T53	125 Min	n/a	n/a
Original G*/sind @ 82 °C	T315	n/a	n/a	n/a

Subsection 904.03 (pg.954), 5-18-15; Replace with the following:

Subsection 904.03, Table 904.03-1(c). Modify as follows for TTT-1, TTT-2:

Table 904.03-1(c): Test Requirements for Emulsified Asphalt

Practices	AASHTO Test Method	CRS-2P	RS-2	RS-1	TTT-1	TTT-2
Saybolt-Furol Viscosity @ 77 °F, seconds	T59	n/a	n/a	20-100	20-100	10-100
Saybolt-Furol Viscosity @ 122 °F, seconds	T59	100-400	75-400	n/a	n/a	n/a
Storage Stability Test, 24- h, %	T59	1 Max	1 Max	1 Max	1 Max	1 Max
5-day Settlement, %	T59	n/a	n/a	n/a	n/a	n/a
Particle Charge	T59	Positive	n/a	n/a	n/a	Positive
Sieve Test, %	T59	0.1 Max	0.1 Max	0.1 Max	0.1 Max	0.1 Max
Residue by	T59	*Evaporation*	Distillation	Distillation	Distillation	Distillation (1)

Practices	AASHTO Test Method	CRS-2P	RS-2	RS-1	TTT-1	TTT-2
Residue, %	T59	65 Min	63 Min	55 Min	50 Min	50 Min
Demulsibility, %	T59	40 Min	60 Min	60 Min	n/a	n/a
Distillate, %	T59	n/a	n/a	n/a	n/a	n/a
Oil Test, %	T59	n/a	n/a	n/a	n/a	n/a
Stone Coating	T59	n/a	n/a	n/a	n/a	n/a
Float Test, seconds	T50	n/a	n/a	n/a	n/a	n/a
Penetration	T49	75-175	100-200	100-200	0-20	40-90
Elastic Recovery, % [(2)]	T301	50 Min	n/a	n/a	n/a	n/a
Ductility @ 77 °F, cm	T51	40 Min	40 Min	40 Min	n/a	n/a
Ductility @ 40 °F, cm	T51	n/a	n/a	n/a	n/a	n/a
R&B Softening Point, °F	T53	125 Min	n/a	n/a	60-75	n/a
Original G*/sind @ 82 °C	T315	n/a	n/a	n/a	1.0 Min	n/a

[(1)] Distill at 350 °F

[(2)] Straight-sided mold, 20-cm elongation, 5min hold, 25 °C

Subsection 908.04 (pg. 968), 5-18-15, High Strength Bolts, A. Specifications; Add the following to the first paragraph:

> "Unless otherwise shown on the Plans, mechanically galvanize all bolts, nuts and washers in accordance with ASTM B695 Class 50."

Subsection 908.04 (pg. 968), 12-2-16, High Strength Bolts, A. Specifications; revise the first paragraph:

> "Unless otherwise shown on the Plans, all bolts, nuts and washers shall be coated with acceptable coating in accordance with ASTM F3125 for the respective grade."

Subsection 908.04 (pg. 968) 12-2-16; revise A. Specifications, 1.:

"A. Specifications: 1. Bolts. ASTM F3125, Grade 325 and Grade 490 - High Strength Bolts for Structural Joints"

Subsection 908.04 (pg. 970) 12-2-16; Revise C. Testing, 3. Assemblies, subsection f., update Table 908-04-2:

C. Testing, 3. Assemblies, f. Table 908.04-2 The minimum rotation, from a snug tight condition (10% of the specified proof load), shall be as specified in Table 908.04-2.

Table 908.04-2: Rotation from Snug Tight Condition

Bolt Length	Minimum Rotation from Snug
Up to and including 4 diameters	240 degrees (2/3 turn)
Over 4 diameters, but not exceeding 8 diameters	360 degrees (1 turn)
Over 8 diameters	480 degrees (1-1/3 turn)

(Note: These values differ from those shown in ASTM F3125.)

Subsection 909.02(pg. 977), 12-2-16; Remove the 4th paragraph referencing a tolerance of 5% from B. Steel Posts and Braces.

Subsection 909.02 (pg. 980-981), 12-2-16; Remove the word minimum from Table 909.02-1:

Table 909.02-1: Post and Braces

Application	Material	ASTM Specification	Nominal Diameter (inches)	Outside Diameter (inches)
Line Posts	Galvanized steel pipe	F1083	1.5	1.900
	Aluminum alloy standard (ANSI Schedule 40) pipe	B429, Alloy 6063, Temper T6	1.5	1.900
	Triple coated steel pipe with a	F1043, Group I-C	1.5	1.900

Application	Material	ASTM Specification	Nominal Diameter (inches)	Outside Diameter (inches)
	0.120-inch wall thickness			
End, Corner, and Pull Posts	Galvanized standard steel pipe	F1083	2.0	2.375
	Aluminum alloy standard (ANSI Schedule 40) pipe	B429, Alloy 6063, Temper T6	2.0	2.375
	Triple coated steel pipe with a 0.130-inch wall thickness	F1043, Group I-C	2.0	2.375
End and Corner Braces	Galvanized standard steel pipe	F1083	1.25	1.660
	Aluminum alloy standard (ANSI Schedule 40) pipe	B429, Alloy 6063, Temper T6 (for corner posts: B241)	1.25	1.660
	Triple coated steel pipe with a 0.111-inch wall thickness	F1043, Group I-C	1.25	1.660

Subsection 909.03 (pg. 983), 12-2-16; Remove the last paragraph of the subsection.

Subsection 912.05 (pg. 1001), 6-27-16; Add subsection 912.05 – Brick Paving Units:

"912.05 Brick Paving Units

Provide brick of the kind and grade specified.

A. Masonry Brick

1. Sidewalk: ASTM C902, Class SX, Type 1
2. Crosswalks and Roadway: ASTM C1272, Type R

B. Concrete Brick and Truncated Dome Concrete Brick

Provide brick conforming to ASTM C936

C. Truncated Dome Brick

Provide brick conforming to ASTM C902, Class SX, Type 1"

Subsection 915.02 (pg. 1007), 6-27-16; modify the description of 915.03, remove zinc coated, iron from 915.02 A. update the first paragraph of 915.02 A., Remove subsection B. Aluminum Coated Steel Pipe, Revise C. to become B., revise D to become C, Remove 1st and 2nd paragraphs of D now C, revise E to become D, update 915.03 to match index title: :

"SECTION 915 – METALLIC PIPE

915.01 Ductile Iron or Cast Iron Pipe
Provide ductile iron pipe conforming to ASTM A716 for the specified diameters and strength classes. Unless otherwise specified, either smooth, corrugated, or ribbed pipe may be furnished. For pipe diameters in excess of 48 inches, conform to ANSI Standard for Cast Iron Pit Cast Pipe, or as otherwise specified in the Contract, for the specified diameter and strength class.
Provide cast iron drain pipe conforming to ASTM A74. Unless otherwise specified, provide ductile iron pressure pipe for water lines or sewer construction conforming to the requirements of ASTM A377 for the diameters and working pressures specified.

915.02 Corrugated Metal Pipe Culverts, Pipe Arches, and Underdrains
A. Corrugated Steel Pipe, Pipe Arches, and Underdrains
Provide corrugated steel pipe, pipe arches, or underdrains, including special sections, such as elbows and flared ends, that conform to AASHTO M 36, aluminum-coated Type 2 meeting AASHTO M274. Special Sections shall be the same thickness as the pipe, arch, or underdrain to which they are joined. Furnish shop-formed elliptical pipe and shop-strutted pipe only where shown on the Plans.

B. Corrugated Aluminum Pipe, Pipe Arches, and Underdrains
When using corrugated aluminum pipe, pipe arches, or underdrains, conform to the applicable requirements of AASHTO M 196. Use special sections, such as elbows and flared end sections

that conform to the applicable requirements of AASHTO M 196 and that are of the same gauge as the conduit to which they are joined.

C. Structural Plate Corrugated Steel and Aluminum Structures

Corrugated aluminum alloy structural plate for pipe, pipe arches, and arches shall conform to the requirements of AASHTO M 219.

D. Bituminous Coating
When material supplied for any of the items specified above are to be bituminous-coated, ensure that the metal to be coated is free of grease, dirt, and other contaminants. Bituminous coating and paving shall conform to the requirements of AASHTO M 190. Apply the coating in accordance with the manufacturer's recommended procedures and as directed by the Department."

915.03 Polymer Pre-coated, Corrugated Steel Pipe, Culverts and Underdrains
Provide polymer pre-coated corrugated steel pipe conforming to AASHTO M 245, Grade250/250, unless otherwise specified."

Subsection 916.05 E. (pg. 1012); 12-2-16, Add sentence to first paragraph:

"Fabricators must be AISC certified as specified in **602.04 A.4**."

Subsection 917.02.A.6. (pg. 1023), 6-27-16; Revise the following:

"**6. Anchor Bolts.** Use anchor rods of high strength steel meeting the requirements of ASTM F 1554, Grade to be determined by design. Fit each anchor bolt with a hex nut and lock-washer."

Subsection 918.04 (pg. 1036), 12-2-16; add as a 2nd paragraph:

"For small quantities less than 100 units of seeding or sod, bagged pelletized or agricultural limestone meeting the Department of Agriculture Tennessee Liming Materials Act may be utilized."

Subsection 921 (pg. 1049), 11-6-17, Section 921 – Miscellaneous Materials, add Ground Tire Rubber to the Index:

"921.17 Ground Tire Rubber ……..1060"

Subsection 921.01 (pg. 1049), 5-18-15, Water; Replace subsection with the following:

"For mixing concrete, use water that is reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable matter, and other substances injurious to the finished product. Water provided by a municipal utility may be used without testing.

All other water shall have quality results submitted in accordance with the frequency listed in Table 921.01-01. All water quality results shall adhere to Table 921.01-2.

Table 921.01-1 Testing Frequency for Mixing Water

Water Source	**Testing Frequency(1)**
Municipal	NA
Non-Municipal	Every 3 months; tested annually after 4

	consecutive passing tests

(1) The frequency may vary at the discretion of the Department.

Table 921.01-2 Quality Requirements for Mixing Water

Maximum Concentration in Mixing Water	Limits	ASTM Test Method (1)
Chloride Ion Content, ppm	500	C114
Alkalies as (NaO2 + 0.658 K2O), ppm	600	C114
Sulfates as SO4, ppm	3000	C114
Total Solids by mass, ppm	50000	C1603
pH	4.5-8.5	(2)
Resistivity, Minimum, kohm-cm	0.500	D1125
Soluble Carbon Dioxide, ppm	600	D513
Calcium and Magnesium, ppm	400	D511
Iron, ppm	20	(2)
Phosphate, ppm	100	D4327

(1) Other methods (EPA or those used by water testing companies) are generally acceptable.
(2) No ASTM method available.

Subsection 921.06 (pg.1051) 11-16-15; B. Bituminous Additives - 1. Anti-Stripping Additive, replace the ASTM C977 reference with AASHTO M 303.

> "Use hydrated lime conforming to AASHTO M 303or other heat-stable asphalt anti-stripping additive containing no ingredient harmful to the bituminous material or the workmen and that does not appreciably alter the specified characteristics of the bituminous material when added in the recommended proportions.**"**

Subsection 921.06 B. Bituminous Additives (pg.1052) 10-10-16; revise the 3rd paragraph to the following:

> "When using an anti-stripping additive other than hydrated lime, use a dosage rate of 0.3%, unless either gravel is used as a coarse aggregate or test results indicate moisture susceptibility, in which case mix at a dosage rate of 0.5%.

Subsection 921.06 B. 2. (pg. 1052) 11-6-17; B. Bituminous Additives, 2. Silicone Additives, Remove description and add the following sentence:

> "2. Silicone Additives. ~~Mix silicone additives at the rate of 1 pint of silicone per 4 gallons of diesel fuel. The Contractor may use a ½ pint of this mixture per 1,000 gallons of asphalt.~~ The amount of silicone added to asphalt cement shall not exceed 2 oz. of silicone per 5500 gallons asphalt cement."

Subsection 921.17 (pg. 1060) 11-6-17; Ground Tire Rubber, add the following subsection:

"921.17 Ground Tire Rubber

Provide Class 30-1 Ground Tire Rubber (GTR) as defined by ASTM D5630 except for as noted in table 921.17-1. The material shall also be certified to meet the requirements of Table 921.17-01. Include certification of the GTR with the bill of lading for the modified asphalt cement.

Table 921.17-1: Requirements for Ground Tire Rubber

Property	Specification
Specific Gravity	1.15 +/- 0.05
Moisture Content	0.75% Max
Ferrous Metal Content	0.01% Max
Fiber Content	0.5% Max
Ash (ASTM E1131)	10% Max

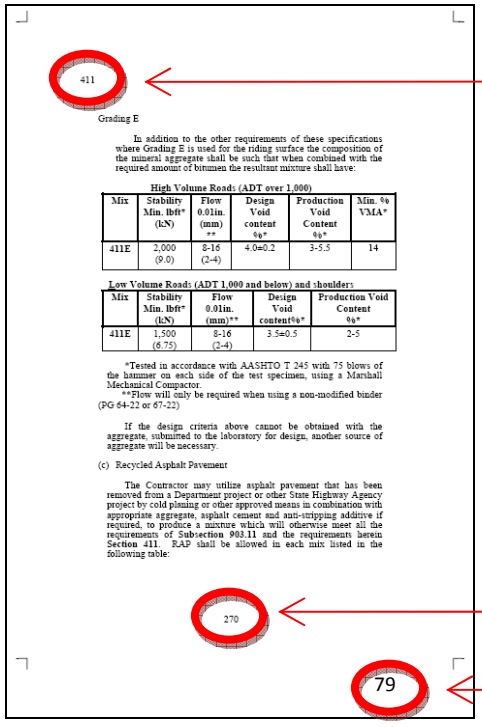
2

Standard Specifications

TDOT SPECIFICATIONS

TABLE OF CONTENTS

Specifications:



411

Grading E

In addition to the other requirements of these specifications where Grading E is used for the riding surface the composition of the mineral aggregate shall be such that when combined with the required amount of bitumen the resultant mixture shall have:

High Volume Roads (ADT over 1,000)

Mix	Stability Min. lbft* (kN)	Flow 0.01in. (mm) **	Design Void content %*	Production Void Content %*	Min. % VMA*
411E	2,000 (9.0)	8-16 (2-4)	4.0±0.2	3-5.5	14

Low Volume Roads (ADT 1,000 and below) and shoulders

Mix	Stability Min. lbft* (kN)	Flow 0.01in. (mm)**	Design Void content%*	Production Void Content %*
411E	1,500 (6.75)	8-16 (2-4)	3.5±0.5	2-5

*Tested in accordance with AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.
**Flow will only be required when using a non-modified binder (PG 64-22 or 67-22)

If the design criteria above cannot be obtained with the aggregate, submitted to the laboratory for design, another source of aggregate will be necessary.

(c) Recycled Asphalt Pavement

The Contractor may utilize asphalt pavement that has been removed from a Department project or other State Highway Agency project by cold planing or other approved means in combination with appropriate aggregate, asphalt cement and anti-stripping additive if required, to produce a mixture which will otherwise meet all the requirements of Subsection 903.11 and the requirements herein Section 411. RAP shall be allowed in each mix listed in the following table:

270

79

Spec. Section Number

Page Number in Blue 2015 Spec. Book

Page Number in This Workbook as Listed in Table of Contents Above

SECTION 106 – CONTROL OF MATERIALS

106.01 Quality of Materials

Only use materials in the Work that conform to all of the Contract quality requirements. Control and incorporate materials to produce completed construction that conforms to and is fully acceptable under the terms of the Contract.

Where reference is made in the Contract to certain manufacturers' materials or products, it is not the intent to preclude the use of others, but rather to establish minimum acceptable design standards. The Contractor may substitute material and products of other manufacturers provided they are equal to or better than the minimum design standards and are approved by the Department.

106.02 Material Information

When the Department has readily available test reports on materials from local sources near the Project, it will furnish copies to the Contractor covering each source for which a specific request is made. In furnishing such reports, the Department will not be responsible for materials failing to conform to the test reports either as to quality or quantity.

106.03 Local Material Sources

If the Contractor desires preliminary tests of local materials, it shall deliver samples of the materials to the Laboratory. The Department will test such samples, up to a reasonable number, and in such time as the work load in the Laboratory may permit. Acceptable test results on preliminary samples will not guarantee acceptance of materials from the same source later.

106.04 Sampling and Testing, or Inspection

Incorporate into the Work only those materials that have been sampled and tested, inspected, and approved by the Engineer. Untested or unaccepted materials used in the Work without the Engineer's written permission shall be removed and replaced at no cost to the Department. Unless otherwise specified, sampling and testing, or inspection will be conducted by qualified representatives in accordance with the most current published national standard specifications, AASHTO or ASTM methods on the date of the Advertisement. Furnish all materials for samples at no cost to the Department. The Department will perform sampling and testing, or inspection, at its expense unless otherwise specified. If the Department does not elect to sample and test or inspect at the source, it will sample and test, or inspect, materials after delivery to the site or to the batching plant. Furnish all facilities, and provide all reasonable assistance to secure and transport samples, and move materials being inspected.

The Departmental procedures will provide sampling and testing frequencies for the acceptance, quality control, independent assurance, verification, or certification for materials and products.

The Engineer may accept certain materials or products and assemblies based on Certificate of Compliance signed by the manufacturer or its authorized representative, stating that such materials, products, and assemblies fully comply with the requirements of the Contract. For each lot of such materials or assemblies delivered to the Work, provide a Certificate of Compliance that clearly identifies the lot. Provide all necessary paperwork with certification submittals as specified in Departmental Procedures.

Furnish a notarized Certificate of Compliance for a non-bid item, not permanently incorporated in the Work, but that must meet a designated specification upon delivery of the material to the Project and prior to its being used.

The Department may sample and test materials, products, or assemblies accepted on the basis of Certificate of Compliance at any time, and may reject such materials and assemblies if found to be in non-conformance with the Contract.

106.05 Source or Plant Inspection

The Contractor is entirely responsible for securing satisfactory material. However, if the volume of any given material, the progress of construction, and other considerations of interest to the Department so justify, the Department may inspect materials at the source of supply. The Department will undertake such inspection only when the Engineer is assured of the fullest cooperation and assistance of the Contractor and of the material producer involved. Provide required copies of all orders, shipping information, and other pertinent papers.

Provide the representatives of the Department with free and safe access at all times to parts of the site or plant concerning the manufacture and production of material for the Project. If the Contractor is not the owner of the place where fabrication, preparation, or manufacture is in progress, the plant owner is deemed to be the agent of the Contractor with respect to the obligation assumed hereunder.

106.06 Field Laboratory

Furnish Type A or Type B laboratory(s) or both, as required to be used exclusively for testing purposes. Provide suitable field laboratories or inspection offices at batch plants and sources or plants at which off-site inspection is provided by the Department under **106.05**. Locate the laboratory(s) as directed by the Engineer. Install, equip, and make building(s) ready for use before the Contractor's operations require field testing. When a concrete batch plant is located near a Type B Laboratory used for testing at an asphalt plant, the Engineer may approve joint use provided there is ample time and equipment to perform all necessary testing for both operations.

All Contractor and producer laboratories must be inspected and qualified in accordance with TDOT procedures before the Contractor can perform any work.

A. Type A

Provide a Type A Laboratory consisting of a building, room, or dedicated area having at least 120 square feet of floor area with a minimum width of 8 feet and a minimum height of 7 feet. Provide laboratory space that is floored, roofed, sealed inside, weather-tight, and furnished with electricity. Furnish the space with adequate work benches, cabinets, and drawers. Provide suitable heat and air conditioning, and equip the laboratory with a laboratory oven capable of maintaining a temperature of 230 °F ± 9 °F. Provide lights, electrical outlets, and adequate ventilation for the tests being performed.

When the determination of aggregate gradation is required, furnish the following equipment:

1. Scales of appropriate capacity and design to weigh the required samples. Scales are to be sensitive to within 0.2% of the sample to be weighed. Provide standard weights for scale calibration.

2. Screens of appropriate size and mesh to separate the samples into the required series of sizes. Woven wire cloth shall conform to AASHTO M 92. Screens for running gradations of coarse aggregates shall have a minimum area of 2.33 square feet.

3. A mechanical shaker approved by the Engineer and suitable for running both coarse and fine aggregate.

4. Facilities to perform wash tests according to AASHTO T 11 that include an adequate and suitable water supply.

B. Type B

In addition to meeting all of the requirements for a Type A Laboratory, a Type B Laboratory shall be equipped with the following:

1. Laboratory space with a minimum of 300 square feet.

2. Two vacuum extractors, each having a minimum bowl capacity of 100 troy ounces meeting the requirements of ASTM D2172, or one vacuum extractor and one ignition

furnace meeting the requirements of AASHTO T308. Supply an adequate amount of an approved solvent from the Department's Qualified Products List and provide for storage and disposal of the waste solvent in accordance with the regulations promulgated under the Tennessee Hazardous Waste Management Act.

To ensure adequate ventilation, house the extractor and drying equipment in an enclosed hood. Equip the hood with an exhaust fan vented to the outside and mounted at the appropriate location in order to remove the vapors of the solvent. Where the extractor is installed outside the laboratory, only vent the drying equipment as outlined above.

3. Supply apparatus meeting the requirements of AASHTO T 166, Section 3.1 and 3.2 for determining the bulk specific gravity of compacted asphalt mix. When required by the Contract, supply an apparatus meeting the requirements of AASHTO T 209, Section 3.1 through 3.5 for determining the maximum specific gravity of an asphalt mix.

4. Supply a minimum of two suitable thermometers with an approximate temperature range of 50 to 400 °F.

5. Provide a furnace capable of performing loss on ignition tests for a minimum 10-troy ounce sample.

6. When required as specified in **407.03**, provide equipment needed to perform Marshall Tests according to AASHTO T 245. The compactor shall be a Marshall Mechanical type with rotating mold(s) and slanted foot hammers that produce a modified kneading action.

Unless otherwise specified in the Contract, the Department will not pay for Field Laboratories as a separate item but will consider it incidental to the applicable contract items.

106.07 Notice of Source or Arrival of Materials

Purchase all materials sufficiently in advance of incorporating into the Work to allow the Engineer to conduct sampling and testing, or inspection. Provide the Department, in writing, the name and location of suppliers that will furnish materials for the Project. When the Department does not elect

to perform materials sampling and testing, or inspection at the source, advise the Engineer in writing within 24 hours after materials requiring sampling for testing, or inspection, are delivered to the site of the Work.

106.08 Handling and Storage of Materials

Transport all materials in tight, clean vehicles, and prevent contamination, segregation, or other damage to the materials when in route to the job site or the batching plant, and when moved from point to point at later stages.

Store materials to preserve their quality and fitness for use. When considered necessary, store materials in weatherproof buildings, place them on wooden platforms or other hard, clean surfaces but not on the ground, and cover them when directed. Locate stored materials to facilitate prompt inspection. Do not use private property for storage purposes without written permission of the owner or lessee. If using portions of the right-of-way for storage of materials or erection of batching plants, obtain the specific approval of the Engineer.

106.09 Resampling and Testing, or Reinspection

At the option of the Engineer, the Department may resample and test all materials or re-inspect at any time after delivery to the site, or to any batching plant. If such materials are found to be unacceptable, the Department will reject the materials.

106.10 Defective Material

Do not deliver to the site materials found to be unacceptable or rejected elsewhere. Remove rejected materials from the site or processing batch plant at no cost to the Department.

SECTION 307 – BITUMINOUS PLANT MIX BASE (HOT MIX)

DESCRIPTION

307.01 Description

This work consists of constructing one or more base course layers of aggregate and asphalt, prepared in a hot bituminous mixing plant and spread and compacted on a prepared subgrade, granular sub-base, or base.

MATERIALS

307.02 Materials

Provide materials as specified in:

Aggregate for Mixture,
Grading A, ACRL, AS, B, BM, BM2, C, CS, or CW **903.06**
Asphalt Cement, Grade PG 64-22, 70-22, 76-22, 82-22..... **904.01**
Chemical Additive **921.06.B**

The specific grading of aggregate to be used will be specified in the Contract or shown on the Plans. The Engineer will accept mineral aggregate, bituminous material, and the plant mix in accordance with **407.02**.

307.03 Composition of Mixtures

A. General

The bituminous base and/or leveling course shall be composed of aggregate and bituminous materials. The hot plant mixes shall comply with the applicable requirements of **407.03**.

Combine the specified mineral aggregate and asphalt cement in proportions that will meet the design composition limits specified in Table 307.03-1.

Table 307.03-1: Mixture Composition

Mixtures	Proportions of Total Mixture, Percent by Weight	
	Combined Mineral Aggregate, %	Asphalt Cement, % [1]
Grading AS and ACRL	96.3 - 97.7	2.3 - 3.7
Grading A	95.8 - 96.7	3.3 - 4.2
Grading B, BM and BM2	93.8 - 95.8	4.2 - 6.2
Grading C and CW	93.8 - 95.8	4.2 - 6.2
Grading CS	92.3 - 94.7	5.3 - 7.7

[1] If the effective combined specific gravity of the aggregate exceeds 2.80, the Engineer may adjust the proportions specified.

In addition, combine the materials with the required amount of bitumen to meet the design properties specified in Table 307.03-2, except that on low volume roads (ADT 1,000 or below), the minimum stability shall be 1,500 pound-feet and the VMA and dust-asphalt ratio will be waived for 307-B, 307-BM, 307-BM2 and 307-C mixes.

Table 307.03-2: Mixture Design Properties

Mix [1]	Stability (minimum) lbf [2]	Design Void Content % [2]	Production Void Content, % [2]	VMA (minimum) % [2]	Dust-Asphalt Ratio [3]
307-B	2,000	4.0±0.2	3-5.5	11.5	0.6-1.5
307-BM	2,000	4.0±0.2	3-5.5	13.5	0.6-1.5
307-BM2	2,000	4.0±0.2	3-5.5	13.5	0.6-1.5
307-C	2,000	4.0±0.2	3-5.5	13.0	0.6-1.5
307-CS	2,000	3.0±0.5	1-5	---	---
307-CW	1,500	4.0±0.2	3-5	13.0	0.6-1.5

[1] To identify critical mixes and make appropriate adjustments, the mix design shall meet these design properties for the bitumen content range of Optimum Asphalt Cement ±0.25%.

[2] Tested according to AASHTO T 245 with 75 blows with the hammer on each end of the test specimen, using a Marshall Mechanical Compactor.

[3] The dust-asphalt ratio is the percent of the total aggregate sample that passes the No. 200 sieve, as determined by AASHTO T 11, divided by the percent asphalt in the total mix.

If the materials proposed for use do not meet the design criteria specified in Table 307.03-2, find other suitable sources of materials. If the material at the asphalt plant will not combine within the tolerances of the Job Mix Formula (JMF), provide a new design.

B. Recycled Asphalt Pavement and Recycled Asphalt Shingles

1. Recycled Asphalt Pavement (RAP). The Contractor may use asphaltic concrete removed from a Department project or other State Highway Agency project by an approved method and stored in a Department approved stockpile. RAP combined with the appropriate aggregate, asphalt cement, and anti-strip additive when required shall produce a mixture that meets **903.06** and this Section **307**. The Contractor may incorporate RAP in the mixes specified in Table 307.03-3.

Table 307.03-3: Mixtures Using RAP

Mix Type	% RAP (Non-processed)[1]	Maximum % RAP (Processed)[2]	Maximum % RAP Processed & Fractionated [3]	Maximum Particle Size (inches)
307-ACRL	0	00	-	-
307-AS	0	00	-	-
307-A	15	20	35	1-1/2
307-B	15	30	35	1-1/2
307-BM	15	30	35	3/4
307-BM2	15	30	35	3/4
307-C	15	30	35	3/8
307-CW	15	30	35	1/2
307-CS	0	15	25	5/16

(1) "Non-processed" refers to RAP that has not been crushed and screened or otherwise sized prior to its use.

(2) "Processed" refers to RAP that has been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that listed in Table 307.03-3 prior to entering the dryer drum.

(3) "Fractionated" refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes (e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

All mixes shall contain at least 65% virgin asphalt.

The Contractor shall obtain a representative sample from the recycled material stockpile, and shall establish a gradation and asphalt cement content. The Contractor shall determine the gradation and asphalt content of the recycled material at the beginning of a project and every 2,000 tons thereafter. The stockpile asphalt cement content for all recycled material shall not

vary by more than 0.8%. The stockpile gradation tolerance for all recycled material on each sieve is specified in Table 307.03-4.

Table 307.03-4: Stockpile Gradation Tolerance

Sieve Size	Tolerance
3/8 inch and larger	± 10%
No. 4	± 8%
No. 8	± 6%
No. 30	± 5%
No. 200	± 4%

The Engineer will accept the mixture for aggregate gradation and asphalt content in accordance with **407.20.B**.

Provide a special mix design with asphalt content in the range of 5 to 7% where 307-C Mix is used as a surface on the shoulder.

Perform sampling and testing of the planings as well as new materials for bid purposes, and for the submission of the Job Mix Formula (JMF) as specified in **407.03**. Submit all additives to the Engineer for approval at the same time other materials are submitted for design verification.

After mixing, verify the moisture content of the total mix is no more than 0.1% as determined by oven drying. Provisions for lowering the temperature because of boiling or foaming shall not apply.

2. **Recycled Asphalt Shingles (RAS).** RAS may be included to a maximum of 5% of the total weight of mixture. The percentage of RAS used will be considered part of the maximum allowable RAP percentage. The ratio of added new asphalt binder to total asphalt binder shall be 65% or greater for all 307 mixes. Either the mix producer or the RAS supplier shall obtain a representative sample from the recycled material stockpile and establish a gradation and asphalt cement content as required. Determine shingle asphalt binder content according to AASHTO T 164 Method A, with a minimum sample size of 500 grams. Determine the gradation and asphalt content of the recycled material at the beginning of the

Project and every 2,000 tons of recycled material used thereafter. The stockpile asphalt cement content for all recycled material shall not vary by more than 0.8%. All RAS material shall be processed to a minimum 100% passing the 3/8 inch sieve and a minimum 90% passing the No. 4 sieve.

To conduct the gradation testing, air dry a 500 to 700-gram sample of processed shingle material, dry sieve over the 3/8-inch and No. 4 sieves, and weigh. For mix design purposes, the Contractor may use the aggregate gradation specified in Table 307.03-5 as a standard gradation instead of determining the shingle gradation according to AASHTO T 30.

Table 307.03-5: Standard Gradation (for Mix Design Purposes)

Sieve Size	Total Percent Passing
3/8 inch	100
No. 4	97
No. 8	95
No. 16	80
No. 30	60
No. 50	50
No. 100	40
No. 200	30

An aggregate bulk specific gravity (G_{sb}) of 2.650 may be used instead of determining the shingle aggregate G_{sb} according to AASHTO T 84. In addition, the effective binder available for mixing with additional aggregates shall be considered as 75% of the total binder content as determined by AASHTO T 164 and shall be the value listed as the RAS binder content on the JMF.

Scrap asphalt shingle shall not contain extraneous waste materials. Extraneous materials including, but not limited to, asbestos, metals, glass, rubber, nails, soil, brick, tars, paper, wood, and plastics, shall not exceed 0.5% by weight as determined on material retained on the No. 4 sieve. To conduct deleterious material testing, take a representative 500 to 700-gram sample of processed shingle material, place over the No. 4 sieve, and pick

and weigh all extraneous waste material retained on the No. 4 sieve. Base the percent of extraneous material on the total sample weight.

RAS shall contain less than the maximum percentage of asbestos fibers based on testing procedures established by the Department, or State or Federal environmental regulatory agencies. Analyze a minimum of one sample of processed asphalt roofing material for every 500 tons of material processed for the presence of asbestos.

Before a JMF for a particular design is approved, submit the following, along with the materials and information specified in **407.03**:

a. Certification by the processor of the shingle scrap describing the shingle scrap content and source.

b. A 1000-gram sample of the processed RAS material for inspection (new designs only).

Stockpile RAS separate from other salvage material. Do not blend RAS material in a stockpile with other salvage material. Do not blend Manufacture Waste Scrap Shingles (MWSS) and Tear-Off Scrap Shingles (TOSS). In addition, do not blend virgin sand material with the processed shingles, to minimize agglomeration of the shingle material.

All RAS supplied to a Department project shall come from a certified shingle processor/supplier approved by the Division of Materials and Tests.

C. Anti-Strip Additive

Check asphaltic concrete mixtures (Grading A, AS, ACRL, B, BM, BM2, C, CS, and CW) for stripping by the following methods:

1. The Ten Minute Boil test for dosage rate and the Root-Tunnecliff procedure (ASTM D4867) for moisture susceptibility.

   Do not use the Root-Tunnecliff procedure (ASTM D4867) with the following mixtures: Grading A, AS, ACRL, and B.

2. For mixtures not requiring design, the Ten Minute Boil test for dosage rate and moisture susceptibility.

If test results indicate moisture susceptibility, mix an approved anti-strip agent with the asphalt cement at the dosage recommended by the respective test and as specified in **921.06.B**.

EQUIPMENT

307.04 Equipment

Provide equipment as specified in **407.04** through **407.08**.

If using recycled mix, modify the asphalt plant as approved by the Engineer to accommodate the addition of asphalt planings. If using a batch plant to produce recycled mix, heat the aggregate to a temperature that will transfer sufficient heat to the cold planings to produce a mix of uniform temperature within the specified range.

CONSTRUCTION REQUIREMENTS

307.05 General

Conform to the construction requirements specified in **407.09**, and **407.11** through **407.17**.

307.06 Preparing the Subgrade, Sub-base, or Surface

The Plans will indicate whether the plant-mixed base is to be constructed on a treated or untreated subgrade or sub-base, on a granular base, or on an existing surface. Ensure that the surface upon which the plant mix base is to be constructed meets **205**, **207**, **302**, **303**, **304**, or **309**, whichever is applicable. If shown on the Plans, condition the surface as specified in **407.10**. Condition existing mineral aggregate base as specified in **310**. Construct prime coat or tack coat, when shown on the Plans, as specified in **402** or **403**, respectively.

Only place bituminous plant-mix base mixture on a surface that is dry and free of loose particles and other undesirable materials.

307.07 Thickness and Surface Requirement

Control thickness during the spreading operation by frequently measuring the freshly spread mixture to establish a relationship between the uncompacted mixture and the completed course. Thickness or spread rate in pounds per square yards shall be within reasonably close conformity with that shown on the Plans. Each course shall have a thickness after compaction of not more than 4 inches, unless otherwise approved by the Engineer.

The surface of the base shall meet the requirements specified in **407.18**, and when tested in accordance with **407.18**, the deviation of the surfaces from the testing edge of the straightedge shall not exceed the amounts specified in Table 307.07-1.

Table 307.07-1: Maximum Surface Deviation

Mixture	Maximum Deviation (inches)
Grading A, ACRL, and AS	1/2
Grading B, BM, BM2, C, CS, and CW	3/8

COMPENSATION

307.08 Method of Measurement

The Department will measure Mineral Aggregate, including Mineral Filler when required, and Asphalt Cement for Bituminous Plant Mix Base and other related items in accordance with **407.19**.

307.09 Basis of Payment

The Department will pay for accepted quantities at the contract prices in accordance with **407.20**.

For bidding purposes, use the asphalt cement content specified in Table 307.09-1 for the designated mix.

Table 307.09-1: Asphalt Cement Content

Mix Type	Asphalt Content
307 A	4.0%
307 AS	3.5%
307 ACRL	3.5%
307 B	4.3%
307 BM	5.0%
307 BM2	5.0%
307 C	5.0%
307 CW	6.0%
307 CS	6.5%

If the Engineer sets an asphalt content other than that specified in Table 307.09-1, the Department will calculate a price adjustment, based on the asphalt content set by the Engineer and the Monthly Bituminous Index for the specific grade asphalt on the mix design, in accordance with **407.20**.

SECTION 313 – TREATED PERMEABLE BASE

DESCRIPTION

313.01 Description

This work consists of constructing treated permeable base, composed of either a mixture of aggregate, Portland cement, and water, or a mixture of aggregate with asphalt binder, on a prepared sub-base. The Contractor may use either cement treated or asphalt treated permeable base.

MATERIALS

313.02 Materials

Provide materials as specified in:

Portland Cement, Type I	**901.01**
Aggregate for Portland Cement Treated Mixture	**903.03**
Aggregate for Bituminous Treated Mixture	**903.06**
Asphalt Cement, Grade PG 64-22, 70-22, 76-22, 82-22	**904.01**
Liquid Membrane – Forming Compounds	**913.05**
Water	**921.01**

313.03 Composition of Mixtures

A. Portland Cement Treated Permeable Base

In accordance with **604**, submit a concrete mix design, meeting the requirements specified in Table 313.03-1, to the Engineer for approval.

Table 313.03-1: Mix Design Properties

Property	Value
Water-Cement Ratio	0.43 (approximately)
Portland Cement Content	$\geq$ 282 lbs/yd^3
Compressive Strength at 7 days (AASHTO T 22)	$\geq$ 500 psi

B. Bituminous Treated Permeable Base

Asphalt treated permeable base shall be Bituminous Plant Mix Base (Hot Mix) as specified in **307** and **407**. Use liquid asphalt at the rate of 3% by weight of the total mixture. Asphalt content shall be such that all aggregate is visibly coated. Submit a mix design to the Engineer for approval as specified in **407.03**.

EQUIPMENT

313.04 Equipment

To construct Portland cement treated base, provide equipment meeting **501.04.A** and **501.04.B**.

To construct bituminous treated base, provide equipment meeting **407.04** through **407.08**.

The spreading equipment shall meet either **501.04.D.11** or **407.06**.

CONSTRUCTION REQUIREMENTS

313.05 Construction Requirements

Construct cement treated permeable base and asphalt treated permeable base as specified in **309** and **307** respectively, unless otherwise specified below.

A. Cement Treated Permeable Base

1. **Consolidation and Finishing.** Immediately after placing the cement treated permeable base, compact the mixture using a steel wheel roller weighing not less than 6 tons. Continue rolling until maximum densification is achieved; immediately cease rolling if aggregate breakage occurs. Do not use vibratory rollers. Instead of using a steel wheel roller, the Contractor may place the cement treated permeable base with a high-density screed with dual tamping bars.

2. **Curing.** Immediately after spreading and compacting operations, cover the entire surface and exposed edges of the cement treated permeable base with transparent or white polyethylene sheeting as specified in **501.18**, or a white pigmented wax base curing compound meeting AASHTO M 148.

   Use polyethylene sheeting having a thickness of at least 4 mils, and hold the sheeting in place for a minimum of 7 days using a method approved by the Engineer. Before placing the sheeting, thoroughly wet the surface of the cement treated permeable base.

   Place wax-based curing compound at a rate of 0.04 to 0.05 gallons per square yard.

B. Asphalt or Cement Treated Permeable Base

From the time of placement until placement of the following pavement layer, protect the treated permeable base from severe weather conditions, particularly freezing rain, snow, and icing, and from contamination by dust, dirt, mud, or other fine grained material. Remove and replace, at no additional cost to the Department, all portion(s) of the treated permeable base that become contaminated to the extent that drainage is reduced or inhibited.

Do not allow traffic on the treated permeable base, with the exception of equipment required to place the following layer of pavement, provided that it enters and exits as near as possible to the paving operation. Repair damage to the treated permeable base caused by the Contractor's equipment at no additional cost to the Department.

313.06 Limitations

If using asphalt treated permeable base, adhere to the limitations specified in **407.09**. Do not place any treated permeable base that cannot be covered by the next course of pavement within the same construction season.

313.07 Surface Requirements

The Department will test the finished surface of the treated permeable base with a 12-foot straightedge in both transverse and longitudinal directions. The finished surface shall be uniform and shall not vary by more than 1/2 inch from the lower edge of the straightedge. If the tested surface varies by more than 1/2 inch, adjust the surface to a new grade, as established by the Engineer, as follows:

1. Fill the low areas with Portland cement concrete during the concrete paving operation, or

2. Apply emulsified asphalt, RS-2, at a rate not to exceed 0.2 gallons per square yard, as determined by the Engineer, over the specified low areas, and fill the low areas with No. 8 mineral aggregate. Seat the size No. 8 mineral aggregate with a pneumatic tire roller.

313.08 Tolerance in Pavement Thickness

Place treated permeable base to the thickness designated on the Plans. Before beginning any further work, take core samples from the treated permeable base, at locations established by the Engineer, in accordance with **501.24** for verification of base thickness. Take core samples at locations determined and witnessed by a Department representative, and document on the appropriate form.

The Department will make adjustments to the contract unit price in accordance with **501.26** if the base thickness is determined by the Engineer to be deficient.

COMPENSATION

313.09 Method of Measurement

The Department will measure treated permeable base by the square yards complete in place for the width and thickness specified.

313.10 Basis of Payment

The Department will pay for accepted quantities at the contract prices as follows:

Item	*Pay Unit*
Treated Permeable Base	Square Yard

The Department will adjust payment in accordance with **501.26.B** for all base found to be deficient in thickness by more than 1/4 inch. The Department will not make additional payment over the contract unit price for base that has an average thickness in excess of that shown on the Plans.

If the Department orders any increase or decrease in the cement content of the Cement Treated Base from the approved mix design, the measurement and payment for this change will be computed in accordance with **501.25** and **501.26**.

The Department will consider the cost of taking cores for verification of pavement thickness to be included in the contract unit price of treated permeable base.

The Department will not allow additional compensation for leveling of the treated permeable base except on ramps that contain 4,500 square yards or less of Portland cement concrete pavement. The Department will measure and pay for additional concrete used on these ramps in accordance with **501.25** and **501.26**.

SECTION 407 – BITUMINOUS PLANT MIX PAVEMENTS (GENERAL)

DESCRIPTION

407.01 Description

This Section 407 is applicable to all types of bituminous pavements of the asphalt plant mix type as described in **307**, **313**, and **411**. Deviations from these general requirements will be indicated in the specific requirements for each pavement type.

This work consists of constructing one or more courses of bituminous mixture on a prepared foundation in accordance with this Section **407** and the specific requirements of the pavement type under contract.

MATERIALS

407.02 Materials

Provide materials as specified in:

Aggregates	**903**
Mineral Filler	**903.16**
Bituminous Materials	**904**
Chemical Additive	**921.06.B**

Separate aggregate into coarse and fine aggregate stockpiles. If stockpiling of coarse aggregate causes segregation, separate into coarse and medium coarse stockpiles.

Store each size and type of aggregate in a separate pile, bin, or stall. Maintain the storage yard in an orderly condition, clearing a walkway between stockpiles that are not separated by partitions. Make the stockpiles readily accessible for sampling.

The Engineer will conditionally accept the mineral aggregate for quality in the stockpile at the producer's site. The Engineer may conditionally accept the bituminous material at the asphalt terminal. The Engineer will accept for aggregate gradation and asphalt cement content from hot bin samples or sample(s) taken from the completed mix at the asphalt plant after it has been loaded onto the trucks for transport to the Project.

If anti-stripping additive, other than hydrated lime, meeting **921.06.B.1** is required, use approved in-line blending equipment, as specified in **407.04.A.6**, to add it at the mixing plant or inject it at the asphalt terminal.

If the resurfacing plans call for a Performance Grade (PG) asphalt mix with properties greater than that of PG 64-22 and this is the only asphalt grade on the Project, the Contractor may use either the asphalt grade shown on the Plans or an asphalt grade equal to or better than PG 64-22 for driveways and business entrances unless otherwise directed by the Engineer. The Department will pay for this material at the same unit price as bid for the

asphalt or asphalt mix. Mark the material tickets "**FOR DRIVEWAYS AND BUSINESS ENTRANCES ONLY**" at the point of delivery.

If using a warm mix asphalt additive meeting **921.06.B.3**, use approved blending equipment to add it at the mixing plant, or deliver it premixed with the asphalt cement.

For 411-OGFC mixtures, include a stabilizing additive listed on the Department's Qualified Products List (QPL). Do not use fiber pellets. Slag wool fiber or cellulose fiber shall be blown into the asphalt plant measured by a flow meter or sensing device that is accurate to within ±10% of the amount required. For batch plants, add fibers in to the pugmill or weigh hopper. For drum plants, place the fiber line 1 foot upstream of the asphalt binder line so that the fibers are captured by the asphalt binder before being exposed to high-velocity gases in the drum. The minimum additive for a slag wool fiber shall be 0.4% and the minimum for a cellulose fiber shall be 0.3% of the total mix. The addition of a stabilizing additive material (fiber) shall be included in the cost of the asphalt cement.

407.03 Composition of Mixtures

A. General

Develop a bituminous mixture composed of aggregate (coarse, fine, or mixtures thereof), mineral filler if required, anti-strip additive if required, and bituminous material. Ensure that the aggregate fractions are sized, uniformly graded, and combined in such proportions so that the resulting mixture will meet the grading and physical properties of the approved Job Mix Formula (JMF).

B. Gradation and Bituminous Material Requirement

The requested aggregate gradation and bituminous material percentages shown on the JMF shall be within the design ranges specified in **903**, **307**, and **411**, respectively. Establish a recommended asphalt cement content for all mixes, with the final optimum asphalt cement content to be determined by the Engineer.

C. Job Mix Formula (JMF)

1. **General.** At least 14 working days before the scheduled start of production of any asphaltic paving mixture, submit a proposed Job Mix Formula (JMF) and Laboratory Design in electronic form,

where applicable, prepared in accordance with the Marshall Method of Mix Design (Asphalt Institute, MS-2), as modified by the Department, or by Gyratory Compaction (AASHTO T 312). Regardless of which method is used, prepare trial blends with at least four different asphalt contents (at least two above the optimum and two below the optimum).

When using the Marshall method of compaction, compact the specimens to 75 blows per side. When using the gyratory method of compaction, compact specimens to 65 gyrations.

All 411-OGFC design procedures shall follow the most current version of National Asphalt Pavement Association (NAPA) Publication IS-115, "Design, Construction and Maintenance of Open-Graded Friction Courses" except where modified herein. Design the OGFC using a Marshall compaction hammer at 50 blows or a standard gyratory compactor at 50 gyrations.

Provide the following information with JMF submittals:

a. The specific project on which the mixture will be used.

b. The source and description of all materials to be used in the mix.

c. The gradations and approximate proportions of the raw materials as intended to be combined in the paving mixture.

d. A single percentage of the combined mineral aggregate passing each specified sieve. Plot the combined aggregate gradation on a gradation chart with sieve sizes raised to the 0.45 power to ensure a well graded mix.

e. The Loss on Ignition (L.O.I.) results on the combined aggregate of the mixture used as a wearing course.

f. The Bulk Specific Gravity, Apparent Specific Gravity, and absorption on the combined mineral aggregate in the paving mixture (AASHTO T 84 and T 85)

g. The fractured face count and glassy particle count of the plus No. 4 material, if applicable.

h. A single percentage of asphalt by weight of total mix intended to be incorporated in the completed mixture.

i. The dosage rate and source of anti-stripping additive, if required, meeting the requirements of **921.06.B.1**, to be added to the asphalt.

j. The maximum specific gravity of the asphalt mixture (AASHTO T 209).

k. A single temperature at which the mixture is intended to be discharged from the plant.

l. Evidence that the completed mixture will conform to all physical requirements specified in **903.06** and **307.03.A** or **903.11** and **411.03.B**; however, for mixes designed according to AASHTO T 312, the stability and flow requirements will be waived and the resistance to rutting requirements for surface mixtures must be met.

m. The tensile strength ratio (TSR) indicating the stripping and moisture susceptibility characteristics of the mix.

n. To identify critical mixes and make appropriate adjustments, the mix design shall meet the required design properties for stability, flow, voids in mineral aggregate (VMA), and production void content as specified in **307.03** and **411.03** at the bitumen content range of Optimum Asphalt Cement ±0.25%.

Establish the laboratory mix and compaction temperatures for the JMF in accordance with Table 407.03-1.

Table 407.03-1: Laboratory Mix and Compaction Temperatures

PG Binder Grade	Lab Mix Temperature (°F)	Lab Compaction Temperature (°F)
64-22, 67-22	Per temp./visc. chart	Per temp./visc. chart
70-22	320 – 345	295 – 320
76-22	320 – 345	305 – 330
82-22	320 – 345	305 – 335

Perform any additional laboratory testing of the mix using the laboratory mix and compaction temperatures listed on the approved JMF, with a tolerance of ± 5 °F for each temperature.

A Certified Laboratory Technician shall prepare and sign the Laboratory Design. To be certified, the technician shall have completed the Marshall Method of Mix Design School conducted by the Department, including the written and lab performance testing.

2. **Revision of Job Mix Formula.** The approved JMF shall remain in effect until the Engineer authorizes a change in writing. The Contractor, at any time after construction has started, may request that the JMF be revised, provided evidence is shown that the revision is necessary and the revised aggregate gradation will meet all applicable gradation requirements.

   Submit a revised JMF if, during the test strip construction and mix design/production verification procedure, changes are made to the mixture to comply with the specified criteria.

   Provide a new design for any change in source of materials.

   Submit all requests for design mix adjustments, redesigns, and new design mixes in writing to the Engineer for approval.

3. **Resistance to Plastic Flow.** Include, with the submitted JMF, test data showing that the material as produced will meet **307.03.A** or **411.03.B** when tested according to AASHTO T 245. Determine the bulk specific gravity of the laboratory compacted bituminous mixture (Marshall specimens) according to AASHTO T 166.

Mixes designed according to AASHTO T 312 are exempt from AASHTO T 245.

For surface mixtures used on roads with greater than 5,000 ADT, designed with the gyratory compactor (AASHTO T 312), include sufficient raw materials (aggregate and asphalt cement) with the submitted JMF so that the Central Laboratory may conduct rut testing in accordance with AASHTO T 340. The maximum allowable rut depth shall be 0.35 inches for roads with greater than or equal to 10,000 ADT and 0.40 inches for roads with 5,000 to 10,000 ADT.

Base the percent voids in the total mix on the maximum specific gravity of the bituminous mixture (Rice Gravity) according to AASHTO T 209. Calculate the voids in mineral aggregate (VMA) using the effective specific gravity of the aggregates.

D. Contractor's Quality Control

1. General. Assume responsibility for the quality of construction and materials incorporated in the Work. Provide and maintain a quality control system that will provide reasonable assurance that all materials conform to specification requirements.

Conduct all quality control sampling and testing according to the approved Quality Control Plan and the Department's Policies on Sampling and Testing Procedures and Sampling of Asphalt Mixes for Verification of Laboratory Design. The requirements for the Contractor's quality control sampling and testing will remain in effect until final Project acceptance.

2. Contractor Quality Control System. Develop, implement, and maintain a quality control system that will provide reasonable assurance that all materials and products submitted to the Department for acceptance conform to the specified requirements.

a. Quality Control Technician. Ensure that a Quality Control Technician, who is currently certified by the Department as a Certified Asphalt Plant Technician, is present at the asphalt plant during mix production. If the Department finds that the Quality Control Technician cannot perform as required by the position, the Department will revoke the certification and require replacement with a certified technician.

b. Documentation. Document all quality control procedures, inspections, and tests and make this information available for review by the Department throughout the life of the Contract. Maintain adequate records of all inspections and tests. The records shall indicate the nature and number of tests performed, the number and type of deficiencies found, and the nature of corrective action taken as appropriate.

The Contractor's documentation procedures will be subject to the review and approval of the Department before the start of the work and to compliance checks during progress of the work. Provide copies of all charts and records documenting quality control tests and inspections to the Engineer on a daily basis.

c. Charts and Forms. Record all conforming and nonconforming inspections and test results on approved forms and charts, and keep these records current and complete. Maintain test results at the Contractor's plant site laboratory and make such records available to the Engineer at all times during the performance of the work. Chart test results for the various materials and mixtures on forms that meet the Engineer's requirements. Provide an example of each proposed chart and form to the Engineer. Supply all charts and forms to be used to record results.

d. Corrective Actions. Promptly correct all errors, equipment malfunctions, process changes, or other assignable causes that have resulted or could result in the submission of materials, products, and completed construction that do not conform to the specifications.

If the Engineer finds that the Contractor is not controlling its process and is making no effort to take corrective actions, the Engineer will require that plant operations be ceased until the Contractor can demonstrate that it can and will control the process.

e. Laboratories with Measuring and Testing Equipment. Provide a fully equipped laboratory at the production site as specified in **106.06**. This facility may be permanent or portable. Furnish the laboratory with the necessary testing equipment and supplies for performing Contractor Quality

Control sampling and testing as well as Department Acceptance sampling and testing. To assure accuracy, the Department will check the testing equipment periodically according to the Department's Procedure for Qualified Laboratories.

f. Sampling and Testing. Sampling and testing methods and procedures to determine quality conformance of the materials and products shall be in accordance with **106.04**. Address in the Quality Control Plan the taking of samples for material characteristics and the plotting of the test results on control charts.

g. Alternative Procedures. The Engineer may approve the use of alternative sampling methods, procedures, and inspection equipment if such procedures and equipment provide, as a minimum, the quality assurance required by the Contract. Before applying such alternative procedures, describe them in a written proposal and demonstrate, for the Engineer's approval, that their effectiveness is equal to or better than the Contract requirements.

h. Mix Design/Production Verification. After the JMF has been approved, provide material that conforms to the approved JMF within the acceptance range specified in Table **407.20-2**. Consider the process to be out of control and cease plant operations if test results from a lot fall below the 90% pay factor limit for the values specified in Table **407.20-2**. The Contractor may resume plant operations upon demonstrating that it can and will control the process.

Sample and test asphaltic concrete base and surface mixes throughout production to verify that the mix being produced is within the criteria specified in Table 407.03-2. Also record such information on control charts. Note that this requirement applies only to mixes designed according to the Marshall Method of Mix Design.

With the exception of any individual mix of 1,000 tons or less, meet the requirements specified in Table 407.03-2 for all interstate projects, any project with a current Average Daily Traffic (ADT) exceeding 12,000, and any project utilizing modified asphalt cements.

Table 407.03-2: Mix Design Requirements

Property	Value
Maximum Theoretical Gravity	± 0.025 of Mix Design Value
Voids in Total Mix	As noted for production in **307.03** and **411.03**
Voids in Mineral Aggregate	Minimum as noted in **307.03** and **411.03**
Marshall Stability	Minimum as noted in **307.03** and **411.03**
Dust/Asphalt Ratio	As noted in **307.03** and **411.03**

The asphalt pavement mix design/production verification procedure shall consist of the following:

(1) Submit mix designs to the Engineer for approval before mix production. Once approved, produce sufficient mix to construct a test strip as specified in **407.15.C**.

(2) Perform maximum theoretical gravity and gradation tests from material produced for constructing the test strip. A Quality Control Technician, who is currently certified by the Department as a Certified Asphalt Mix Design Technician, shall perform these tests under the Engineer's observation.

(3) Place no more than 500 tons of mix until the verification testing, with the exception of TSR, is complete. Without complete test results, the Contractor, at its risk, may continue to produce and place mixture in excess of the first 500 tons; however, all mixture will be subject to price adjustment or removal at the discretion of the Engineer if the test results do not comply with the specifications.

If the test results for the produced mix are within the limits required for production, as specified in Table 407.03-2, and mix density requirements are met, the Contractor may proceed.

If not, prepare a revised design before start up and submit to another evaluation process for the revised design. Place no more than 100 tons of mix during this trial. Repeat this process until an acceptable mix can be produced. All test strip and mixture design/production verification material will be subject to applicable price adjustments or removal at no cost to the Department. If the tensile strength ratio (TSR) results are not in compliance with the specifications, immediately stop production until mixture adjusts are made.

(4) During construction, perform verification testing, for each half-day's production, for mix quality control. Use a random numbers table to determine when to collect samples for testing.

(a) When the test results are outside the allowable criteria, immediately obtain a subsequent sample and test it for compliance.

(b) If the subsequent test results are within allowable limits, the Contractor may continue mix production.

(c) If the subsequent test results are outside allowable limits, do not resume mix production until it can be demonstrated to the Engineer that adequate corrective action has been taken. The Contractor may then produce sufficient mix, not to exceed 100 tons, to provide a representative sample for determining stability, voids in the total mix, and the dust/asphalt ratio. Do not continue with mix production until test results indicate compliance with Table 407.03-2 and the specified density.

3. Quality Control Plan. At the beginning of each paving season, submit in writing the proposed Quality Control Plan for the Engineer's approval. Include in this plan the sampling, testing, and inspection activities, and the anticipated frequencies of each, which the Contractor will follow to maintain process control. This Quality Control Plan shall apply to all Department contracts for the

calendar year. If a change is made to the Quality Control Plan during the year, communicate such changes to the Regional Materials Supervisor. Refer to the recommended series of sampling, testing, and inspecting activities shown in Table 407.03-3.

Table 407.03-3: Recommended Items for a Contractor Quality Control Plan

A. All Types of Plants

1. Stockpiles
   a) Determine gradation of all incoming aggregates.
   b) Inspect stockpiles for separation, contamination, segregation, etc.
   c) Conduct a fractured face count when gravel is used as coarse aggregate.
   d) Determine the percent of glassy particles in slag coarse aggregate.
   e) Determine gradation and asphalt content of reclaimed asphalt pavement when used as a component material.
2. Cold Bins
   a) Calibrate the cold gate settings.
   b) Observe operation of cold feed for uniformity.
   c) Ensure that bins have proper dividers to prevent materials from spilling over into adjacent bins.
3. Dryer
   a) Observe pyrometer for aggregate temperature control.
   b) Observe efficiency of the burner.
   c) Determine the percent dust coating on plus 4 material.
   d) Check dried aggregate for contamination due to incomplete combustion of fuel.
4. Hot Bins
   a) Determine gradation of aggregates in each bin.
   b) Determine theoretical combined grading.
5. Bituminous Mixture
   a) Determine percent bitumen.
   b) Determine mix gradation.
   c) Check mix temperature.
   d) Determine percent moisture in mix when reclaimed

asphalt pavement is a component material. e) Determine Loss-On-Ignition (LOI) of aggregates in mix where applicable. f) Check the mix for uncoated aggregate. g) Ensure that handling procedures do not contribute to segregation of the mix.
B. Batch Plants 1. Batch Weights – Determine percent used and weight to be pulled from each bin to assure compliance with the JMF. 2. Check mixing time (both dry and wet). 3. Check operations of weigh bucket and scales. 4. Document accuracy of all weighing and metering devices for: a) Asphalt cement b) Aggregate c) Anti-strip additive
C. Drum Mixer Plant 1. Calibrate the cold feed and prepare a calibration chart for each cold gate. 2. Develop information for the synchronization of the aggregate feed and the bituminous material feed. 3. Determine moisture content of aggregate being fed into dryer. 4. Determine the percent dust coating on dried plus 4 material. 5. Check dried aggregate for incomplete combustion of fuel. 6. Document accuracy of all weighing and metering devices for: a) Asphalt cement b) Aggregate c) Anti-strip additive

Consider the activities identified in Table 407.03-3 to be normal activities necessary to control the production of asphalt concrete at an acceptable quality level. However, note that depending on the type of process or materials, some of the activities listed may not be necessary, and in other cases, additional activities may be

required. The frequency of these activities will also vary with the process and the materials. When the process varies from the defined process average and variability targets, increase the frequency of these activities as necessary to restore proper conditions.

Plot and keep up-to-date control charts for all Quality Control Sampling and Testing. Provide control charts for the following:

(a) Extracted asphalt content

(b) Mix gradation

(c) Dust to asphalt ratio

(d) Maximum theoretical gravity (when required)

(e) Voids in total mix (when required)

(f) Stability (when required)

Post all current control charts in the asphalt lab where they can be seen.

The Contractor is responsible for formulating all design mixes with the exception of plant mix seal coat mixes. No lab design is required for **307** Grading A, AS, and ACRL mixes. However, establish the anti-strip additive dosage rate and verify compatibility of mixture materials by the ten minute boil test as specified in **407.03.E.2**. Submit all Contractor-furnished design mixes to the Department for approval prior to their use. Provide process control of all materials during handling, blending, mixing, and placing operations.

If reclaimed asphalt pavement (RAP) is approved for use as a component material in a hot bituminous mixture, the Contractor's Quality Control Plan shall include determination of the gradation and asphalt content of the RAP material at a minimum frequency of 1 stockpile sample per 2,000 tons used in the mixture.

E. Testing Procedures

Conduct the Tensile Strength Ratio (TSR), Stripping, and Loss on Ignition (LOI) testing in accordance with the following:

1. Tensile Strength Ratio. Perform testing for stripping and moisture susceptibility of the mixture according to ASTM D 4867, Standard Test Method for Effect of Moisture on Asphalt-Concrete Paving Mixtures (Root-Tunnecliff Procedure).

Specimen tested for stripping and moisture susceptibility according to Root-Tunnecliff Procedures shall meet the criteria specified in Table 407.03-4.

Table 407.03-4: Criteria for Stripping and Moisture Susceptibility

Asphalt Cement	Minimum Tensile Strength	Minimum TSR
Polymer Modified	100 psi	80%
Non-Polymer Modified	80 psi	80%

2. Ten Minute Boil Test (Stripping)

a. Field Test. Test the completed mix for stripping at the asphalt plant as follows:

(1) From a sample of the completed mix, visually select a minimum of 50 grams of the plus No. 4 material and place immediately in boiling water.

(2) Continue to boil for 10 minutes, pour off water, and place coated aggregate on a paper towel.

(3) Perform a visual inspection to verify that the coated aggregate shows no evidence of stripping.

b. Laboratory Test. Determine the dosage rate for anti-stripping additive in the laboratory as follows:

(1) Wash and surface dry 50 grams of the mineral aggregate passing the 1/2-inch sieve and retained on the No. 4 sieve.

(2) Thoroughly coat the selected aggregate with the blend by stirring the mixture heated to 250° F.

(3) Immediately place the material in boiling water.

(4) Continue to boil for 10 minutes, pour off water, and place coated aggregate on a paper towel.

(5) Perform a visual inspection to verify that the coated aggregate shows no evidence of stripping.

3. **Test for Percent Loss on Ignition (LOI) of the Mineral Aggregate in an Asphalt Paving Mixture.**. Conduct Loss on Ignition Testing as follows:

a. Obtain a representative aggregate sample and weigh approximately 600 grams into an assayer's fire clay crucible that has been ignited to constant weight. Place a cover on the crucible to prevent pop-out of aggregate while heating.

b. Ignite the covered crucible and its contents in a muffle furnace at 1742° F to constant weight (minimum of 8 hours).

c. Cool the crucible and contents to room temperature and weigh.

If the aggregate sample is obtained by extraction with a vacuum extractor, correct the weights before and after ignition for filter aid using the following equation:

$$\text{Percent loss on ignition} = \frac{(A - B) \times 100}{A}$$

Where:

A = weight of sample before ignition (corrected for filter aid)
B = weight of sample after ignition (corrected for filter aid)

EQUIPMENT

407.04 Bituminous Mixing Plant

Provide sufficient storage space for each size aggregate. Keep the different sizes separated until they have been delivered to the cold elevator or belt feeding the dryer. Maintain the storage yard in a neat and orderly condition and ensure that the separate stockpiles are readily accessible for sampling.

Plants used to prepare bituminous mixture shall meet all requirements specified in **407.04.A**. In addition, batch mixing plants shall meet **407.04.B**, continuous mixing plants shall meet **407.04.C**, and dryer-drum mixing plants shall meet **407.04.D**.

A. Requirements for All Plants

Mixing plants shall be of sufficient capacity and so coordinated to adequately handle the proposed bituminous construction.

1. **Equipment for Preparing Bituminous Material.** Provide tanks that are equipped to heat and hold bituminous material at the required temperatures. The circulating system for the bituminous material shall be designed to ensure proper and continuous circulation during the operating period. Make provisions for measuring and sampling the storage tanks' contents.

2. **Feeders for Dryer.** For each size aggregate, provide separate feeders that can deliver the aggregates onto the belt going to the dryer in proper proportions. Use mechanical feeders with separate adjustable gates to feed each size aggregate onto the belt.

   Provide adequate means to ensure a constant and uniform flow of material from each bin. Equip bins containing fine aggregate with vibrators if necessary.

   Do not blend or mix different aggregates, or different sizes of the same aggregates, with clam shells, bulldozers, high lifts, or similar equipment.

   Feed the aggregate into the dryer so as to obtain a uniform production and uniform temperature.

3. **Dryer.** The plant shall include a dryer or dryers that are capable of:

    a. agitating the aggregate continuously during the heating and drying process;

    b. heating and drying all aggregates to the temperature required, and

    c. supplying the mixing unit continuously at its operating capacity.

    Ensure that dryers are constructed and operated so that aggregates will not be contaminated with unburned fuel.

4. **Screens.** Provide plant screens, capable of screening all aggregates to the specified sizes and proportions and having normal capacities in excess of the mixer's full capacity.

    The Contractor may allow a consistent carry-over, not to exceed 20%, on any screen. If any bin contains more than 20% of material that is undersized for that bin, empty the bin and correct the cause of this condition.

    Provide approved scalping screens on all dryer-drum mixing plants; additional screens will not be required.

5. **Bins.** Provide storage bins of sufficient capacity to supply the mixer when it is operating at full capacity. Arrange bins to ensure separate and adequate storage of appropriate fractions of the mineral aggregates. For each bin, provide overflow pipes of the size and at the location needed to prevent material from backing up into other compartments or bins. Provide each compartment with an outlet gate constructed so that, when closed, no leakage occurs. The gates shall be cut off quickly and completely. The bins shall be constructed to provide adequate and convenient approved facilities for obtaining representative samples of aggregate from the full flow of each compartment. These bins are not required in an approved Dryer-Drum Mixing Plant. When using mineral filler, provide separate dry storage and equip the plant to uniformly and accurately feed the filler into the mixer.

6. **Bituminous Control Unit and Anti-Stripping Additive (ASA) Systems.** Provide means for weighing or metering the bituminous material to ensure the proper amount of material is added to the mix within the tolerance specified. Provide means for checking the quantity or rate of flow of bituminous material into the mixer.

   Where required, use approved in-line blending equipment to add anti-stripping additive, other than hydrated lime, meeting **921.06.B**. Provide a storage tank for the ASA that can maintain a constant temperature without overheating the additive. Store the additive according to the manufacturer's recommendations and at a temperature of 150 ºF or less. The in-line blending equipment on drum plants shall have a totalizing "flow meter" capable of measuring the actual flow rate within the production range of 0.00 to 1.00 gallons per minute at increments of 0.05 gallons. Batch plants shall have a totalizing flow meter that displays the total gallons of material dispensed. The dispenser and/or pumps shall be capable of adding the heat stable ASA within a tolerance of 10% of the specified rate.

7. **Thermometric Equipment.** Fix an armored thermometer, capable of reading an adequate temperature range, in the bituminous feed line at a suitable location near the charging valve at the mixer unit.

   At the discharge chute of the dryer, also place an approved thermometric instrument that can register automatically or indicate the temperature of the heated aggregates. With the Engineer's approval, the Contractor may place the thermometric instrument within the fines bin.

   Equip the plant with an approved automatic recording and regulating apparatus to control the temperature of the aggregates.

8. **Dust Collector.** Equip the plant with a dust collector constructed to uniformly waste or return to the dried aggregate all or any part of the material collected. Handle collected baghouse fines intended for recirculation into the mix as if it were mineral filler or feed by another suitable method approved by the Engineer. Provide means to calibrate and adjust the dust fed from a baghouse.

9. **Safety Requirements.** Provide adequate and safe stairways to the mixer platform and sampling points. Place guarded ladders to other plant units at all points requiring access to plant operations. Provide access to the top of truck bodies by a platform or other suitable device to allow the Engineer to obtain samples and mixture temperature data. Provide a hoist or pulley system to raise scale calibration equipment, sampling equipment, and other similar equipment from the ground to the mixer platform and return. Guard and protect all gears, pulleys, chains, sprockets, and other dangerous moving parts. Provide ample and unobstructed space on the mixing platform. Maintain a clear and unobstructed passage at all times in and around the truck loading area. Keep this area free of drippings from the mixing platform.

10. **Field Laboratory.** Provide a Type B field laboratory as specified in **106.06**.

11. **Surge and Storage Systems.** The Contractor may use surge and storage systems if the Department approves each system before use, and if the systems are designed to limit differences between material discharged from the bin or silo and material discharged directly from the plant.

    Equip the surge bins and storage silos with low and high mix level indicators. Place the low level indicator at a location on the bin or silo that has been predetermined to prevent segregation of the mix.

    Arrange the conveyor system used with the surge bins or storage silos so that samples of the mix or dry material may be conveniently taken.

    Ensure that storage silos are closed, insulated, and heated so as to prevent localized heating. The storage silo shall be capable of being sealed to prevent oxidation of the mixture. Equip surge bins with a rain cover capable of preventing water from entering the mix in the bin.

    The Engineer will base approval of a surge or storage system on inspection and tests that indicate that the system is capable of conveying, retaining, and delivering the bituminous mixture:

    a. Within the tolerance ranges as set forth on the JMF;

b. Without segregation; and

c. Without balling or hardening.

The Engineer may withdraw approval of a surge or storage system if tests, inspections, or both indicate that the system is having a detrimental effect on the bituminous mixture.

The Engineer will reject bituminous mix found to be damaged in any way by the use of a surge or storage system.

Mount, under the loading hopper, platform truck scales that meet the requirements of **109** and that are capable of recording tare and gross weights.

12. Warm Mix Asphalt Process Equipment. The Contractor may modify plants to reduce production and placement temperatures as specified in **407.11.B**. Obtain the Department's approval before making plant modifications for warm mix asphalt production temperatures. Modifications shall not impair the plant's ability to maintain temperature control or mixture proportions.

Ensure that modifications made to the plant to reduce mixing temperatures meet the requirements listed for warm mix asphalt additives in the Department's Qualified Products List (QPL).

B. Requirements for Batching Plants

1. Plant Scales. Provide dial scales for weighing of all aggregates and mineral filler, in the suspended weigh box. Dial scales shall be of a standard make and of sufficient size to allow the numerals on the dial to be read at a distance of 25 feet. The dials shall be of the compounding type having a full complement of index pointers. The value of the graduation of scales shall be as specified in Table 407.04-1.

Table 407.04-1: Graduation of Scales

Aggregate Amount (pounds)	Scale Graduation
< 5,000	≤ 5 pounds
5,000 to 10,000	≤ 10 pounds
> 10,000	≤ 0.1% scale capacity

Do not use pointers that give excessive parallax errors. Locate dial scales to be in plain view of the operator at all times. When bituminous material is measured by weight, equip the asphalt weigh bucket with a separate dial scale with a minimum graduation not greater than 2 pounds. All dial scales shall be accurate within a tolerance of 0.5%. Eliminate vibration by setting the scales on a separate foundation, if required. Provide each installation of scales with ten standard 50-pound weights meeting the requirements of the U.S. Bureau of Standards for calibrating and testing weighing equipment. Inspect scales as often as the Engineer deems necessary to ensure their continued accuracy.

Provide an approved automatic printer system that will print the weights of the material delivered, when the system is used in conjunction with an approved automatic batching and mixing control system. Provide a weigh ticket for each load as evidence of such weights.

2. **Weigh Box or Hopper.** Provide means for accurately weighing each size of aggregate and mineral filler in a weigh box or hopper suspended on scales. The weigh box or hopper shall be of ample size to hold a full batch without hand raking or running over. The gate shall close tightly so that no material can leak into the mixer while a batch is being weighed.

3. **Bituminous Control.** Provide a bituminous material bucket of a non-tilting type. The length of the discharge opening or spray bar shall be not less than 3/4 the length of the mixer, and it shall discharge directly into the mixer. The bituminous material bucket, its discharge valve or valves, and spray bar shall be adequately heated. Steam jackets, if used, shall be efficiently drainable and all connections shall be so constructed that they will not interfere with the efficient operation of the bituminous scales. The capacity of the bituminous material bucket shall be at least 15% in excess of

the weight of bituminous material required in any batch. Provide the plant with an adequately heated, quick-acting, non-drip, charging valve located directly over the bituminous material bucket. If the bituminous material is metered, the indicator dial shall have a capacity of at least 15% in excess of the quantity of bituminous material used in a batch. The meter indicator dial shall have a scale with divisions measuring in gallons equivalent to a weight sensitivity of 0.04% of the total batch weight. The meter shall be accurate within a tolerance of 0.5%. The controls shall be capable of being locked at any dial setting and automatically resetting to that reading after the addition of bituminous material to each batch. The dial shall be in full view of the mixer operator. Automatically control the flow of bituminous material so that it will begin when the dry-mixing period is over. All of the bituminous material required for one batch shall be discharged in not more than 15 seconds after the flow has started. The size and spacing of the spray bar openings shall provide a uniform application of bituminous material the full length of the mixer. Provide the section of the bituminous line between the charging valve and the spray bar with a valve, and provide the spray bar with a valve and outlet for checking the meter when a metering device is substituted for a bituminous material bucket.

4. **Mixer.** Provide an approved twin pugmill type mixer, steam or hot oil jacketed, that is capable of producing a uniform mixture within the job mix tolerances and that is constructed to prevent leakage of its contents. Equip the mixer with a sufficient number of paddles or blades set in the "run around" order, and operate at such speed as to produce a properly and uniformly mixed batch. The depth of the material in the pugmill shall not be above the tips of the paddles. If not enclosed, equip the mixer box with a dust hood to prevent loss of dust.

   The clearance of blades from all fixed and moving parts shall not exceed 1 inch unless the maximum diameter of the aggregate in the mix exceeds 1-1/4 inches, in which case the clearance shall not exceed 1-1/2 inches.

5. **Control of Mixing Time.** Equip the mixer with an accurate time lock to control the operations of a complete mixing cycle. It shall lock the weigh box gate after the charging of the mixer until the closing of the mixer gate, at the completion of the cycle. It shall lock the bituminous material bucket throughout the dry-mixing

period and shall lock the mixer gate throughout the dry and wet-mixing periods. The dry-mixing period is defined as the time interval between the opening of the weigh box gate and the start of introduction of bituminous material. The wet-mixing period is the time interval between the start of introduction of bituminous material and the opening of the mixer gate. The control of the timing shall be flexible and capable of being set at intervals of 5 seconds or less throughout a total cycle of up to 3 minutes. As a part of the timing device, install a mechanical batch counter that is designed to register only batches that have been mixed for the full time interval. Set the time intervals in the presence of and at the direction of the Engineer, who will then lock the case covering the timing device until a change is needed in the timing periods.

6. **Operator's Platform Observation House.** Equip the plant with a scale observer's house, mounted on or near the weigh platform and situated so that the aggregate and asphalt scales, asphalt thermometer, and pyrometer are plainly visible from within the house.

   Using approved materials, soundly construct the house to have at least 45 square feet of floor space and to be air conditioned by a unit of at least 12,000 Btu. The Contractor may install all batch controls in the house. However, do not use the house for storage or purposes other than to house the batch controls, plant operator, and Department Inspector. If choosing not to move the plant controls into the house, situate it so as to provide the scale inspector with a full view of the control panel.

   If the scale-observer's house is located on the asphalt plant, provide an adequate secondary means of escape in the event of fire or explosion.

   The Department will consider the house to be part of the plant and will not directly pay for its construction and maintenance.

C. Requirements for Continuous Mixing Plants

1. **Aggregate Proportioning.** Provide the plant with means for accurately proportioning each size of aggregate. The plant shall have a feeder mounted under each compartment bin. Each compartment bin shall have an accurately controlled individual gate to form an orifice for measuring volumetrically the material

drawn from each compartment. Equip bins with adequate tell-tale devices to indicate the position of the aggregates in the bins at the lower quarter points.

The feeding orifice shall be rectangular with one dimension adjustable by positive mechanical means provided with a lock. Provide indicators for each gate to show the respective gate opening in inches.

Ensure that mineral filler can be fed into the mixer continuously and uniformly in the proportion set out in the JMF, and in a manner satisfactory to the Engineer.

2. **Weight Calibration of Aggregate Feed.** Equip the plant with an approved revolution counter that is in satisfactory working condition. Provide means to calibrate gate openings by weighing test samples. Make provisions so that materials fed out of individual orifices may be bypassed to individual test boxes. Equip the plants to handle individual test samples weighing not less than 200 pounds. Provide accurate scales to weigh such test samples.

3. **Synchronization of Aggregate Feed and Bituminous Material Feed.** Provide positive interlocking control between the flow of aggregate from the bins and the flow of bituminous material from the meter or other proportioning device. This control may be achieved using mechanical means or any other positive method satisfactory to the Engineer.

4. **Mixer.** Provide a continuous mixer of an approved twin pugmill type, which is adequately heated and capable of producing a uniform mixture within the job mix tolerances. The paddles shall be adjustable for angular position on the shafts and reversible to retard the flow of the mix. The mixer shall have a manufacturer's plate indicating the net volumetric contents of the mixer at the several heights inscribed on a permanent gauge. Provide charts showing the rate of feed of aggregate per minute for the aggregate being used. Determine the mixing time by the weight method, using the following formula (with weights determined for the job using tests conducted by the Engineer) where:

$$\text{Mixing time in seconds} = \frac{\text{Pugmill dead capacity in pounds}}{\text{Pugmill output in pounds per second}}$$

5. **Surge Hopper.** Equip the mixer with a discharge hopper with dump gates that will allow rapid and complete discharge of the mixture and of such size and design that no segregation of the mixture occurs.

6. **Platform Truck Scales.** Platform truck scales shall meet the requirements of **109**.

D. Requirements for Dryer-Drum Mixing Plants

1. **Control of Aggregate.** Stockpile and handle aggregates so as to prevent any significant amount of segregation, contamination, or degradation. Construct stockpiles as specified in **903.20**.

   Each aggregate shall have a separate feeder with a positive feed that can be easily and accurately calibrated. Provide a flow indicator and an audible warning device on each separate feeder to ensure a constant and uniform flow of aggregate from each bin onto the belt.

   Feed mineral filler, if required, into the mixer continuously and uniformly in the proportion set out in the JMF and in a manner approved by the Engineer.

2. **Synchronization of Aggregate Feed and Bituminous Material Feed.** Provide satisfactory means to allow a positive interlocking control between cold aggregate feed and asphalt. Base the control setting for the asphalt flow on the dry weight of the aggregate. Provide an acceptable method for proportioning asphalt flow as variations in aggregate flow take place. Provide a metering system to measure the flow of asphalt into the drum, and locate an approved method of checking and calibrating the metering system in the control house. Provide an automatic interlock system that will shut off the asphalt flow and the burner when the aggregate flow ceases.

3. **Temperature Control.** Provide dryer-drum mixing plants equipped with a recording pyrometer or other approved thermometric instrument sensitive to a rate of temperature change of not less than 10 °F per minute. The system shall be equipped with automatic burner controls and shall provide for temperature sensing of the bituminous mixture at discharge from the drum.

4. **Scales and Metering Systems.** Provide weights and charts for checking the accuracy of the belt scales and the bituminous metering system. The scales and meters shall be accurate within a tolerance of 0.5%.

   The belt scale that weighs the combined aggregate shall be in accordance with the National Institute of Standards and Technology Handbook 44.

5. **Sampling Devices.** Use an approved method for sampling individual cold feeds and sequential sampling of aggregate and asphalt under full scale production. The sampling device and procedures used shall be approved by the Engineer and shall not interrupt normal operation.

6. **Platform Scales.** Make certified platform scales available for checking the asphalt metering system and for weighing or checking loads of asphalt mix as specified in **109**.

7. **Silos or Surge Bins.** Provide surge bins or storage silos as specified in **407.04.A.11**. If a silo is not provided, use an approved surge bin capable of holding sufficient mix to allow the plant to operate at an efficient rate of production, and ensure the system is capable of conveying, retaining, and delivering the bituminous mixture so that it is within the JMF and without segregation. The Engineer will reject mix that is damaged in any way.

   The surge bin may include an approved weighing system. If a weighing system is included in the surge system, provide approved weights for checking the weighing system. Check the system in maximum increments of 5,000 pounds and in a minimum of 3 increments. Check the system through its entire weighing range to or above the maximum weight that is expected to be applied. The system shall be accurate within a tolerance of 0.5%.

   For surge bins that do not include a weighing system, mount platform truck scales meeting the requirements of **109** under the loading hopper.

8. **Aggregate Feed.** Proportion aggregate by feeding each size aggregate from a separate cold bin. The belt that delivers the aggregate shall have a load cell capable of registering the amount of flow from each individual bin on a readout in the control office;

alternatively, the Contractor may proportion the aggregate by a linear system based on measured RPM of each feeder belt at a constant gate opening to feed aggregate at a predetermined rate that is set in the control office and that has a readout in the control office. Ensure that the rate of feed as determined from the bin settings agrees with the load cell on the collection belt feeding the dryer within a tolerance of ±10%. If the predetermined tolerance is exceeded, an alarm shall sound, and if corrections are not made within 60 seconds, the plant shall automatically shut down. The aggregate feed system shall employ computer controlled adjustments to automatically produce mix of the correct proportions over the plant's entire range of production rates.

If the Engineer has previously calibrated and approved the plant for temporary manual operation, the plant may run for a period not to exceed 2 working days, or portions thereof, on manual should a computer breakdown occur.

9. **Electronic Data Retention.** The computer system and automatic weighing system shall include means to retain all electronic data during electrical power failures.

407.05 Hauling Equipment

Trucks used for hauling bituminous mixtures shall have tight, clean, smooth metal beds that have been thinly coated with a minimum amount of paraffin oil, hydrated-lime solution, or other approved material from the Department's QPL to prevent the mixture from adhering to the beds. Immediately after loading at the plant, cover each truck with a cover of canvas or other suitable material that is of sufficient size to protect the mixture from the weather. Allow the cover to lap down along the sides and rear of the truck bed a minimum of 6 inches, and use tie downs to secure the cover at a maximum of 5-foot spacing along the sides and rear of the truck bed. When necessary to ensure the mixture will be delivered on the road at the specified temperature, insulate truck beds and securely fasten the covers. Provide a 3/8-inch hole in the side of each truck bed for inserting a thermometer.

407.06 Bituminous Pavers and Material Transfer Devices

A. Pavers

Bituminous pavers shall be self-contained, power-propelled units provided with an activated screed, equipped to be heated, and capable of spreading and finishing courses of bituminous plant mix material in lane widths applicable to the specified typical section and thickness shown on the Plans. All paver extensions shall be full assembly extensions, including activated and heated screeds, auger extensions, auger guards, and throw-back blades to place mix beneath the auger gearbox. When augers are extended, the maximum distance from the augers to the end plate shall be 18 inches. Augers shall be within 4 feet of the end plate on trailing edge extendible screeds; however, if using bolt-on extensions, extend the augers a distance equal to the length of the bolt-on extensions. Do not use strike-off boxes, except on sections of continuously varying width. For shoulders less than 8 feet in width and similar construction, the Contractor may place materials using approved mechanical spreading equipment.

Equip the paver with a receiving hopper that has sufficient capacity for a uniform spreading operation. The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed.

The screed or strike-off assembly shall produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

Equip all asphalt paving machines with automatic grade and slope controls. Both the grade and slope controls shall be in working order at all times; however, if the automatic controls fail, the Contractor may finish the day's work using manual controls, but shall not resume work the following day until both the grade and slope controls are in first class working order.

The Engineer may allow the Contractor to pave the inside shoulder concurrently with the inside traffic lane, subject to the Engineer's approval of the price adjustment for the mix used on the shoulder and of the paving and rolling equipment. In addition, the paver shall have an articulated screed that can be adjusted to fit the pavement cross-section and a power unit capable of handling the increased loading without undue stress.

B. Material Transfer Devices (MTDs)

Provide a Material Transfer Device (MTD) capable of transferring the asphalt from the truck or trailer to the asphalt paver without coming in contact with the asphalt paver. Use a MTD when placing all asphalt mixes, including shoulder mixes, with the exception that it will not be required when placing CS mix. An exception may be allowed due to lane width or safety issues if approved by the Engineer.

The MTD shall have a minimum storage capacity of 15 tons, and shall be equipped with mixing augers in the bottom of the storage hopper that are capable of remixing or re-blending the material as the material is removed from the storage hopper. The mixing augers shall be operational and used at all times during placement of the asphalt mixes. The MTD shall have a rear discharge conveyor that swivels a minimum of 150 degrees to allow feeding the paving machine from the front, side or rear.

Insert a stationary surge hopper into the paving hopper of the paver being fed by the MTD. The stationary surge hopper shall be considered as part of the MTD and shall have sloping sides (minimum of 60 degrees from horizontal) and a minimum storage capacity of 15 tons.

Obtain the Department's approval of models and manufacturers of MTDs before using on the Project. The Department will make no direct payment for use of an MTD and will consider all cost of furnishing and operating the MTD as incidental to the work.

407.07 Rollers

Provide self-propelled rollers, of steel-wheel, pneumatic tire, and/or vibratory type, which are in good condition and capable of reversing without backlash. Operate rollers at speeds slow enough to avoid displacement of the bituminous mixture. Equip rollers with a device for moistening and cleaning the wheels as required.

The required rollers shall be on the job, inspected, and approved before the start of paving operations.

Rollers shall meet the following additional requirements:

1. The steel-wheel roller shall weigh a minimum of 8 tons and may be either a three wheel or tandem type.

2. The pneumatic tire rollers shall have a minimum contact pressure of 85 pounds per square inch. The roller shall contain two axles upon which at least seven pneumatic-tire wheels are mounted so as to ensure the rear set of tires will not track the front set. The axles shall be mounted in a rigid frame provided with a loading platform or body suitable for ballast loading. Uniformly inflate the tires. Provide the Engineer with charts or tabulations of the contact area and contact pressures for the full range of tire inflation pressures and loadings for each size of roller tire provided. In place of a pneumatic tire roller, the Contractor may substitute a combination roller (pneumatic and steel wheel combination) of the make and model approved by the Department.

3. The Contractor may use vibratory rollers if the Engineer approves the particular roller proposed for use.

When paving the inside shoulder concurrently with the inside traffic lane, provide an additional roller, having a minimum width of 4 feet to a maximum width of 1 foot wider than the inside shoulder being paved, to compact the shoulder. Do not allow either the roller(s) on the inside traffic lane or the roller on the shoulder to traverse between the inside shoulder and the inside traffic lane.

407.08 Small Tools

Provide all necessary small tools, and keep them clean and free from accumulations of bituminous materials.

CONSTRUCTION REQUIREMENTS

407.09 Weather Limitations

The Contractor may place bituminous plant mix on properly constructed and accepted subgrade or previously applied layers if:

1. The subgrade and the surface upon which the bituminous plant mix is to be placed is free of excessive moisture, and

2. The bituminous plant mix is placed according to the temperature limitations specified in Table 407.09-1 and when weather conditions otherwise allow the pavement to be properly placed, compacted, and finished.

Table 407.09-1: Temperature Limitations

Compacted Thickness	Minimum Air or Surface Temperature (°F)	
	Unmodified mixes (PG 64, 67)	Modified mixes (PG 70, 76, 82)
≤ 1.5 inches	45	55
> 1.5 inches to < 3.0 inches	40	50
≥ 3.0 inches	35	45

3. Do not place bituminous plant mix, with a compacted thickness of 1.5 inches or less, between November 30 and April 1. Do not place bituminous plant mix, with a compacted thickness greater than 1.5 inches, between December 15 and March 16. Only place 411-TL, 411-TLD, and 411-OGFC mixtures when the pavement surface temperature and the ambient air temperature are a minimum of 55 °F and rising; limit placement to the period from April 1 to November 1.

4. The Contractor may request a variance from the above required temperature and seasonal limitations to pave at lower temperatures if there is a benefit to the public. Submit such requests in writing at least one week before the anticipated need, and include a Paving and Compaction Plan for Cold Weather that meets the Department's Procedure. The plan shall identify what practices and precautions the Contractor intends to use to ensure the mixture is placed and compacted to meet the specifications. The plan shall include compaction cooling curves estimating the time available for compaction, the intended production, haul, and compaction rates, with paver and roller speeds estimated. The Contractor may consider using such practices as the addition of rollers, reduced production and paving rates, insulated truck beds, and heating the existing surface.

If the specified densities are not obtained, stop all paving operations and develop a new plan. All mixture failing to meet specifications will be subject to price adjustments or removal and replacement at no cost to the Department.

407.10 Conditioning the Existing Surface

If bituminous mixes are to be placed upon an existing concrete pavement, with or without a bituminous overlay, remove all excess bituminous material from joints and cracks. Remove sections of existing pavement that are broken and pumping under traffic. Remove pavement where blowups have occurred at joints or cracks to provide a minimum opening of 1 foot for the full width of the pavement.

If the bituminous mixture is to be placed upon an existing bituminous pavement, remove areas containing excess bitumen and failures in the existing surface and base as directed by the Engineer.

Adjust all manholes and catch basin frames, which are associated with the storm sewer system, to the finished grades of the pavement. Unless otherwise specified, make such adjustments at no additional cost to the Department. The respective Utility Owner(s) will properly adjust all utility manholes, utility valve covers, and similar structures, to the finished grades of the pavement, unless otherwise shown on the Plans.

Remove unsatisfactory subgrade material encountered when removing the existing pavement and replace with approved material. Use overlay mixture or other approved material to fill openings left by the pavement and base removal to the full depth of the existing pavement, as directed by the Engineer, and compact the material in layers not to exceed 3 inches in thickness.

Paint contact surfaces of curbing, gutters, manholes, and other structures with a thin, uniform coating of bituminous material before placing the mixture against them.

When shown on the Plans, bring existing surfaces that are warped and irregular to uniform grade and cross-section using the leveling mixture specified in **307**.

407.11 Preparing the Bituminous Material

A. Hot Mix Asphalt (HMA)

Heat the bituminous materials for hot mixes to the required mixing temperature specified in Table 407.11-1.

Table 407.11-1: Mixing Temperatures

PG Binder Grade	Minimum Temperature (°F)	Maximum Temperature (°F)
PG 64-22, PG 67-22	270	310
PG 70-22	290	330
PG 76-22	290	330
PG82-22	290	330

The temperature for Grading AS, Grading ACRL, and Grading TPB mixtures shall be between 225 and 275 °F, except when modified binders are used, and then the temperatures shall be between 250 and 310 °F. Aggregate should be coated and no visible drain down should occur in storage silos or hauling equipment.

B. Warm Mix Asphalt (WMA)

The Contractor may subject the produced mixture to reduced production and placement temperatures by adding a chemical warm mix additive meeting **921.06.B.3** or by making plant modifications as specified in **407.04.A.12.**

When using either WMA technology, the maximum mixing temperature for any grade of asphalt cement shall be no more than 300 °F. At the beginning of a day's production, the producer may produce up to five truckloads at the temperatures specified in Table 407.11-1 to pre-heat placement equipment (pavers, transfer devices) before producing WMA. Indicate the laboratory mixing and compaction temperatures on the JMF during the mix design approval process. A tolerance of ±5.0 °F for each temperature will be allowed.

During test strip construction, ensure that all plant-produced WMA exhibits the ability to meet the test requirements for tensile strength ratio (TSR), conditioned tensile strength, Marshall Stability and flow,

volumetrics, and boil test, as specified for HMA in specifications **307**, **407**, and **411**. Procedures for testing shall be in accordance with that which is defined for quality control and acceptance in **407.03.D.2.h** and **407.20.B.3**, respectively.

407.12 Preparation of Aggregates

Unless otherwise specified, dry and heat the aggregate for hot mixes so as to produce a completed mix of a uniform temperature as specified in Table 407.11-1. Adjust flames used for drying and heating to avoid damage to the aggregate and to avoid soot on the aggregate.

On all plants requiring screens, screen the hot dried aggregate into two or more fractions as specified. Convey the separated fractions into separate compartments ready for batching and mixing with bituminous material.

407.13 Mixing

Combine the dried aggregates within the mixer in the amount of each fraction of aggregates required to meet the JMF. Measure the bituminous material and introduce it into the mixer in the amount specified by the JMF.

After introducing the required amounts of aggregate and bituminous material into the mixer, mix the materials as long as necessary to obtain a complete and uniform coating of the particles and a thorough distribution of the bituminous material. The Engineer will determine wet-mixing time for each plant and for each type of aggregate used, but in no case shall the wet-mixing time be less than 25 seconds for batch type plants and 40 seconds for continuous mix plants.

The temperature of the completed mixture (determined at the time it is dumped from the mixer), made with aggregates containing absorbed moisture that causes foaming or boiling in the completed mix, shall be not less than 225 °F. The temperature of the mix when it is discharged from the mixer shall not deviate from that specified in **407.11.A**.

The Contractor may place hot-mixed bituminous mixtures in surge or storage silos if the mixture as used from the silos meets all the specification requirements for the particular mix involved.

When using surge or storage silos, as approved by the Engineer, meet the following additional requirements:

1. Provide a surge bin or storage silo system meeting **407.04.A.11**.

2. Empty the storage silos or surge bins when directed by the Engineer to check material quantities.

3. Limit hours of plant operation, whether for storage or direct shipment to the road, to reasonable working hours to allow normal inspection of plant operations.

4. Remove bituminous mixtures placed in a surge bin on the same day in which it is stored.

5. The Contractor may store bituminous mixtures of Gradings A, AS, ACRL, and B for up to 48 hours, and Gradings BM, BM2, C, CS, CW, D, E, and F for up to 96 hours, in a storage silo by complying with the following:

   (a) Add an approved silicone additive to the asphalt cement for mixes to be stored beyond the day of mixing.

   (b) Keep the stored bituminous mixture sealed at all times during storage.

   (c) Fill the storage silo to at least 90% of capacity.

6. The Inspector will take samples of the stored material following the period of storage.

7. The stored material is subject to the same temperature, segregation, and laying requirements as required for unstored plant production.

8. The Engineer will reject mixtures having excessive segregation, lumpiness, or stiffness.

9. Locate the surge bins and storage silos in a position that enables the top of the truckload to be visible to the load operator during the loading operation.

407.14 Spreading and Finishing

For Contracts requiring night work, supply sufficient lighting and equipment as specified in **712.04.H**.

Table 407.15-1: Density Requirements for ADT 1,000 or less

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	90	87
B, BM & BM2	90	87
C & CW	90	87
D	90	87
E	90	87

Table 407.15-2: Density Requirements for ADT 1,000 to 3,000

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	91	89
B, BM & BM2	91	89
C & CW	91	89
D	91	89
E	91	89

Table 407.15-3: Density Requirements for ADT 3,000 or greater

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	92	90
B, BM & BM2	92	90
C & CW	92	90
D	92	90
E	92	90

Table 407.15-4: Density Requirements for any ADT

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
Shoulder Mix (B, BM, BM2, D or E)	88	85
AS and A-CRL	None [1]	None
CS	None [1]	None
TL, TLD, and OGFC	None	None

[1] The Department will waive density requirements on Bituminous Plant Mix Base Grading ACRL, Grading AS and Bituminous Plant Mix Leveling Course, Grading CS; however, the Contractor shall use a system of compaction for roadway pavements that has been approved by the Engineer. When placing Bituminous Plant Mix Base Grading ACRL and Grading AS, the Contractor may replace the specified intermediate roller (pneumatic tire) with a steel-wheel type if irreparable damage to the pavement is occurring.

Correct base or surface course that tests below the minimum density so that the density of the area is equal to or above the minimum, at which point it can be used to determine the average density of the lot. Do not place any successive layers until the area has been corrected. As necessary to determine the classification of open graded or dense graded mixes and to measure segregation, use AASHTO T 269 or ASTM D3203.

Repair or replace defective mixture to the satisfaction of the Engineer and at no cost to the Department.

The Department will perform density testing in accordance with **407.20.B.5**.

C. Test Strips

Construct test strips for all A, B, BM, BM2, C, CW, D, and E mixes to establish rolling patterns, to calibrate nuclear gauges, to verify that the base course or surface course meets the density requirements of the specifications, and for mix design and production verification as required.

Before constructing the test strip, obtain the Engineer's approval of the underlying base or other pavement course. Compact the test strip using equipment as specified in this subsection and **407.07**.

Construct the test strip at the beginning of work on the pavement course. Prepare new test strips when:

1. A change in the JMF is necessary;

2. A change in the source of materials occurs;

3. A change in the material from the same source is observed;

4. There is reason to believe that the test strip density is not representative of the bituminous mixture being placed; and when

5. A change in paving or compaction equipment occurs.

With the approval of the Engineer, the Contractor may construct additional test strips.

Construct each test strip with approved bituminous mixture. The test strip shall remain in place as a section of the completed work. Construct each test strip to be 1 paver width wide, with an area of at least 400 square yards and of the depth specified for the pavement course concerned.

Immediately after placing the bituminous mixture, begin compacting the test strip. Perform compaction in a continuous and uniform manner over the entire test strip.

Continue compacting the test strip until additional roller coverage will produce no appreciable increase in density (1 pound per cubic foot), as measured using a nuclear gauge. Use the roller coverage necessary to obtain this maximum density as the rolling pattern for the remainder of the project.

Take cores on the test strip at ten randomly selected locations as designated by the Engineer. Do not take cores within 2 feet of the longitudinal edges for calibration. Provide these cores to the Department for use in calibrating the nuclear gauge and to verify that

the average density of the test strip meets the density requirements of the specifications. The Department will report all densities using the corrected nuclear gauge readings. Correction factors are specific to the nuclear gauges used during the test strip construction. If a different nuclear gauge needs to be used for acceptance, it will be necessary to cut new cores from the ongoing pavement construction to calibrate the new gauge.

When testing test strip cores, the Department will determine density (bulk specific gravity) in accordance with AASHTO T 166, Method A only. All core samples shall be completely dry before testing. Air drying is permitted provided core samples are weighed at 2-hour intervals until dry in accordance with AASHTO T166, Section 6.1. Cores may also be dried in accordance with ASTM D7227.

If the density of the asphaltic concrete in the test strip does not meet specification requirements, make whatever changes are necessary to obtain the specified density. Use other sources and combinations of aggregates as necessary, subject to the Engineer's approval, to produce a mix meeting the required density.

407.16 Joints

Place bituminous paving as continuously as possible. Do not pass rollers over the unprotected end of a freshly laid mixture unless approved by the Engineer. Form transverse joints by cutting back on the previous run to expose the full depth of the course. Use a brush or sprayed coat of bituminous material on contact surfaces of longitudinal and transverse joints just before placing additional mixture against the previously rolled material.

407.17 Pavement Samples

When directed, cut samples from the compacted pavement for testing by the Engineer. Take samples of the mixture for the full depth of the course at locations selected by the Engineer. Cut the samples with a power saw or core drill. Samples shall have a top surface area of at least 10 inches.

Fill holes left by taking samples with the same type mixture that was used to construct the course sampled, and compact to conform to the surrounding pavement. Cut samples and repair sample holes at no cost to the Department.

407.18 Surface Requirements

Test the surface with a 12-foot straightedge applied parallel to the centerline of the pavement. The deviation of the surface from the testing edge of the straightedge shall not exceed that specified for the respective types of bituminous construction under the applicable Subsections of these Specifications.

Test the transverse slopes of tilted pavements with a string-line and string-level applied at right angles to the centerline of the pavement. The percent of slope, when computed for the full width of the pavement, shall not deviate more than 0.5 percentage points from that shown on the Plans.

Test the crown in crowned pavements with a string-line applied at right angles to the centerline of the pavement. The crown shall not deviate more than 1/2 inch from that shown on the Plans.

Correct deviations that exceed the specified tolerances. Remove and replace pavement that cannot be corrected to comply with the specified tolerances at no cost to the Department.

COMPENSATION

407.19 Method of Measurement

The Department will measure:

1. Asphalt cement and mineral aggregate, including mineral filler when required, by the ton and as follows:

    a. If the mix is loaded from a storage or surge bin, the Department will determine quantities by weighing the completed mix on truck scales meeting **109** and calculating the weight of asphalt cement and mineral aggregate based on the percentages measured into the mix by the appropriate scales or meters as specified in **407.04**.

    b. If the mix is loaded directly into the hauling equipment from a batch plant, the Department will measure asphalt cement and mineral aggregate in batch quantities by scales or scales and meters as specified in **407.04.B.**

c. If a continuous mix plant is used, the Department will measure Bituminous Material for Bituminous Plant Mix Pavement by the ton in accordance with **109**. The Department will determine quantities of mineral aggregate, including mineral filler when required, by weighing the bituminous pavement mixture on truck scales meeting **109**, and deducting the weight of the bituminous material from the weight of total mixture accepted.

d. If recycled mix is permitted, the Department will measure the completed mix, including new mineral aggregate, planings, asphalt cement, and additive, by the ton in accordance with **109**.

2. Removal and disposal of existing surface (concrete) by the square yards in accordance with **109,** if such work is required as specified in **407.10**. Such measurement will include the removal of bituminous overlay.

3. Removal and Disposal of Existing Surface (Bituminous) by the square yards in accordance with **109**. Such measurement shall include the removal of base material, except concrete, as directed by the Engineer.

4. Removal of unsatisfactory subgrade material where existing pavement has been removed by the cubic yard, in accordance with **203.09**. The Department will measure material used to replace such undercutting in accordance with the specification for the type of material used.

5. Adjustment of catch basin grates and frames, water valve boxes, gas valve boxes and manhole covers and frames by each when required.

6. Liquid anti-strip additive by the gallon.

7. Hydrated lime by the ton.

The Department will measure bituminous mixtures used to fill openings left by pavement removal as specified in this Subsection **407.19**. The Department will measure base materials used to fill openings left by base removal as provided for in the respective Sections for each type specified.

The Department will not measure chemical additives or modifiers, when required, for payment, but will consider them incidental to asphalt cement.

The Department will not measure mineral filler separately for payment, but will consider it incidental to mineral aggregates.

407.20 Basis of Payment

A. General

The Department will pay for accepted quantities of Asphaltic Concrete (Hot Mix) with or without recycled material, at the contract prices, complete in place, as follows:

Item	*Pay Unit*
Bituminous Plant Mix Base (Hot Mix)	Ton
Aggregate	Ton
Asphalt Cement	Ton

The Department will pay for liquid anti-strip additive and hydrated lime anti-strip additive based on certified invoices of material cost not to exceed $15 per gallon and $90 per ton, respectively. This payment is full compensation for all labor, materials, equipment, and other incidentals incurred in using the anti-strip additive.

The Department will pay for accepted quantities of Prime Coat or Tack Coat as specified in **402** or **403**, respectively.

The Department will pay for the work required to prepare the subgrade, sub-base, base, or surface in accordance with **307.06** and **411.06** as provided for in the applicable Section or Subsection under which the work is performed.

The Department will not make direct payment for polymer or latex additives, but will consider such additives to be included in the price bid for the modified asphalt cement or modified mixture.

B. Acceptance of the Mixture

1. **General.** The Department will perform all necessary sampling and testing for acceptance purposes in strict conformance with the Department's Policies in addition to monitoring and observing the

Contractor's quality control test procedures and results. However, the Engineer will reject for use in the work any load or loads of mixture which, in the Engineer's opinion, are unacceptable due to excessive segregation, improper coating of aggregates, or excessively high or low temperature.

The Engineer will accept bituminous mixture at the plant with respect to gradation and asphalt content, on a lot basis. A standard size lot at the asphalt plant will consist of a day's production. The number of sublots in a lot will vary from n=1 to n=4 according to Table 407.20-1.

Table 407.20-1: Sublot Requirements

Quantity (tons)	Number of Sublots
3001 – 4000	4 tests
2001 – 3000	3 tests
1001 – 2000	2 tests
Less than 1000	1 test

When the total plan quantity of any mix is less than 500 tons, the Department will accept the mix on the basis of visual inspection and Contractor Quality Control certification. The Department may run extraction, gradation analysis, or other tests deemed necessary for acceptance purposes.

2. Defective Materials

a. Acceptance or Rejection. Consider the Engineer's decision to be final as to the acceptance, rejection, or acceptance at an adjusted payment of the lots.

It is the intent of these specifications that each lot of material will meet specification requirements at the time of acceptance testing. The Department will not take check samples for acceptance purposes.

All acceptance samples will be split, and half of the sample will be retained by the Inspector. If the results of an acceptance test are questioned, the Central Laboratory will test the remaining half of the acceptance sample. The Department

will use the results obtained by the Central Laboratory to evaluate the quality of the lot.

b. Disposition of Lots. Remove and replace, at no cost to the Department, nonconforming lots of materials, products, or complete construction that cannot be corrected by reworking. Alternatively, the Department may accept the nonconforming work at an adjusted payment as specified in these Specifications or as directed by the Engineer.

When a deficiency is determined, the Department will apply the applicable payment as specified in these Specifications to the entire lot. When multiple deficiencies occur, the Department will apply the applicable partial payments to the lot of material that is identified by each deficiency. The Department will apply the payment adjustment for each deficiency separately so as not to affect any other payment adjustment occurring for the same lot; however, if there are two or more deficiencies in the gradation acceptance tests, the Department will apply only the greater payment adjustment. When an area or linear measurement is used to specify lot size, the Department will determine the equivalent tons of mix placed in each lot by using the average calculated spread from the plant inspector's daily report for that day's production.

3. Acceptance. The Engineer will base acceptance of the mixture on test results of consecutive random samples taken from each lot. One random sample will be taken from each sublot. The bituminous mixture will be sampled at the plant according to AASHTO T 168. The percent bitumen content of the mixture will be determined according to AASHTO T 164 or by AASHTO T 308 except as herein revised.

The Contractor may use an approved ignition furnace instead of a vacuum extractor for the use in determining asphalt content and gradation. The method of calibration and test procedures shall comply with AASHTO T 308 Method A and the following.

At least once per week, per mixture, during production, check the AASHTO T 308 correction factors with a sample of the aggregate mixture proportions, blended at the optimum asphalt content. Adjust the correction factor accordingly. Keep records of all correction factors for all mixtures. Adjusted payment for asphalt

content and gradation will be based on the ignition furnace results as specified in Table 407.20-2. Use of this alternative equipment shall be at no additional cost to the Department.

The percents passing the sieves will be determined in accordance with AASHTO T 30.

Table 407.20-2: Acceptance Schedule of Payment (Asphalt Plant Mix Characteristics)

Characteristics	Pay Factor	Average Arithmetic Deviation of the Lot Acceptance Test from the JMF	
		1 Test	2 Tests or more
Asphalt Cement Content [1] (Extraction or ignition oven)	1.00	0.00-0.30	0.00-0.25
	0.95	0.31-0.35	0.26-0.30
	0.90	0.36-0.40	0.31-0.35
	0.80 [2]	over 0.40	over 0.35
Gradation 3/8 inch sieve and larger	1.00	0.00-6.50	0.00-5.70
	0.95	6.51-7.08	5.71-6.20
	0.90	7.09-7.66	6.21-6.69
	0.80 [2]	over 7.66	over 6.69
Gradation No. 4 sieve [3]	1.00	0.00-4.62	0.00-4.00
	(0.95	4.63-5.20	4.01-4.50
	0.90	5.21-5.77	4.51-5.00
	0.80 [2]	over 5.77	over 5.00

Characteristics	Pay Factor	Average Arithmetic Deviation of the Lot Acceptance Test from the JMF	
		1 Test	2 Tests or more
Gradation No. 8, 16, 30 & 50 sieves [3]	1.00	0.00-3.80	0.00-3.30
	0.95	3.81-4.46	3.31-3.91
	0.90	4.47-5.12	3.92-4.52
	0.80 [2]	over 5.12	over 4.52
Gradation No. 100 & 200 sieves [3]	1.00	0.00-1.80	0.00-1.60
	0.95	1.81-2.00	1.61-1.75
	0.90	2.01-2.20	1.76-1.90
	0.80 [2]	over 2.20	over 1.90

[1] Does not apply to 307 Grading A, AS, or ACRL mixes.

[2] If approved by the Engineer, the Contractor may accept the indicated partial pay. The Department may require removal and replacement at no cost. The Contractor may remove and replace at no cost to the Department at any time.

[3] When there is more than one reduced payment relating to gradation in 1 lot of material, only the greatest reduction in payment will be applied. Reductions applicable for any other reason will be cumulative.

Deduction for both asphalt content and gradation deficiencies will be cumulative. The Department will apply deductions to the total price of the mix (asphalt cement and aggregate combined) under the item for Asphalt Cement Content and Gradation Deduction.

4. **Additional Tests.** The Engineer may perform any test at any time to determine the effectiveness of the Contractor's quality control. In addition, the Department will conduct production verification tests parallel to that which is defined for quality control in **407.03.D.2.h**.

5. **Acceptance for Mix Density on the Roadway.** The Department will apply a deduction in payment, not as a penalty but as liquidated damages, for failure to meet the density requirements specified in **407.15**. As soon as practicable after the final rolling is completed on each lot, the Department will perform 5 density tests at locations determined by the Engineer, and will compute an average of all such tests. Deductions for failure to meet density requirements will be computed to the nearest 0.1% as a percentage

of the total payment otherwise due for each lot. The percent of total payment to be deducted will be 5 times the percent the average in-place density for each lot that fails to meet **407.15**. The Department will make deductions in monies due the Contractor for failure to meet the density requirements under the item for Density Deduction. The Department will conduct acceptance testing for density in accordance with ASTM D2950 unless otherwise specified. The Department inspector will be a certified Asphalt Roadway Technician.

For density testing purposes, the Department will divide the pavement into lots of 10,000 square yards, except for 307 Gradings A, B, BM, and BM2, which will be divided into lots of approximately 5,000 square yards. Five density tests will be performed in each lot and the average results compared with the requirements specified in Tables **407.15-1** to **407.15-4**. At the beginning of a project or at any time it is deemed advisable, the Department may consider smaller lots to evaluate compaction methods or for other reasons as approved or directed by the Engineer.

The Department will randomly select acceptance test samples that are representative of the lot or sublot. Although performing compaction after the acceptance test is acceptable, the Department will use the original test result to determine lot density. The Department may take information only samples to spot check compaction, but will not use these tests for acceptance testing.

C. Adjustments

1. **Asphalt Cement Adjustment.** If the Engineer sets an asphalt content other than that specified in Tables **307.09-1** and **411.09-1**, the Department will calculate a price adjustment, based on the asphalt content set by the Engineer and the Monthly Bituminous Index for the specific grade asphalt on the mix design, according to the following formula:

$$PA = \frac{MBI \times (DA - BA) \times T}{100}$$

Where:

PA = Price Adjustment

MBI	=	Monthly Bituminous Index
DA	=	Percent asphalt set on the mix design
BA	=	Percent asphalt specified above to be used for bidding
T	=	Total tons asphalt mix for price adjustment

2. **Specific Gravity.** In cases where the effective combined specific gravity of the mineral aggregate exceeds 2.80, the Department will adjust the tonnage of mineral aggregate, or plant produced mixture, for payment by multiplying the tonnage of mineral aggregate, or plant produced mixture, used by a specific gravity of 2.80 and dividing by the higher specific gravity.

3. **Loss on Ignition (LOI).** If the approved JMF includes a surface mixture of limestone with gravel, granite, slag, quartzite or gneiss, perform tests for the percent LOI of the limestone aggregate in the asphalt paving mix as specified in **407.03.E.3**.

   If the percent of LOI in the aggregate differs by more than ±2% from the LOI indicated in the JMF, the Department will make a payment deduction in the price bid for the mix, not as a penalty but as liquidated damages. The percent of total payment to be deducted will be 5 times the percent that the LOI exceeds the JMF tolerance of ±2%.

   Replace or overlay all mix produced with aggregate tested and found to have a LOI that differs more than ±6% from the LOI indicated in the JMF at no additional cost to the Department.

   To determine the deduction, the Department will use lots of approximately 5,000 square yards. The Department inspector will perform sampling and testing to establish the LOI according to the Department's sampling and testing procedures. If the initial tests indicate a variation in the LOI of greater than ±2% than the value shown on the mix design, the Contractor shall perform the additional sampling necessary to establish the LOI of the aggregate in each lot, with the cost of the sampling being included in the contract unit prices bid for the paving items.

   The Department will make deductions for excess variation in LOI under the item for Material Variation (Deduction).

SECTION 411 – ASPHALTIC CONCRETE SURFACE (HOT MIX)

DESCRIPTION

411.01 Description

This work consists of constructing an asphaltic concrete pavement, composed of a mixture of coarse aggregate, fine aggregate, mineral filler if specified or required, and asphalt cement, on a prepared roadbed at the rate of application shown on the Plans or established by the Engineer.

The provisions of **407** shall apply to this work unless otherwise stipulated.

MATERIALS

411.02 Materials

Provide materials as specified in:

Mineral Aggregate **903.11**
Mineral Filler **903.16**
Asphalt Cement, PG 64-22, 70-22, 76-22 or 82-22 ..... **904.01**
Chemical Additive **921.06.B**

The Engineer will accept mineral aggregate, bituminous material, and plant mix in accordance with **407.02**.

411.03 Composition of Mixtures

A. General

Composition of mixtures shall be as specified in **407.03**.

B. Proportioning

Combine the specified mineral aggregate and asphalt cement according to the proportions specified in Table 411.03-1.

Table 411.03-1: Proportions of Total Mixture, Percent by Weight

Surface Course	Effective Combined Mineral Aggregate	Asphalt Cement
Grading D	93.0 - 94.3	5.7 - 7.0 (1)
Grading E (2)	93.0 - 94.3	5.7 - 7.0 (1)
Grading E (shoulders)	92.0 - 94.7	6.0 - 6.5 (1)
Grading TL	92.5 - 94.3	5.7 - 7.5 (1)
Grading TLD	93.0 - 94.3	5.7 - 7.0 (1)
Grading OGFC	92.0 - 94.0	6.0 - 8.0 (1)

(1) If the effective combined specific gravity of the aggregate exceeds 2.80, the above proportions may be adjusted as directed by the Engineer. The upper limit for flow values shall not apply to mixes with modified asphalt liquids.

(2) The minimum allowable asphalt cement content for 411E low volume mixtures is 5.3%.

1. **Grading D.** In addition to the other requirements of these Specifications, the composition of the mineral aggregate shall be such that when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-2.

Table 411.03-2: Mixture Properties (All Roads)

Mix[1]	Stability, Min. lb-ft [2]	Flow 0.01 inch [3]	Design Void Content % [2]	Production Void Content % [2]	VMA, Min. % [2]	Dust-Asphalt Ratio [4]
411D	2,000	8 – 16	4.0 ± 0.2	3 - 5.5	14	0.6 - 1.2

(1) In order to identify critical mixes and make appropriate adjustments, the mix design shall have these required production properties for the bitumen content range of Optimum Asphalt Cement ±0.25%.

(2) Tested in accordance with AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

(3) Flow will only be required when using a non-modified binder (PG 64-22 or 67-22).

(4) The dust to asphalt ratio is the percent of the total aggregate sample that passes the No. 200 sieve, as determined by AASHTO T 11, divided by the percent asphalt in the total mix.

2. Grading E. In addition to the other requirements of these Specifications, if using Grading E for the riding surface, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-3.

Table 411.03-3: Mixture Properties (High vs. Low Volume Roads)

Mix	Traffic Volume	Stability Minimum lb-ft [1, 3]	Flow 0.01 inch [2]	Design Void Content % [1]	Production Void Content % [1]	VMA, Min % [1]
411E	High Volume (ADT > 1,000)	2,000	8 - 16	4.0 ± 0.2	3 - 5.5	14
411E	Low Volume (ADT ≤ 1,000)	1,500	8 - 16	3.5 ± 0.5	2 - 5	n/a

[1] Tested according to AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

[2] Flow will only be required when using a non-modified binder (PG 64-22 or 67-22)

[3] Minimum stability for shoulder mixes will be 1,500 lb-ft and optimum asphalt cement content for shoulder mixes shall be as directed by the Regional Materials Supervisor.

If the design criteria specified above cannot be obtained with the aggregate submitted to the laboratory for design, provide another source of aggregate.

3. Gradings TL and TLD. In addition to the other requirements of these specifications, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-4.

Table 411.03-4: Mixture Properties (Gradings TL and TLD)

Mix	Stability, Min lb-ft [1]	Design Void Content % [1]	Production Void Content % [1]	Minimum VMA % [1]	Dust-Asphalt Ratio [2]
411TL	2,000	4.0 ± 0.2	3 - 5.5	16	1.0 - 2.0
411TLD	2,000	3.8 ± 0.3	3 - 5.5	14	0.6 - 1.2

[1] Tested according to AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

[2] The dust to asphalt ratio is the percent of the total aggregate sample that passes the No. 200 sieve, as determined by AASHTO T 11, divided by the percent asphalt in the total mix.

4. Grading OGFC. In addition to the other requirements of these specifications, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-5.

Table 411.03-5: Mixture Properties (Grading OGFC)

Mix	Minimum Void Content %	Voids in Coarse Aggregate % [1]	Max. Cantabro Abrasion Loss (Non-Aged) % [1]	Drain Down Loss % [2]
411OGFC	20	$VCA_{DRC} > VCA_{MIX}$	20	<0.3%

[1] As described in National Asphalt Pavement Association (NAPA) Publication IS-115, "Design, Construction and Maintenance of Open-Graded Friction Courses"

[2] Tested in accordance with AASHTO T 305.

C. Recycled Asphalt Pavement and Recycled Asphalt Shingles

1. Recycled Asphalt Pavement. The Contractor may use asphalt pavement that has been removed from a Department project or other State Highway Agency project by an approved method and stored in a Department approved stockpile. RAP combined with the appropriate aggregate, asphalt cement, and anti-strip additive

when required shall produce a mixture that will otherwise meet all the requirements specified in **903.11** and this Section **411**. The Contractor may use RAP in each mix specified in Table 411.03-6.

Table 411.03-6: Use of Recycled Asphalt Pavement

Mix Type	% RAP (Non-processed) (1)	Maximum % RAP (Processed) (2)	Maximum % RAP Processed and Fractionated (3)	Maximum Particle Size (inch)
411D (PG64-22, PG67-22)	0	15	20	1/2
411D (PG70-22, PG76-22, PG82-22)	0	10	15	1/2
411E (Roadway)	0	15	20	1/2
411E (Shoulder)	15	30	35	1/2
411TL (PG64-22, PG67-22)	0	15	15	5/16
411TL (PG70-22, PG76-22, PG82-22)	0	10	10	5/16
411TLD (PG64-22, PG67-22)	0	15	15	5/16
411TLD (PG70-22, PG76-22, PG82-22)	0	10	10	5/16

(1) "Non-processed" refers to RAP that has not been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that listed above prior to entering the dryer drum.

(2) "Processed" refers to RAP that has been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that

Mix Type	% RAP (Non-processed) (1)	Maximum % RAP (Processed) (2)	Maximum % RAP Processed and Fractionated (3)	Maximum Particle Size (inch)

above prior to entering the dryer drum.

(3) "Fractionated" refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes (e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

All mixes shall contain at least 80% virgin asphalt, except for 411E Shoulder Mix which shall have at least 65% virgin asphalt.

Obtain a representative sample from the recycled material stockpile and establish a gradation and asphalt cement content as required. Determine the gradation and asphalt content of the recycled material at the beginning of a project and every 2,000 tons thereafter. The stockpile asphalt cement content for all recycled material shall not vary from the JMF by more than ± 0.8%. Table 411.03-7 specifies the stockpile gradation tolerance for all recycled material on each sieve.

Table 411.03-7: Stockpile Gradation Tolerances for Recycled Material

Size	Tolerance
3/8 inch sieve and larger	± 10%
No. 4 sieve	± 8%
No. 8 sieve	± 6%
No. 30 sieve	± 5%
No. 200 sieve	± 4%

The Contractor is responsible for its own sampling and testing of the RAP as well as new materials for bid purposes, and for submitting the JMF as specified in **407.03**. After mixing, the moisture content of the total mix shall be no more than 0.1% as

determined by oven drying, and the provisions for lowering the temperature because of boiling or foaming shall not apply.

The Engineer will accept mixture for aggregate gradation and asphalt content based on extractions in accordance with AASHTO T 164 or in accordance with AASHTO T 308.

2. **Recycled Asphalt Shingles (RAS).** Recycled Asphalt Shingles (RAS) may be included to a maximum of 5% of the total weight of mixture. The percentage of RAS used will be considered part of the maximum allowable RAP percentage. The ratio of added new asphalt binder to total asphalt binder shall be 80% or greater for all 411 mixes. Either the mix producer or the RAS supplier shall obtain a representative sample from the recycled material stockpile and establish a gradation and asphalt cement content as required. Determine shingle asphalt binder content according to AASHTO T 164 Method A, with a minimum sample size of 500 grams. Determine the gradation and asphalt content of the recycled material at the beginning of the Project and every 2,000 tons of recycled material used thereafter. The stockpile asphalt cement content for all recycled material shall not vary by more than 0.8%. All RAS material shall be processed to a minimum 100% passing the 3/8 inch sieve and a minimum 90% passing the No. 4 sieve.

   To conduct the gradation testing, air dry a 500 to 700-gram sample of processed shingle material, dry sieve over the 3/8-inch and No. 4 sieves, and weigh. For mix design purposes, the Contractor may use the aggregate gradation specified in Table 411.03-8 as a standard gradation instead of determining the shingle gradation according to AASHTO T 30.

Table 411.03-8: Standard Gradation (for Mix Design Purposes)

Sieve Size	Total Percent Passing
3/8 inch	100
No. 4	97
No. 8	95
No. 16	80
No. 30	60
No. 50	50
No. 100	40
No. 200	30

An aggregate bulk specific gravity (G_{sb}) of 2.650 may be used instead of determining the shingle aggregate G_{sb} according to AASHTO T 84. In addition, the effective binder available for mixing with additional aggregates shall be considered as 75% of the total binder content as determined by AASHTO T 164 and shall be the value listed as the RAS binder content on the JMF.

Scrap asphalt shingle shall not contain extraneous waste materials. Extraneous materials including, but not limited to, asbestos, metals, glass, rubber, nails, soil, brick, tars, paper, wood, and plastics, shall not exceed 0.5% by weight as determined on material retained on the No. 4 sieve. To conduct deleterious material testing, take a representative 500 to 700-gram sample of processed shingle material, place over the No. 4 sieve, and pick and weigh all extraneous waste material retained on the No. 4 sieve. Base the percent of extraneous material on the total sample weight.

RAS shall contain less than the maximum percentage of asbestos fibers based on testing procedures established by the Department, or State or Federal environmental regulatory agencies. Analyze a minimum of one sample of processed asphalt roofing material for every 500 tons of material processed for the presence of asbestos.

Before a JMF for a particular design is approved, submit the following, along with the materials and information specified in **407.03**:

a. Certification by the processor of the shingle scrap describing the shingle scrap content and source.

b. A 1000-gram sample of the processed RAS material for inspection (new designs only).

Stockpile RAS separately from other salvage material. Do not blend RAS material in a stockpile with other salvage material. Do not blend Manufacture Waste Scrap Shingles (MWSS) and Tear-Off Scrap Shingles (TOSS). In addition, do not blend virgin sand material with the processed shingles, to minimize agglomeration of the shingle material.

All RAS supplied to a Department project shall come from a certified shingle processor/supplier approved by the Division of Materials and Tests.

D. Anti-Strip Additive

Check asphaltic concrete surface mixtures (Grading D and E) for stripping by the Ten Minute Boil test for dosage rate and ASTM D4867 (Root-Tunnecliff procedure) for moisture susceptibility.

If moisture susceptibility is indicated, then mix an approved anti-strip agent with the asphalt cement at the dosage recommended by the respective test and as specified in **921.06.B**.

EQUIPMENT

411.04 Equipment

Provide equipment as specified in **407.04** through **407.08**.

To construct shoulder mixes with recycled material, provide equipment that complies with **407**, except modify the asphalt plant as approved by the Engineer to accommodate the addition of asphalt planings. If using a batch plant to produce recycled mix, heat the aggregate to a temperature that will transfer sufficient heat to the cold planings to produce a mix of uniform temperature within the specified range.

CONSTRUCTION REQUIREMENTS

411.05 General Requirements

Construct the pavement as specified in **407.09**, **407.11**, **407.12**, and **407.14** through **407.17** and the following Subsections.

411.06 Preparing the Designated Surface

Prepare the designated surface upon which the material is to be placed as specified in **404.05.**

Ensure that loops used for traffic signals are installed before applying the final surface.

411.07 Mixing

Perform mixing as specified in **407.13**. In addition, the mixing cycle for surface course mixtures may require a dry-mixing period.

411.08 Surface Requirements

The surface shall meet the requirements specified in **407.18**, and when tested according to the provisions of that Subsection, the deviation of the surface from the testing edge of the straightedge shall not exceed 1/4 inch.

COMPENSATION

411.09 Method of Measurement

The Department will measure Mineral Aggregate, including Mineral Filler when required, Asphalt Cement for Asphaltic Concrete Surface (Hot Mix), and other related items in accordance with **407.19**.

For bidding purposes, use the asphalt cement content specified in Table 411.09-1.

Table 411.09-1: Asphalt Cement Content

Mix Type	Asphalt Content, %
411-D	5.9
411-E Roadway	6.3
411-E Shoulder	6.3
411-TL	6.3
411-TLD	5.9
411-OGFC	6.0

If the Engineer sets an asphalt content other than that specified above, the Department will make a price adjustment based on the asphalt content set by the Engineer and the Monthly Bituminous Index for the specific grade asphalt cement on the mix design. The Department will calculate a price adjustment in accordance with **407.20**.

411.10 Basis of Payment

The Department will pay for accepted quantities of Asphaltic Concrete Surface (Hot Mix) or asphaltic Concrete Surface (Hot Mix) (Shoulders) with or without recycled material, at the contract prices, complete in place, in accordance with **407.20**.

SECTION 903 – AGGREGATES

903.01 Fine Aggregate for Concrete

For concrete provide aggregate conforming to AASHTO M 6, with the following exceptions and additions:

903.06 Aggregate for Plant Mix Base and Leveling Courses (Hot Mix)

For plant mix base and leveling courses, provide coarse aggregate, fine aggregate, and mineral filler when required.

If at any time the sources of materials are changed, prepare and submit a new mix design as specified in **407.03**.

A. Coarse Aggregate (retained on a No. 4 sieve)

Provide crushed stone, crushed granite, crushed gravel, crushed slag, or a combination of these materials. This material shall conform to the quality requirements of ASTM D692, except that the sodium sulfate soundness loss shall not exceed 9%, and the aggregate shall contain no more than 5% soft or nondurable particles.

Crushed gravel shall consist of siliceous particles processed from washed material. At least 70% by count of the gravel retained on the No. 4 sieve shall have a minimum of two fractured faces, one of which must be fractured for the approximate average diameter or thickness of the particle. Do not add pea gravel or uncrushed particles.

For virgin coarse aggregate for Grading A, ACRL, and AS mixes, use crushed stone, crushed slag, or a combination of these materials.

The absorption of combined aggregate passing the 3/4-inch sieve and retained on the No. 4 sieve, for use in Grading CW mixes, shall not exceed 5% when tested in accordance with AASHTO T 85.

B. Fine Aggregate (passing a No. 4 sieve)

Provide limestone fines, natural sand, sand manufactured from stone, gravel, or slag, or combinations of these materials, consisting of hard, tough grains free from injurious amounts of deleterious substances. When subjected to five cycles of the sodium sulfate soundness test, the material shall have a weighted loss of not more than 12%. Do not use fine aggregate or screenings containing calcium sulfate ($CaSO_4$/gypsum) if more than 5% of the material passing the No. 8 sieve is chemically composed of sulfur trioxide (SO_3).

In natural sand or sand manufactured from gravel, the percentage of material finer than No. 200 sieve shall not exceed 5%.

For use in Grading A and AS mixes, provide virgin fine aggregate consisting of crushed stone or crushed slag only, and store the material separately from the coarse aggregate.

Ensure that the amount of deleterious substances in natural sand does not exceed the limits specified in Table 903.06-1.

Table 903.06-1: Maximum Limits for Deleterious Substances in Natural Sand

Substance	Maximum Permissible Limits, Percent by Weight
Clay Lumps	0.5
Coal and Lignite	0.5
Other deleterious substances (such as shale, alkali, mica, coated grains, soft and flaky particles) and organic impurities as determined by AASHTO T 267	3.0

C. Combined Aggregate Grading

Provide the appropriate combination of coarse aggregate and fine aggregate to achieve the combined grading. Use a minimum of three sizes of aggregate for all mix designs except for C, CS, and CW mixes, which shall be designed from a minimum of two sizes of aggregate.

Establish a gradation for each aggregate used in the mix. Table 903.06-2 specifies the stockpile gradation tolerance on each sieve for each virgin aggregate component used in the mix.

Table 903.06-2: Stockpile Gradation Tolerance

Sieve Size	Gradation Tolerance
3/8 inch sieve and larger	± 10%
No. 4 sieve	± 7%
No. 8 sieve	± 5%
No. 30 sieve	± 4%
No. 200 sieve (coarse aggregate)	± 2%
No. 200 sieve (fine aggregate)	± 4%

When the coarse aggregate portion of Grading CW mix is crushed limestone, use no less than 20% and no more than 50% by weight natural sand, or sand manufactured from slag or other approved non-skid aggregate. When the coarse aggregate portion is crushed gravel or crushed slag, between 15% and 40% by weight of the mineral aggregate shall be agricultural limestone or Size No. 10 limestone screenings.

The gradations of the coarse and fine fractions of aggregate shall be such that, when combined in proper proportions, the resultant mixture will meet one of the gradings specified in Tables 903.06-3 and 903.06-4.

Table 903.06-3: Hot Plant Mix Base Course Mixture Design Range of Gradations

Sieve Size	Total Percent Passing, by Weight			
	Grading A	Grading AS	Grading ACRL	Grading B
2 inch	100	100	100	100
1-1/2 inches	81-100	75-100	80-93	95-100
3/4 inch	50-71	55-80	60-75	70-85
3/8 inch	35-50	--	--	49-72
No. 4	24-36	7-11	12-16	34-51
No. 8	13-27	--	--	23-42
No. 30	7-17	--	--	11-22

Sieve Size	Total Percent Passing, by Weight			
	Grading A	Grading AS	Grading ACRL	Grading B
No. 50	--	--	--	9-14
No. 100	0-10	0-6	0-4	4-10
No. 200	0-4.5	0-4.5	0-3.5	2.5-6.5

Table 903.06-4: Hot Plant Mix Leveling Course Mixture Design Range of Gradations

Sieve Size	Total Per Cent Passing, by Weight				
	Grading BM	Grading BM2 (1)	Grading C	Grading CW	Grading CS
1-1/4 inch	--	100	--	--	--
1 inch	100	--	--	--	--
3/4 inch	85-100	81-93	100	100	--
3/8 inch	59-79	57-73	70-90	75-100	100
No. 4	42-61	40-56	39-66	--	89-94
No. 8	29-47	28-43	23-47	43-67	53-77
No. 30	13-27	13-25	10-27	23-47	23-42
No. 50	7-20	9-19	8-15	--	--
No. 100	4-10	6-10	4-8	4-10	9-18
No. 200	0-6.5	2.5-6.5	2.5-6.5	2.5-6.5	6-13.5

(1) When using natural sand as the fine aggregate, limit it to a maximum amount of 20% by weight of the mineral aggregate.

For asphalt treated permeable base as specified in **313**, meet the gradation requirements specified in Table 903.06-5.

Table 903.06-5: Gradation Requirements for Asphalt Treated Permeable Base

Sieve Size	Total Percent Passing by Weight
2 inch	100
1-1/2 inch	70-100
3/4 inch	55-80
No. 4	0-11
No. 100	0-4
No. 200	0-3

903.07 Reserved

903.08 Reserved

903.09 Reserved

903.10 Aggregate for Bituminous Plant Mix Surface Course (Cold Mix)

For cold bituminous plant mix, provide mix aggregate, consisting of crushed stone or crushed slag, meeting the quality requirements of ASTM D692. Crushed slag aggregate retained on the No. 4 sieve shall contain no more than 20% by weight of glassy particles.

The amount of material finer than the No. 200 sieve, as determined in accordance with AASHTO T 11, shall not exceed 1%. If all material finer than the No. 200 sieve consists of the dust of fracture, essentially free from clay or shale, this percentage may be increased to 1.5.

For leveling and surface course mixtures, provide mix aggregate meeting the gradation requirements specified in **903.22** for Size No. 68.

For key or choker aggregate, provide crushed stone, crushed slag, or crushed gravel meeting the gradation requirements specified in **903.22** for Size No. 8 and the same quality requirements as the mix aggregate.

903.11 Aggregate for Asphaltic Concrete Surface Courses (Hot Mix)

Provide aggregate, consisting of a combination of coarse and fine aggregate, and mineral filler when required or specified. Use a minimum of three sizes of aggregates for all mix designs.

If at any time the sources of materials are changed, provide a new mix design as specified in **407.03.C.2**.

A. Coarse Aggregate (retained on a No. 4 sieve)

Provide aggregate, consisting of crushed stone, crushed slag, crushed gravel, crushed granite, crushed quartzite, crushed gneiss, or combinations of these materials. The coarse aggregate shall meet the quality requirements of ASTM D692, with the following exceptions and additions:

1. Sodium sulfate soundness loss shall not exceed 9%.

2. Material retained on the No. 4 sieve shall contain a maximum of 20% elongated pieces (length greater than five times the average thickness).

3. Combined aggregate shall consist of siliceous particles processed from washed material, of which at least 70% by count of the material retained on the No. 4 sieve shall have a minimum of two fractured faces, one of which must be fractured for the approximate average diameter or thickness of the particle. Do not add pea gravel or uncrushed particles. The absorption of the crushed combined aggregate retained on the No. 4 sieve shall not exceed 5% when tested in accordance with AASHTO T 85.

4. Crushed slag coarse aggregate shall contain no more than 20% by weight of glassy particles.

B. Fine Aggregate (passing a No. 4 sieve)

Provide fine aggregate, consisting of natural sand, fines prepared from stone, slag, gravel, granite, quartzite, gneiss, or combinations of these materials. The fine aggregate shall meet the following requirements:

1. Fine aggregate shall consist of hard tough grains free from injurious amounts of clay, loam, or other deleterious substances.

2. When subjected to five cycles of sodium sulfate soundness test, the fine aggregate shall have a weighted loss of not more than 12%.

3. Manufactured sand shall have no more than 5% passing the No. 200 sieve when tested in accordance with AASHTO T 11.

4. Do not use fine aggregate or screenings containing calcium sulfate ($CaSO_4$/gypsum) if more than 5% of the material passing the No. 8 sieve is chemically composed of sulfur trioxide (SO_3).

5. Wash and grade natural sand so that not more than 5% will be retained on the No. 4 sieve.

6. For fine aggregate consisting of natural sand, the amount of material finer than a No. 200 sieve, as tested in accordance with AASHTO T 11, shall not exceed 4% by weight.

   The amount of deleterious substances in natural sand shall not exceed the limits specified in Table 903.11-1.

Table 903.11-1: Limits of Deleterious Substances in Natural Sand used in Hot Mix

Substance	Maximum Permissible Limits Percent by Weight
Clay Lumps	0.5
Coal and Lignite	0.5
Other deleterious substances (such as shale, alkali, mica, coated grains, soft and flaky particles) and organic impurities as determined by AASHTO T 267	3.0

7. When using agricultural limestone as a portion of the fine aggregate, manufacture it from sound, durable stone that is

crushed so that at least 85% will pass the No. 8 sieve and at least 50% will pass the No. 30 sieve.

C. Combined Aggregate Grading

Provide aggregate fractions sized, graded, and combined in proportions that will ensure the resulting composite blend will meet one of the gradation requirements specified in Table 903.11-2, together with the additional requirements pertaining to the constituents of the blend specified thereafter.

Establish a single value for each sieve size required in the mix for each virgin aggregate stockpile, with an allowable stockpile tolerance on each sieve as specified in Table **903.06-2**.

When using Gradings D or E for the surfacing of shoulders or for other non-traffic lane construction, the Contractor may modify the design with the Engineer's approval.

Table 903.11-2: Asphalt Concrete Surface Course Mixture Designation Design Range of Gradations

Sieve Size	Total Percent Passing by Weight				
	Grading D	Grading E	Grading TL	Grading TLD	Grading OGFC
3/4 inch	--	--	--	--	100
5/8 inch	100	100	--	--	--
1/2 inch	95-100	95-100	100	100	85-100
3/8 inch	80-93	80-93	100	90-100	55-75
No. 4	54-76	54-76	89-94	54-76	10-25
No. 8	35-57	35-57	53-77	35-57	5-10
No. 30	17-29	17-29	23-42	17-33	--
No. 50	10-18	10-18	--	10-18	--
No. 100	3-10	3-11	9-18	3-10	--
No. 200	0-6.5	0-8	6-14	4-7	2-4

1. **Grading D and TLD.** Use fine aggregate consisting of natural sand or sand manufactured from gravel, slag, or from crushed stone aggregate meeting the physical and chemical requirements specified in **903.24**. The use of carbonate rocks such as limestone and dolomite or other aggregates that tend to polish under traffic will not be permitted in the coarse aggregate and will be permitted only to the extent specified herein in the fine aggregate.

   When using limestone screenings or agricultural limestone, the maximum amount by weight of the mineral aggregate shall be 25% unless the material is shown to meet the same requirements for limestone as specified in Table **903.24-1** for Surface Mixtures. In no case shall the combined aggregate blend consist of less than 75% non-skid material. When using natural sand as fine aggregate, limit it to a maximum amount of 25% by weight of the mineral aggregate. The Contractor may substitute a maximum of 5% mineral filler meeting the requirements of **903.16** for an equal quantity of the limestone fines. If the mixture does not comply with the design criteria, provide another source of aggregate.

   When using gravel as the coarse aggregate for a 411 Grading D mix, use a minimum of 20% by weight limestone screenings, agricultural limestone, or mineral filler.

   Recycled Asphalt Pavement (RAP) milled from Department or other State Highway Agency projects shall be assumed to contain 75% non-skid material.

2. **Grading E.** When using Grading E as a surface for traffic lanes, 50% to 80% of the mineral aggregate shall be composed of crushed limestone, and the remaining 50% to 20% shall be natural sand, slag sand, sand manufactured from gravel or other approved non-skid aggregates, or any combination of these materials, with the following exceptions:

   a. The sand percentage on the Job Mix Formula (JMF) shall range from 20% to 50%. However, if needed to meet or improve the specified design criteria, the Contractor may alter the limestone and sand percentage by 5% from the percentage shown on the original JMF. If altering the aggregate percentages shown on the original JMF, submit a revision of the original design showing the altered percentages of aggregate.

b. When using Grading E for surfacing of shoulders or other non-traffic lane construction, the mineral aggregate may be composed entirely of limestone, including Size No. 10 (screenings) and manufactured sand, but in no case shall the mineral aggregate for this construction consist of less than 50% limestone.

c. Recycled Asphalt Pavement (RAP) milled from Department or other State Highway Agency projects shall be assumed to contain 75% non-skid material.

3. **Grading OGFC.** A minimum of 75% of the aggregate shall meet the requirements specified in **903.24** for Surface Mixtures (Non-Skid Aggregates). The coarse aggregate shall have at least 90% crushed aggregate with two fractured faces and 100% with one fractured face as determined in accordance with ASTM D5821. The coarse aggregate shall have a LA Abrasion value of less than 30% and a maximum absorption of 3.0%.

   Recycled Asphalt Pavement (RAP) milled from Department or other State Highway Agency projects shall be assumed to contain 75% non-skid material.

4. **Grading TL.** A minimum of 75% of the aggregate shall meet the requirements specified in **903.24** for Surface Mixtures (Non-Skid Aggregates) for the appropriate traffic level. The mixture shall contain a maximum of 15% natural sands.

   Recycled Asphalt Pavement (RAP) milled from Department or other State Highway Agency projects shall be assumed to contain 75% non-skid material.

903.12 Aggregate for Slurry Seal and Micro-Surface

A. Aggregate for Slurry Seal

A minimum of 50% of the aggregate shall be crushed slag, crushed granite, or crushed stone (crushed stone as specified in **903.24**), meeting the requirements of ASTM D692, except the gradation shall be as specified in Table 903.12-1. The aggregate shall have a minimum sand equivalent, as determined in accordance with AASHTO T 176, of 45.

Use a pug mill to mix blends of more than one aggregate source. Do not blend aggregates with a front end loader. Proportion the aggregate to produce a uniform gradation meeting the requirements specified in Table 903.12-1.

Table 903.12-1: Gradation Limits for Aggregate for Slurry Seal Based on Wash Gradation

Sieve	Design Master Range (Total Percent Passing)	Mixture Control Tolerances
3/8 inch	100	
No. 4	90-100	±6.0
No. 8	65-90	±5.0
No. 16	45-70	±5.0
No. 30	30-50	±4.0
No. 50	20-38	±4.0
No. 100	12-28	±3.0
No. 200	8-16	±3.0

B. Aggregate for Micro-Surface

A minimum of 50% of the aggregate shall be crushed slag, crushed granite, or crushed stone (crushed stone as specified in **903.24**) meeting the gradation limits specified in Table 903.12-2 and the physical properties of ASTM D692, except the percent of fractured pieces shall be 100. The aggregate shall have a minimum sand equivalent, as determined in accordance with AASHTO T 176, of 65. Polish-resistant aggregates will not be required for leveling courses, provided they will be covered with riding surface mixtures.

Use a pug mill to mix blends of more than one aggregate source. Do not blend aggregates with a front end loader. Proportion the aggregate to produce a uniform gradation meeting the requirements specified in Table 903.12-2.

Table 903.12-2: Gradation Limits for Aggregate for Micro-Surfacing Based on Wash Gradation

Sieve	Design Master Range (Total Percent Passing)	Mixture Control Tolerances
3/8 inch	100	
No. 4	70-98	±6.0
No. 8	45-70	±5.0
No. 16	28-50	±5.0
No. 30	19-34	±4.0
No. 50	12-25	±4.0
No. 100	7-18	±2.0
No. 200	4-15	±2.0

903.13 Aggregate for Bituminous Seal Coat

Provide aggregate consisting of crushed stone, crushed slag, or crushed gravel, meeting the quality requirements of ASTM D692, except that at least 50% by count of crushed gravel aggregates shall have at least one fractured face. Crushed slag aggregate retained on the No. 4 sieve shall contain no more than 20% by weight of glassy particles. Provide aggregates meeting the requirements of **903.24**.

The amount of material finer than the No. 200 sieve shall not exceed 1%. If all material finer than the No. 200 sieve consists of the dust of fracture, essentially free from clay or shale, the percentage may be increased to 1.5.

Use aggregate meeting the gradation requirements in **903.22** for the size identified on the Plans and in accordance with Table **405.06-1**.

903.14 Aggregate for Double Bituminous Surface Treatment

Provide aggregate meeting **903.13**. In the mat, use aggregate meeting the gradation requirements specified for Size No. 7 in **903.22**. In the seal, use aggregate meeting the gradation requirements specified for Size No. 8 in **903.22**. Ensure that at least 90% of the aggregate particles retained on the No. 4 sieve have one or more fractured faces fractured for the approximate average diameter or thickness of the particle.

903.15 Aggregate for Aggregate-Cement Base Course

Provide coarse aggregate, composed of sound, tough, durable fragments of crushed stone, crushed slag, crushed or uncrushed gravel, or crushed or uncrushed chert, which may be blended with crushed recycled concrete or screened reclaimed asphalt pavement (RAP), and fine aggregate composed of natural or manufactured sand, and silt-clay or other finely divided mineral matter.

Provide gravel or chert aggregate that is screened and of such gradation that 100% will pass a 1-1/2 inch sieve, not more than 75% will pass the No. 4 sieve, and not less than 5% nor more than 15% will pass the No. 200 sieve. The fraction passing the No. 40 sieve shall have liquid limit not greater than 35, and a plasticity index not greater than 10. Provide crushed stone or slag aggregate that is sized and proportioned to meet the gradation requirements specified in **903.05** for Grading D. Blend materials, if required, at the screening plant or at the stationary mixing plant.

The Contractor may use recycled concrete aggregate or reclaimed asphalt pavement (RAP), at a maximum rate of 25% by weight, provided the combined aggregate blend meets all the requirements specified above. Crush and screen the recycled concrete and/or asphalt to produce a uniform stockpile before blending it with the virgin material. Keep the recycled stockpiles free of bricks, steel, wood, and all other deleterious materials. The virgin and recycled material blend shall meet the quality requirements specified in Table **903.05-1**.

Ensure that the combined total of shale, organic material, and other unwanted substances does not exceed 5% by weight.

903.16 Mineral Filler

Provide mineral filler conforming to AASHTO M 17, except that the mineral filler shall be non-plastic.

903.17 Aggregate for Underdrains

Provide crushed stone, crushed slag, or washed gravel meeting the quality requirements of ASTM D692 and the gradation requirements specified for Size 6, 7, 8, 57, or 78 in **903.22**.

903.18 Aggregate for Sand-Asphalt Surface Course

Provide aggregate, consisting of natural sand, crushed siliceous material, or a combination of these materials, meeting the quality requirements of ASTM D1073. For natural sand, the percentage of material finer than the No. 200 sieve shall not exceed 5.

The natural sand or combination of these materials shall meet the gradation requirements specified in Table 903.18-1.

Table 903.18-1: Gradation Requirements for Aggregate for Sand-Asphalt Surface Course

Sieve Size	Total Percent Passing by Weight
No. 4	100
No. 8	95-100
No. 30	50-80
No. 50	30-60
No. 100	8-25
No. 200	2-10

903.19 Lightweight Aggregates for Structural Concrete

Provide lightweight aggregate conforming to AASHTO M 195, with the following additions:

1. Produce the lightweight aggregate by fusing raw shale, slate, or clay in a rotary kiln, to yield particles having a wear of not more than 40% when tested in accordance with AASHTO T 96.

2. The lightweight coarse aggregate shall conform to the gradation requirements for size 3/4 inch to No. 4, as shown in Table 1 of AASHTO M 195.

3. The absorption of the coarse aggregate shall not exceed 10% when tested in accordance with AASHTO T 85.

4. When the coarse aggregate is subjected to five alterations of the sodium sulfate soundness test in accordance with AASHTO T 104, the weighted percentage of loss shall not be more than 9.

5. Concrete with approximately 6% air content made from the aggregate shall have a minimum durability factor of 90% when tested in accordance with AASHTO T 161.

6. Use material listed on the Department's QPL.

903.20 Stockpiling Aggregates

Clean and grub sites for aggregate stockpiles before storing aggregates, and ensure the ground is firm, smooth, and well-drained. Maintain a cover of at least 3 inches of aggregate to prevent contamination by soil or foreign material. Build the stockpiles in layers not exceeding 4 feet in height, and have each layer completely in place before starting the next layer to prevent segregation. Deposit the material so as to prevent coning, except in the case of aggregate composed essentially of material finer than the No. 4 sieve and base material.

Do not dump, cast, or push material over the sides of stockpiles, except in the case of aggregate for base material and fine aggregate materials.

Unless otherwise approved, store aggregates from different sources or of different gradings, or that differ in specific gravity by more than 0.03, in separate stockpiles. To prevent the aggregates from mixing, either locate stockpiles of different types or sizes of aggregates far enough apart, or separate them with suitable walls or partitions.

When building stockpiles, only operate trucks or other equipment on a stockpile in a manner approved by the Engineer. Use stockpiling methods that will prevent both excessive degradation of the aggregate and contamination of the stockpile with foreign matter. The Engineer will determine excessive degradation by conducting sieve tests of samples taken from any portion of the stockpile over which equipment has operated; failure of such samples to meet all gradation requirements for the aggregate is cause for discontinuing such stockpiling procedure.

903.21 Test Methods

In stating requirements for most materials in Section **903**, reference has been made to AASHTO and ASTM Standard Specifications for materials. The current AASHTO or ASTM Standard Specification effective at the time of letting for a particular Contract shall be the governing specification. Those Specifications, in turn, include reference to the respective AASHTO and ASTM methods of sampling and testing. In a few instances, however,

properties of materials in Section **903** have been specified without reference to corresponding AASHTO and ASTM Standard Specifications. In such instances, the methods of sampling and testing specified in Table 903.21-1 will govern.

Table 903.21-1: Aggregate Sampling and Testing Methods

Test	Test Method
Unit Weight	AASHTO T 19
Percentage of Wear	AASHTO T 96
Soundness	AASHTO T 104
Liquid Limit	AASHTO T 89
Plastic Limit and Plasticity Index	AASHTO T 90
Sieve Analysis	AASHTO T 27
Hydrometer Analysis	AASHTO T 88
Material Passing No. 200 Sieve in Aggregate	AASHTO T 11
Ten Minute Boil Test	**407.03.E.2**
Resistance to Plastic Flow by Marshall Method	AASHTO T 245 (1)

(1) Use a mechanically operated hammer with a rotating base. The compaction hammer shall have a slanted, circular tamping face. The slant on the face shall be 1.6% + 0.0/-0.1.

903.22 Sizes of Coarse Aggregate

See AASHTO M 43.

Table 903.22-1: Standard Sizes of Processed Aggregate

Size	Nominal Size, Square Openings	Amounts Finer than Each Laboratory Sieve (Square Openings), Percent by Weight															
		4"	3-1/2"	3"	2-1/2"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	No.4	No.8	No.16	No.50	No.100
1	3-1/2" - 1-1/2"	100	90-100	--	25-60	--	0-15	--	0-5	--	--	--	--	--	--	--
2	2-1/2" - 1-1/2"	--	--	100	90-100	35-70	0-15	--	0-5	--	--	--	--	--	--	--
24	2-1/2" - 3/4"	--	--	100	90-100	--	25-60	--	0-10	0-5	--	--	--	--	--	--
3	2" - 1"	--	--	--	100	90-100	35-70	0-15	--	0-5	--	--	--	--	--	--
357	2" - No. 4	--	--	--	100	95-100	--	35-70	--	10-30	--	0-5	--	--	--	--
4	1-1/2" - 3/4"	--	--	--	--	100	90-100	20-55	0-15	--	0-5	--	--	--	--	--
467	1-1/2" - No. 4	--	--	--	--	100	95-100	--	35-70	--	10-30	0-5	--	--	--	--
5	1" - 1/2"	--	--	--	--	--	100	90-100	20-55	0-10	0-5	--	--	--	--	--
56	1" - 3/8"	--	--	--	--	--	100	90-100	40-85	10-40	0-15	0-5	--	--	--	--
57	1" - No. 4	--	--	--	--	--	100	95-100	--	25-60	--	0-10	0-5	--	--	--
6	3/4" - 3/8"	--	--	--	--	--	--	100	90-100	20-55	0-15	0-5	--	--	--	--
67	3/4" - No. 4	--	--	--	--	--	--	100	90-100	--	20-55	0-10	0-5	--	--	--
68	3/4" - No. 8	--	--	--	--	--	--	100	90-100	--	30-65	5-25	0-10	0-5	--	--
7	1/2" - No. 4	--	--	--	--	--	--	--	100	90-100	40-70	0-15	0-5	--	--	--
78	1/2" - No. 8	--	--	--	--	--	--	--	100	90-100	40-75	5-25	0-10	0-5	--	--
8	3/8" - No. 8	--	--	--	--	--	--	--	--	100	85-100	10-30	0-10	0-5	--	--
89	3/8" - No. 16	--	--	--	--	--	--	--	--	100	90-100	20-55	5-30	0-10	0-5	--
9	No. 4 - No. 16	--	--	--	--	--	--	--	--	--	100	85-100	10-40	0-10	0-5	--
10	No. 4 – 0 (1)	--	--	--	--	--	--	--	--	--	100	85-100	--	--	--	10-30

(1) Screenings

903.23 Reserved

903.24 Aggregates for Riding Surfaces (Polish-Resistant Aggregates)

Provide coarse aggregate consisting of crushed gravel, crushed granite, crushed slag, crushed quartzite, or crushed gneiss meeting the BPN requirements of the table below. The Contractor may use other crushed aggregate provided it has the chemical, physical, and performance characteristics specified in Table 903.24-1.

Table 903.24-1: Quality Requirements for Type I, II, III, and IV Aggregate

Aggregate Property	Test Method	Type I (all roads)	Type II (all roads)	Type III (15,000 ADT max, excluding Interstates)	Type IV (5,000 ADT max)
Silica Dioxide Content, % min	ASTM C25	40%	30%	20%	10%
Calcium Carbonate Content, % max		32%	--	--	--
Acid Insoluble Residue, % min	ASTM D3042	50%	35%	25%	--
British Pendulum Number,(1) min	AASHTO T 278 AASHTO T 279	30	30	25	22

(1) After 9 hours of accelerated polishing using the British Wheel in accordance with AASHTO T 279

In addition to the requirements specified in Table 903.24-1, Type II, III, and IV aggregates shall have met the preapproval process of the Division of Materials and Tests. All aggregate types must also maintain a satisfactory level of field performance to remain an approved source.

Process and stockpile the material as an independent and separate operation. The Engineer will sample and test each stockpile for approval prior to use.

SECTION 904 – BITUMINOUS MATERIALS

904.01 Asphalt Cements

Only obtain asphalt cement for use on Department projects from Certified Asphalt Suppliers that have an approved Quality Control Plan in accordance with the Department's Standard Operating Procedures.

Asphalt cement shall conform to AASHTO M 320 and Department procedures.

Instead of PG 64-22, the Contractor may use asphalt cement graded to PG 67-22. PG 67-22 shall conform to the requirements of AASHTO M 320 when the applicable tests are conducted at 67 °C and -12 °C, and the dynamic shear of the rolling thin film, pressure aged vessel sample is tested at 26.5 °C.

To modify the asphalt, properly blend styrene butadiene (SB), styrene butadiene styrene (SBS), or styrene butadiene rubber (SBR) to a PG 64-22 or PG 67-22 base asphalt.

In addition to the above requirements, the PG 70-22, PG 76-22, and 82-22 shall meet the requirements specified in Table 904.01-1.

Table 904.01-1: Requirements for Asphalt Cement

Property	PG 70-22	PG 76-22	PG 82-22
Ring & Ball Softening Point, degrees F, minimum	128	135	150
Elastic Recovery by means of Ductilometer, % minimum	45	65	70

A. Test Procedures

1. **Elastic Recovery by means of a Ductilometer.** Test in accordance with AASHTO T 301 at 77 °F.

2. **Screen Test.** Pour a 1,000-gram sample heated to 275 °F through a No. 10 sieve. Ensure no lumps or particles are retained on the sieve.

3. **Viscometer Test.** In addition to the above, all hot mix asphalt mix plants using modified liquid asphalt products shall have a rotational viscometer, meeting ASTM D4402 requirements, with a thermostatically controlled cell. The mix producer shall run a minimum of one test per week on samples taken from the Contractor's storage tank. Viscosity values shall be in the ranges specified in Table 904.01-2 when tested at 275 °F.

Table 904.01-2: Asphalt Cement Viscosity Requirements

Property	PG 70-22	PG 76-22	PG 82-22
Viscosity Range (centipoise)	650-3,000	1,000-3,000	2,000-4,000 (1)

(1) Store PG82-22 at proper temperatures to maintain pumpability.

B. Materials Certification

Furnish a certification to the Engineer on each project stating that the asphalt cement provided meets the Department's specification. Ensure that quality control and compliance testing are completed in accordance with the asphalt supplier's approved quality control plan and Department procedures.

Where blending or modification occurs after the material has left the storage tanks, the supplier shall conduct a complete series of tests on a sample taken on the first day's production and biweekly thereafter for each grade being produced. Brookfield viscosity and DSR original tests shall be performed daily at the point of blending or modification. The DSR value $G^*/\sin\delta$ shall be ≥ 1.0 kPa at the high PG grade temperature (i.e., 158 °F for PG 70-22).

In addition, the producer shall provide a temperature-viscosity curve with a recommended mixing temperature range. In order to develop a temperature-viscosity curve, it may be necessary to run the viscosity test at a higher temperature, based on the softening point of the modified asphalt cement.

904.02 Reserved

904.03 Emulsified Asphalts

Provide emulsified asphalts meeting the test requirements specified in Table 904.03-1.

inspected by the Cement and Concrete Reference Laboratory and approved by the Department.

B. Bituminous Additives

1. **Anti-Stripping Additive.** Use hydrated lime conforming to ASTM C977 or other heat-stable asphalt anti-stripping additive containing no ingredient harmful to the bituminous material or the workmen and that does not appreciably alter the specified characteristics of the bituminous material when added in the recommended proportions.

   When hydrated lime is the anti-stripping additive, use an amount equal to 1% by weight of the aggregate. Uniformly coat the aggregate with the lime, to the Engineer's satisfaction, before adding the bituminous material to the mixture.

   When using an anti-stripping additive other than hydrated lime, the percentage of anti-stripping additive used shall range between 0.3% to 0.5% by weight of the asphalt cement.

   The Department's QPL identifies qualified antistripping products. Do not use any product unless it appears on this list.

2. **Silicone Additives.** Mix silicone additives at the rate of 1 pint of silicone per 4 gallons of diesel fuel. The Contractor may use a 1/2 pint of this mixture per 1,000 gallons of asphalt.

3. **Warm Mix Asphalt (WMA) Additives.** The Contractor may add organic wax or foaming additives to bituminous plant mix to reduce placement temperatures as specified in **407.11**. Introduce the WMA additives into the mixture at a constant rate, sufficient to produce the mix temperatures specified in **407.11**, and in a manner approved by the Department. Record all changes to the proportions of the additive used during the course of mix production. The Department's QPL identifies qualified WMA additives. Only use additives appearing on this list.

921.07 Masonry Stone

Provide sound, dense, and durable masonry stone, free from excessive cracks, pyrite intrusions, and other structural defects. Ensure that stones

3

AASHTO/ASTM Specifications

Table of Contents

Designation: D75/D75M – 14

American Association State
Highway and Transportation
Officials Standard
AASHTO No.: T2

Standard Practice for Sampling Aggregates[1]

This standard is issued under the fixed designation D75/D75M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers sampling of coarse and fine aggregates for the following purposes:

1.1.1 Preliminary investigation of the potential source of supply,

1.1.2 Control of the product at the source of supply,

1.1.3 Control of the operations at the site of use, and

1.1.4 Acceptance or rejection of the materials.

NOTE 1—Sampling plans and acceptance and control tests vary with the type of construction in which the material is used.

1.2 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *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.*

NOTE 2—The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of Practice D3666 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3666 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of Practice D3666 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C702 Practice for Reducing Samples of Aggregate to Testing Size

D8 Terminology Relating to Materials for Roads and Pavements

D2234/D2234M Practice for Collection of a Gross Sample of Coal

D3665 Practice for Random Sampling of Construction Materials

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

E105 Practice for Probability Sampling of Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

3. Terminology

3.1 *Definitions:*

3.1.1 *maximum size of aggregate, n—in specifications for, or descriptions of aggregate*—the smallest sieve opening through which the entire amount of aggregate is required to pass.

3.1.2 *maximum aggregate size, (Superpave) n—in specifications for, or descriptions of aggregate*—one size larger than the nominal maximum aggregate size.

3.1.3 *nominal maximum aggregate size (of aggregate), n—in specifications for, or descriptions of aggregate*—the smallest sieve opening through which the entire amount of the aggregate is permitted to pass.

3.1.4 *nominal maximum aggregate size (Superpave), n—in specifications for, or descriptions of aggregate*—one size larger than the first sieve that retains more than 10 % aggregate.

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.30 on Methods of Sampling.

Current edition approved June 1, 2014. Published June 2014. Originally approved in 1920. Last previous edition approved in 2009 as D75/D75M – 09. DOI: 10.1520/D0075_D0075M-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.4.1 *Discussion*—The definitions in 3.1.1 and 3.1.2 also appear in Terminologies C125 and D8. They are presented in this standard to illustrate the differences between the aggregate definitions and Superpave definitions of similar terms. The definitions in 3.1.2 and 3.1.4 apply to hot mix asphalt (HMA) mixtures designed using the Superpave system only.

3.1.4.2 *Discussion*—Specifications on aggregates usually stipulate a sieve opening through which all of the aggregate may, but not need to, pass so that a slated maximum portion of the aggregate may be retained on that sieve. A sieve opening so designed is the *nominal maximum size*.

4. Significance and Use

4.1 Sampling is equally as important as the testing, and the sampler shall use every precaution to obtain samples that will show the nature and condition of the materials which they represent.

4.2 Samples for preliminary investigation tests are obtained by the party responsible for development of the potential source (Note 3). Samples of materials for control of the production at the source or control of the work at the site of use are obtained by the manufacturer, contractor, or other parties responsible for accomplishing the work. Samples for tests to be used in acceptance or rejection decisions by the purchaser are obtained by the purchaser or his authorized representative.

NOTE 3—The preliminary investigation and sampling of potential aggregate sources and types occupies a very important place in determining the availability and suitability of the largest single constituent entering into the construction. It influences the type of construction from the standpoint of economics and governs the necessary material control to ensure durability of the resulting structure, from the aggregate standpoint. This investigation should be done only by a responsible trained and experienced person. For more comprehensive guidance, see the Appendix.

5. Securing Samples

5.1 *General*—Where practicable, samples to be tested for quality shall be obtained from the finished product. Samples from the finished product to be tested for abrasion loss shall not be subject to further crushing or manual reduction in particle size in preparation for the abrasion test unless the size of the finished product is such that it requires further reduction for testing purposes.

5.2 *Inspection*—The material to be sampled shall be visually inspected to determine discernible variations. If any discernible variations are noted, corrective action shall be taken to establish homogeneity in the material prior to sampling. If it is necessary to indicate the degree of variability existing within the main pile, separate samples shall be drawn from separate areas of the pile. The seller shall provide suitable equipment needed for proper inspection and sampling.

5.3 *Procedure:*

5.3.1 *Sampling from a Flowing Aggregate Stream (Bins or Belt Discharge)*—Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain at least three approximately equal increments, selected at random from the unit being sampled, and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Take each increment from the entire cross section of the material as it is being discharged. It is usually necessary to have a special device constructed for use at each particular plant. This device consists of a pan of sufficient size to intercept the entire cross section of the discharge stream and hold the required quantity of material without overflowing. A set of rails may be necessary to support the pan as it is passed under the discharge stream. Insofar as is possible, keep bins continuously full or nearly full to reduce segregation.

NOTE 4—Sampling the initial discharge or the final few tons from a bin or conveyor belt increases the chances of obtaining segregated material and should be avoided.

5.3.2 *Sampling from the Conveyor Belt*—Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain at least three approximately equal increments, selected at random, from the unit being sampled and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Stop the conveyor belt while the sample increments are being obtained. Insert two templates, the shape of which conforms to the shape of the belt in the aggregate stream on the belt, and space them such that the material contained between them will yield an increment of the required weight (see Fig. 1). Carefully scoop all material between the templates into a suitable container and collect the fines on the belt with a brush and dust pan and add to the container.

NOTE 5—Automatic belt samplers may be used as long as they are properly maintained, and regular inspection ensures all material is being removed from the belt (see Fig. 2).

5.3.3 *Sampling from Stockpiles*—Avoid sampling coarse aggregate or mixed coarse and fine aggregate from stockpiles whenever possible, particularly when the sampling is done for the purpose of determining aggregate properties that may be dependent upon the grading of the sample. If circumstances make it necessary to obtain samples from a stockpile of coarse aggregate or a stockpile of combined coarse and fine aggregate, design a sampling plan for the specific case under consideration to ensure that segregation does not introduce a bias in the results. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained therefrom that is agreed upon by all parties concerned to be

FIG. 1 Belt Sampling Template

FIG. 2 Automatic Belt Sampler

acceptable for the particular situation. The sampling plan shall define the number of samples necessary to represent lots and sublots of specific sizes. The sampling plan shall also define any specialized site-specific sampling techniques or procedures that are required to ensure unbiased samples for existing conditions. The owner and supplier shall agree upon the use of any specialized site-specific techniques or procedures. When site-specific techniques or procedures are developed for sampling a stockpile, those procedures shall supersede the procedures given in 5.3.3.1. (Note 6). General principles for sampling from stockpiles are applicable to sampling from trucks, rail cars, barges, or other transportation units.

NOTE 6—Specific site sampling plans may include the number of sampling increments (loader buckets) required to construct the sampling pad.

5.3.3.1 *Sampling from Stockpiles with Power Equipment (preferred)*—In sampling material from stockpiles it is very difficult to ensure unbiased samples due to the segregation which often occurs when material is stockpiled, with coarser particles rolling to the outside base of the pile. For coarse or mixed coarse and fine aggregate, every effort shall be made to enlist the services of power equipment to develop a separate small sampling pile.

(1) When obtaining a sample from a stockpile for acceptance testing, a loader shall enter the stockpile nearest the area representing material that is currently being shipped or loaded into a production facility, with the bucket approximately 150 mm [6 in.] above ground level, never allowing the front tires of the loader to ramp up on the pile. Without backing up, the loader shall lift the full bucket of material then tilt the bucket down to gently roll the material out of the bucket back onto the pile, thus re-blending any segregated material on the outside surface of the pile. If prior visual inspection noted discernible variation, or if the loader is not of sufficient size to cause a cascading effect down the face of the pile during this remixing process, several buckets of material shall either be remixed or removed and discarded to prevent use of potentially injurious material.

(2) After re-blending, the loader shall re-enter the stockpile, as before, and obtain a full loader bucket of the re-blended material, tilt back and lift the bucket only high enough to back up slightly.

(3) At the base of the main stockpile with the bucket only high enough to permit free-flow of the material from the bucket, the loader operator shall tilt the bucket forward to gently roll the material out of the bucket forming a small sampling pile. If the loader bucket is not of sufficient size to create a sample pad of representative size, multiple buckets shall be used, dumped on top of each other and back-dragged to form a single sample pad.

(4) At this point the loader operator shall raise the bucket, drive forward far enough to reach across the small pile with the loader bucket without allowing the loader tires to ramp up on the sampling pile, lower the bucket to about half the height of the small pile, and backup, therefore creating a flat surface for sampling (see Fig. 3). The loader shall only back-drag the small pile once. This flat surface provides a stable and safe area to obtain a representative sample.

(5) Place the sample bucket(s) near the center of the flat, oval-shaped sampling pad. The sample shall be obtained across the entire flat area, but avoid sampling within 0.3 m [1 ft] of the sample pad edge. Divide the sample pad into 4 quadrants and sample equal amounts of materials evenly across each quadrant. Fully insert the shovel as near vertical as possible then gently roll the shovel back and lift slowly to avoid coarse material rolling off the sides of the shovel (Note 7). Obtain additional shovelfuls from different quadrants of the sampling pad, and in areas that avoid previous “shovel holes.”

NOTE 7—Square-tip shovels with the outer edges rolled up approximately 50 mm [2 in.] on each side works well in preventing material from rolling from the side. Spade-tip shovels are not recommended.

5.3.3.2 *Sampling from Stockpiles Without Power Equipment:*

NOTE 8—Sampling coarse aggregate and coarse and fine mixed aggregate stockpiles without the aid of power equipment is not advised.

(1) Where power equipment is not available, samples from stockpiles shall be made up of at least three increments taken from the top third, at the mid-point, and bottom third of the elevation of the stockpile.

(2) Shove a board vertically into the pile just above the sampling point to prevent coarser material from rolling down and further segregating the material and biasing the sample. The board shall be of ample size to prevent material from cascading down into the sampling area.

(3) With the board in place, scrape off the outer most surface of the pile with the shovel, then insert the shovel perpendicular to the angle of the pile, into the freshly exposed material to obtain the sample. Repeat this process across the face of the stockpile until the recommended minimum field sample size in 5.4.2 is obtained but no less than the three increments described in 5.3.3.2*(1)*.

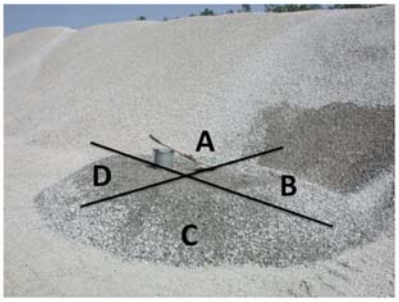
5.3.3.3 *Sampling Fine Aggregate from Stockpiles (Alternative Method for Fine Aggregate Only)*—When sampling fine aggregate from a stockpile, the outer layer, which easily becomes segregated by wind and rain during stockpile storage, shall be removed and the sample taken from the material beneath.

Step 1. Loader enters stockpile with bucket approximately 150mm [6 in.] above ground level

Step 3. Loader reaches across the small pile, lowers bucket, and back-drags small pile to form the sampling pad

Step 2. Loader gently rolls the material out of the bucket to form a small pile

Step 4. Sampling pad



Step 5. Draw sample portions from each quadrant

FIG. 3 Five-Step Photographic Sequence of Constructing Sampling Pad From Stockpile of Aggregate

(1) Sampling tubes approximately 30 mm [1.25 in.] minimum by 2 m [6 ft.] in length shall be inserted into the shipping face of the stockpile horizontally at random locations.

NOTE 9—A sampling tube can be constructed of aluminum, PVC, or other sturdy material. The tip being inserted into the pile can be cut at a 45° angle to ease insertion.

(2) Sample shall be taken at a minimum height of 3 ft from the surrounding grade.

(3) A minimum of five tube insertions randomly spaced across the face of the stockpile shall form a single field sample (see Fig. 4). Ensure that the minimum field sample size recommended in 5.4.2 is obtained.

5.3.4 *Sampling from Transportation Units*—Avoid sampling coarse aggregate or mixed coarse and fine aggregate from transportation units whenever possible, particularly when the sampling is done for the purpose of determining aggregate properties that may be dependent upon the grading of the sample. If circumstances make it necessary to obtain samples from a transportation unit, design a sampling plan for the specific case under consideration to ensure that segregation does not introduce a bias in the results. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained therefrom that is agreed upon by all parties concerned to be acceptable for the particular situation. The sampling plan shall define the number of samples necessary to represent lots and sublots of specific sizes. General principles for sampling from stockpiles are applicable to sampling from trucks, rail cars, barges, or other transportation units.

NOTE 10—Sampling from transportation units should be avoided if at all possible. In sampling material from transportation units it is very difficult to ensure unbiased samples, due to the segregation which often occurs when material is transported, with coarser particles rolling to the outside and finer particles settling.

5.3.4.1 In sampling coarse aggregates from railroad cars or barges, effort shall be made to enlist the services of power equipment capable of exposing the material at various levels and random locations.

5.3.4.2 Where power equipment is not available, a common procedure requires excavation of three or more trenches using a shovel across the unit at points that will, from visual appearance, give a reasonable estimate of the characteristics of the load. The trench bottom shall be approximately level, at least 0.3 m [1 ft] in width and in depth below the surface.

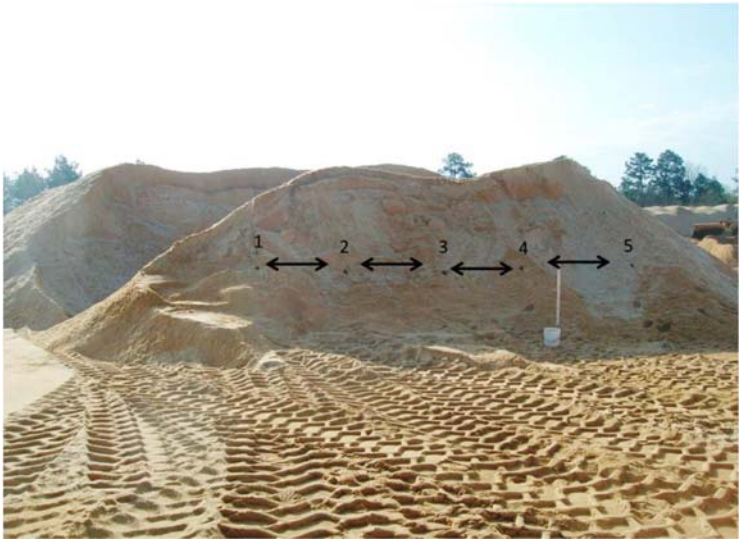


FIG. 4 Sampling Fine Aggregate from Stockpile Using Sampling Tube

5.3.4.3 A minimum of three increments from approximately equally spaced points along each trench shall be taken by pushing a shovel downward into the material.

5.3.4.4 Coarse aggregate in trucks shall be sampled in essentially the same manner as for rail cars or barges, except for adjusting the number of increments according to the size of the truck.

5.3.4.5 For fine aggregate in transportation units, sampling tubes as described in 5.3.3.3, except inserted vertically, may be used to extract an appropriate number of increments from the trenches to form the field sample.

5.3.5 *Sampling from Roadway (Bases and Subbases):*

5.3.5.1 Sample units selected by a random method, such as Practice D3665, from the construction.

5.3.5.2 Obtain at least three approximately equal increments, selected at random from the unit being sampled, after the material has been placed and prior to compaction, and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Take all increments from the roadway for the full depth of the material, taking care to exclude any underlying material. Clearly mark the specific areas from which each sample increment is to be removed.

5.3.5.3 A metal template placed over the area will aid in securing approximately equal increment weights. Place the template on top of the material to be sampled. Sample material from the center of the template. As material is extracted from the center of the template, the template is continuously lowered to prevent the material outside of the template from falling into the sample hole. The template shall be composed of metal or other sturdy material, no less than 0.3 m [12 in.] in diameter and 0.25 m [9 in.] in height, providing a sampling area not less than 0.07 m^2 [110 $in.^2$] (see Fig. 5).

5.4 *Number and Masses of Field Samples:*

5.4.1 The number of field samples (obtained by one of the methods described in 5.3) required depends on the criticality of, and variation in, the properties to be measured. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples from the production shall be sufficient to give the desired confidence in test results.

NOTE 11—Guidance for determining the number of samples required to obtain the desired level of confidence in test results may be found in Test Method D2234/D2234M, Practice E105, Practice E122, and Practice E141.

FIG. 5 Proper Use of Metal Template For Sampling Mixed Coarse and Fine Aggregate From Roadway Grade

TABLE 1 Minimum Size of Field Samples

Aggregate Size[A]	Field Sample Mass, min, kg[B] [lb]	Field Sample Volume, min, L [gal]
Fine Aggregate		
2.36 mm [No. 8]	10 [22]	8 [2]
4.75 mm [No. 4]	10 [22]	8 [2]
Coarse Aggregate		
9.5 mm [⅜ in.]	10 [22]	8 [2]
12.5 mm [½ in.]	15 [35]	12 [3]
19.0 mm [¾ in.]	25 [55]	20 [5]
25.0 mm [1 in.]	50 [110]	40 [10]
37.5 mm [1½ in.]	75 [165]	60 [15]
50 mm [2 in.]	100 [220]	80 [21]
63 mm [2½ in.]	125 [275]	100 [26]
75 mm [3 in.]	150 [330]	120 [32]
90 mm [3½ in.]	175 [385]	140 [37]

[A] For processed aggregates, use the nominal maximum size as indicated by the appropriate specification or description. If the specification or description does not indicate a nominal maximum size (for example, a sieve size indicating 90 to 100 % passing), use the maximum size (that sieve indicating 100 % passing).
[B] For combined coarse and fine aggregates (for example, base or subbase aggregate), the minimum weight shall be coarse aggregate minimum mass plus 10 kg.

5.4.2 The field sample masses cited are tentative. The masses must be predicated on the type and number of tests to which the material is to be subjected and sufficient material obtained to provide for the proper execution of these tests. Standard acceptance and control tests are covered by ASTM standards and specify the portion of the field sample required for each specific test. Generally speaking, the amounts specified in Table 1 will provide adequate material for routine grading and quality analysis. Extract test portions from the field sample according to Practice C702 or as required by other applicable test methods.

6. Shipping Samples

6.1 Transport aggregates in bags or other containers so constructed as to preclude loss or contamination of any part of the sample, or damage to the contents from mishandling during shipment.

6.2 Shipping containers for aggregate samples shall have suitable individual identification attached and enclosed so that field reporting, laboratory logging, and test reporting may be facilitated.

7. Keywords

7.1 aggregates; exploration of potential sources; number and sizes needed to estimate character; sampling

APPENDIXES

(Nonmandatory Information)

X1. EXPLORATION OF POTENTIAL AGGREGATE SOURCES

X1.1 Scope

X1.1.1 Sampling for evaluation of potential aggregate sources should be performed by a responsible trained and experienced person. Because of the wide variety of conditions under which sampling may have to be done it is not possible to describe detailed procedures applicable to all circumstances. This appendix is intended to provide general guidance and list more comprehensive references.

X1.2 Sampling Stone from Quarries or Ledges

X1.2.1 *Inspection*—The ledge or quarry face should be inspected to determine discernible variations or strata. Differences in color and structure should be recorded.

X1.2.2 *Sampling and Size of Sample*—Separate samples having a mass of at least 25 kg [55 lbs] should be obtained from each discernible stratum. The sample should not include material weathered to such an extent that it is no longer suitable for the purpose intended. One or more pieces in each sample should be at least 150 by 150 by 100 mm [6 in. by 6 in. by 4 in.] in size with the bedding plane plainly marked, and this piece should be free of seams or fractures.

X1.2.3 *Record*—In addition to the general information accompanying all samples the following information should accompany samples taken from ledges or quarry faces:

X1.2.3.1 Approximate quantity available. (If quantity is very large this may be recorded as practically unlimited.)

X1.2.3.2 Quantity and character of overburden.

X1.2.3.3 A detailed record showing boundaries and location of material represented by each sample.

NOTE X1.1—A sketch, plan, and elevation, showing the thickness and

location of the different layers is recommended for this purpose.

X1.3 Sampling Roadside or Bank Run Sand and Gravel Deposits

X1.3.1 *Inspection*—Potential sources of bank run sand and gravel may include previously worked pits from which there is an exposed face or potential deposits discovered through air-photo interpretation, geophysical exploration, or other types of terrain investigation.

X1.3.2 *Sampling*—Samples should be so chosen from each different stratum in the deposit discernible to the sampler. An estimate of the quantity of the different materials should be made. If the deposit is worked as an open-face bank or pit, samples should be taken by channeling the face vertically, bottom to top, so as to represent the materials proposed for use. Overburdened or disturbed material should not be included in the sample. Test holes should be excavated or drilled at numerous locations in the deposit to determine the quality of the material and the extent of the deposit beyond the exposed face, if any. The number and depth of test holes will depend upon the quantity of the material needed, topography of the area, nature of the deposit, character of the material, and potential value of the material in the deposit. If visual inspection indicates that there is considerable variation in the material, individual samples should be selected from the material in each well defined stratum. Each sample should be thoroughly mixed and quartered if necessary so that the field sample thus obtained will be at least 12 kg [25 lbs] for sand and 35 kg [75 lbs] if the deposit contains an appreciable amount of coarse aggregate.

X1.3.3 *Record*—In addition to the general information accompanying all samples the following information should accompany samples of bank run sand and gravel:

X1.3.3.1 Location of supply.

X1.3.3.2 Estimate of approximate quantity available.

X1.3.3.3 Quantity and character of overburden.

X1.3.3.4 Length of haul to proposed site of work.

X1.3.3.5 Character of haul (kind of road, maximum grades, and so forth)

X1.3.3.6 Details as to extent and location of material represented by each sample.

NOTE X1.2—A sketch of plans and elevations, showing the thickness and location of different layers, is recommended for this purpose.

X2. NUMBER AND SIZE OF INCREMENTS NEEDED TO ESTIMATE CHARACTER OF UNIT SAMPLED

X2.1 Scope

X2.1.1 This appendix presents the rationale used by the responsible committee in the development of this practice.

X2.2 Descriptions of Terms Specific to This Standard

X2.2.1 *field sample*—a quantity of the material of sufficient size to provide an acceptable estimate of the average quality of a unit.

X2.2.2 *lot*—a sizable isolated quantity of bulk material from a single source, assumed to have been produced by the same process (for example, a day's production or a specific mass or volume).

X2.2.3 *test portion*—a quantity of the material to be tested of sufficient size extracted from the larger field sample by a procedure designed to ensure accurate representation of the field sample, and thus of the unit sampled.

X2.2.4 *unit*—a batch or finite subdivision of a lot of bulk material (for example, a truck load or a specific area covered).

X2.3 Test Unit, Size, and Variability

X2.3.1 The unit to be represented by a single field sample should neither be so large as to mask the effects of significant variability within the unit nor be so small as to be affected by the inherent variability between small portions of any bulk material.

X2.3.2 A unit of bulk material composed of graded aggregate or aggregate mixtures might consist of a full truckload. If it were possible, the entire load might be tested; as a practical matter, a field sample is composed of three or more increments chosen at random from the material as it is loaded or unloaded from the truck. Research has shown that such a procedure permits an acceptable estimate to be made of the average gradation that might be measured from 15 or 20 increments from the truck.

X2.3.3 Significant variability with a lot of material, where it might exist, should be indicated by statistical measures, such as the standard deviation between units selected at random from within the lot.

Standard Method of Test for

Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO Designation: T 11-05 (2013)[1]
ASTM Designation: C117-13

AASHTO
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

Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO Designation: T 11-05 (2013)[1]
ASTM Designation: C117-13

AASHTO

1. SCOPE

1.1. This test method covers determination of the amount of material finer than a 75-µm (No. 200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during the test.

1.2. Two procedures are included, one using only water for the washing operation, and the other including a wetting agent to assist the loosening of the material finer than the 75-µm (No. 200) sieve from the coarser material. Unless otherwise specified, Procedure A (water only) shall be used.

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 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 27, Sieve Analysis of Fine and Coarse Aggregates
- T 248, Reducing Samples of Aggregate to Testing Size

2.2. *ASTM Standards*:

- C117, Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. SUMMARY OF METHOD

3.1. A sample of the aggregate is washed in a prescribed manner, using either plain water or water containing a wetting agent, as specified. The decanted wash water, containing suspended and

dissolved material, is passed through a 75-µm (No. 200) sieve. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-µm (No. 200) sieve by washing.

4. SIGNIFICANCE AND USE

4.1. Material finer than the 75-µm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than 75 µm in fine or coarse aggregate are desired, this test method is used on the sample prior to dry sieving in accordance with T 27. The results of this test method are included in the calculation in T 27, and the total amount of material finer than 75 µm by washing, plus that obtained by dry sieving the same sample, is reported with the results of T 27. Usually the additional amount of material finer than 75 µm obtained in the dry-sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked. A large amount of material could also be an indication of the degradation of the aggregate.

4.2. Plain water is adequate to separate the material finer than 75 µm from the coarser material with most aggregates. In some cases, the finer material is adhering to the larger particles, such as some clay coatings and coatings on aggregates that have been extracted from bituminous mixtures. In these cases, the fine material will be separated more readily with a wetting agent in the water.

5. APPARATUS AND MATERIALS

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. *Sieves*—A nest of two sieves, the lower being a 75-µm (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16), both conforming to the requirement of M 92.

5.3. *Container*—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.

5.4. *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

5.5. *Wetting Agent*—Any dispersing agent, such as liquid dishwashing detergents, that will promote separation of the fine materials.

Note 1—The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

6. SAMPLING

6.1. Sample the aggregate in accordance with T 2. If the same test sample is to be tested for sieve analysis according to T 27, comply with the applicable requirements of that method.

6.2. Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the applicable methods described in T 248. If the same test sample is to be tested according to T 27, the minimum mass shall be as described in the applicable sections of that method. Otherwise, the mass of the test sample, after drying, shall conform with the following:

Nominal Maximum Size	Minimum Mass, g
4.75 mm (No. 4) or smaller	300
9.5 mm ($^3/_8$ in.)	1000
19.0 mm ($^3/_4$ in.)	2500
37.5 mm ($1^1/_2$ in.) or larger	5000

The test sample shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted. If the nominal maximum size of the aggregate to be tested is not listed above, the next larger size listed shall be used to determine sample size.

7. SELECTION OF PROCEDURE

7.1. Procedure A shall be used, unless otherwise specified by the specification with which the test results are to be compared, or when directed by the agency for which the work is performed.

8. PROCEDURE A—WASHING WITH PLAIN WATER

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine the mass to the nearest 0.1 percent of the mass of the test sample.

8.2. If the applicable specification requires that the amount passing the 75-μm (No. 200) sieve shall be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing the designated sieve to 0.1 percent of the mass of this portion of the test sample. Use this mass as the original dry mass of the test sample in Section 10.1.

Note 2—Some specifications for aggregates with a nominal maximum size of 50 mm or greater, for example, provide a limit for material passing the 75-μm (No. 200) sieve determined on that portion of the sample passing the 25.0-mm sieve. Such procedures are necessary because it is impractical to wash samples of the size required when the same test sample is to be used for sieve analysis by T 27.

8.3. After drying and determining the mass, place the test sample in the container and add sufficient water to cover it. No detergent, dispersing agent, or other substance shall be added to the water. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-μm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

8.4. Add a second charge of water to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

Note 3—If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

Note 4—A spray nozzle or a piece of rubber tubing attached to a water faucet may be used to rinse any of the material that may have fallen onto the sieves. The velocity of water, which may be increased by pinching the tubing or by use of a nozzle, should not be sufficient to cause any splashing of the sample over the sides of the sieve.

8.5. Return all material retained on the nested sieves by flushing to the washed sample. Dry the washed aggregate to constant mass at a temperature of 110 ± 5°C (230 ± 9°F) and determine the mass to the nearest 0.1 percent of the original mass of the sample.

Note 5—Following the washing of the sample and flushing any materials retained on the 75-µm (No. 200) sieve back into the container, no water should be decanted from the container except through the 75-µm sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.

9. PROCEDURE B—WASHING USING A WETTING AGENT

9.1. Prepare the sample in the same manner as for Procedure A.

9.2. After drying and determining the mass, place the test sample in the container. Add sufficient water to cover the sample, and add wetting agent to the water (Note 6). Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

Note 6—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

9.3. Add a second charge of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

9.4. Complete the test as for Procedure A.

10. CALCULATION

10.1. Calculate the amount of material passing a 75-µm (No. 200) sieve by washing as follows:

$$A = \left[\left(B - C \right) / B \right] \times 100 \qquad (1)$$

where:

A = percentage of material finer than a 75-µm (No. 200) sieve by washing;
B = original dry mass of sample, g; and
C = dry mass of sample after washing, g.

11. REPORT

11.1. Report the percentage of material finer than the 75-µm (No. 200) sieve by washing to the nearest 0.1 percent, except if the result is 10 percent or more, report the percentage to the nearest whole number.

11.2. Include a statement as to which procedure was used.

12. PRECISION AND BIAS

12.1. *Precision*—The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and ASTM C117. The significant differences between the methods at the time the data were acquired is that T 11 required, and ASTM C117 prohibited, the use of a

wetting agent. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

Table 1—Precision

	Standard Deviation (1s),[a] %	Acceptable Range of Two Results (d2s),[a] %
Coarse aggregate:[b]		
Single-operator precision	0.10	0.28
Multilaboratory precision	0.22	0.62
Fine aggregate:[c]		
Single-operator precision	0.15	0.43
Multilaboratory precision	0.29	0.82

[a] These numbers represent the (1s) and (d2s) limits as described in ASTM C670.

[b] Precision estimates are based on aggregates having a nominal maximum size of 19.0 mm (3/4 in.) with less than 1.5 percent finer than the 75-µm (No. 200) sieve.

[c] Precision estimates are based on fine aggregates having 1.0 to 3.0 percent finer than the 75-µm (No. 200) sieve.

12.1.1. The precision values for fine aggregate in Table 1 are based on nominal 500-g test samples. Revision of this test method in 1996 permits the fine aggregate test sample size to 300-g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 2, which indicates only minor differences due to test sample size.

Table 2—Precision Data for 300-g and 500-g Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	No. Labs	Avg	1s	d2s	1s	d2s
AASHTO T 11/ASTM C117 (Total material passing the	500 g	270	1.23	0.08	0.24	0.23	0.66
No. 200 sieve by washing, %)	300 g	264	1.20	0.10	0.29	0.24	0.68

Note 7—The values for fine aggregate in Table 1 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

12.2. *Bias*—Because there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is made.

13. KEYWORDS

13.1. Aggregate; size analysis; wash loss; 75-µm (No. 200) sieve.

[1] Except for Sections 5.1 and 6.2, and Note 4, this test method is identical with ASTM C117-13.

Standard Method of Test for

Sieve Analysis of Fine and Coarse Aggregates

AASHTO Designation: T 27-14[1]
ASTM Designation: C136-06

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

Sieve Analysis of Fine and Coarse Aggregates

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ASTM Designation: C136-06

AASHTO

1. SCOPE

1.1. This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2. Some specifications for aggregates, which reference this method, contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

1.3. The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only.

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 the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory regulations 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 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T 248, Reducing Samples of Aggregate to Testing Size

2.2. *ASTM Standards*:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI10, American National Standard for Metric Practice

3. TERMINOLOGY

3.1. *Definitions*—For definitions of terms used in this standard, refer to ASTM C125.

4. SUMMARY OF METHOD

4.1. A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. SIGNIFICANCE AND USE

5.1. This method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2. Accurate determination of material finer than the 75-μm (No. 200) sieve cannot be achieved by use of this method alone. Test Method T 11 for material finer than the 75-μm (No. 200) sieve by washing should be employed.

6. APPARATUS

6.1. *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.

6.2. *Sieves*—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of M 92. Nonstandard sieve frames shall conform to the requirements of M 92 as applicable.

Note 1—It is recommended that sieves mounted in frames larger than standard 203.2 mm (8 in.) diameter be used for testing coarse aggregate to reduce the possibility of overloading the sieves. See Section 8.3.

6.3. *Mechanical Sieve Shaker*—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in Section 8.4 is met in a reasonable time period.

Note 2—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg (44 lb) or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples because the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a smaller sample of coarse aggregate or fine aggregate.

6.4. *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

7. SAMPLING

7.1. Sample the aggregate in accordance with T 2. The mass of the field sample shall be the mass shown in T 2 or four times the mass required in Sections 7.4 and 7.5 (except as modified in Section 7.6), whichever is greater.

7.2. Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in T 248. The sample for test shall be the approximate mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted.

Note 3—Where sieve analysis, including determination of material finer than the 75-µm (No. 200) sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3. *Fine Aggregate*—The size of the test sample of aggregate, after drying, shall be 300 g minimum.

7.4. *Coarse Aggregate*—The mass of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size Square Openings, mm (in.)	Minimum Mass of Test Sample, kg (lb)
9.5 ($^3/_8$)	1 (2)
12.5 ($^1/_2$)	2 (4)
19.0 ($^3/_4$)	5 (11)
25.0 (1)	10 (22)
37.5 ($1^1/_2$)	15 (33)
50 (2)	20 (44)
63 ($2^1/_2$)	35 (77)
75 (3)	60 (130)
90 ($3^1/_2$)	100 (220)
100 (4)	150 (330)
125 (5)	300 (660)

7.5. *Coarse and Fine Aggregates Mixtures*—The mass of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in Section 7.4.

7.6. *Samples of Large-Size Coarse Aggregate*—The size of sample required for aggregate with 50-mm (2-in.) nominal maximum size or larger is such as to preclude convenient sample reduction and testing as a unit except with large mechanical splitters and sieve shakers. As an option when such equipment is not available, instead of combining and mixing sample increments and then reducing the field sample to testing size, conduct the sieve analysis on a number of approximately equal sample increments such that the total mass tested conforms to the requirements of Section 7.4.

7.7. In the event that the amount of material finer than the 75-µm (No. 200) sieve is to be determined by T 11, use the procedure described in Section 7.7.1 or 7.7.2, whichever is applicable.

7.7.1. For aggregates with a nominal maximum size of 12.5 mm ($^1/_2$ in.) or less, use the same test sample for testing by T 11 and this method. First test the sample in accordance with T 11 through the final drying operation, then dry sieve the sample as stipulated in Sections 8.2 through 8.6 of this method.

7.7.2. For aggregates with a nominal maximum size greater than 12.5 mm ($^1/_2$ in.), a single test sample may be used as described in Section 7.7.1 or separate test samples may be used for T 11 and this method.

7.7.3. Where the specification requires determination of the total amount of material finer than the 75-µm (No. 200) sieve by washing and dry sieving, use the procedure described in Section 7.7.1.

8. PROCEDURE

8.1. If the test sample has not been subjected to testing by T 11, dry it to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine and record the mass of material that will be placed on the sieves to the accuracy of the balance as defined in Section 6.1.

Note 4—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless (1) the nominal maximum size is smaller than about 12.5 mm ($^1/_2$ in.), (2) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4), or (3) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperature associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2. Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Use additional sieves as desired or necessary to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample, or portion of the sample if it is to be sieved in more than one increment, on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 8.4.

8.3. Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75-mm (No. 4), the quantity retained on any sieve at the completion of the sieving operation shall not exceed 7 kg/m^2 (4 g/in.^{2}) of sieving surface area (Note 5). For sieves with openings 4.75 mm (No. 4) and larger, the quantity retained in kg shall not exceed the product of 2.5 × (sieve opening, mm × (effective sieving area, m^2)). This quantity is shown in Table 1 for five sieve-frame dimensions in common use. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.

8.3.1. Prevent an overload of material on an individual sieve by one or a combination of the following methods:

8.3.1.1. Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve in the original set of sieves.

8.3.1.2. Split the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.

8.3.1.3. Use sieves having a larger frame size and providing greater sieving area.

Note 5—The 7 kg/m^2 amounts to 200 g for the usual 203.2-mm (8-in.) diameter sieve (with effective sieving surface diameter of 190.5 mm (7.5 in.)).

8.3.1.4. In the case of coarse and fine aggregate mixtures, the portion of the sample finer than the 4.75-mm (No. 4) sieve may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

8.3.1.5. Alternatively, the portion finer than the 4.75-mm (No. 4) sieve may be reduced in size using a mechanical splitter according to T 248. If this procedure is followed, compute the mass of each size increment of the original sample as follows:

$$A = \frac{W_1}{W_2} \times B \qquad (1)$$

where:

A = mass of size increment on total sample basis,
W_1 = mass of fraction finer than 4.75-mm (No. 4) sieve in total sample,
W_2 = mass of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved, and
B = mass of size increment in reduced portion sieved.

Table 1—Maximum Allowable Quantity of Material Retained on a Sieve, kg

Sieve Opening Size	Nominal Dimensions of Sieve[a]				
	203.2-mm, dia[b]	254-mm, dia[b]	304.8-mm, dia[b]	350 by 350, mm	372 by 580, mm
	Sieving Area, m^2				
	0.0285	0.0457	0.0670	0.1225	0.2158
125 mm (5 in.)	[c]	[c]	[c]	[c]	67.4
100 mm (4 in.)	[c]	[c]	[c]	30.6	53.9
90 mm (3 1/2 in.)	[c]	[c]	15.1	27.6	48.5
75 mm (3 in.)	[c]	8.6	12.6	23.0	40.5
63 mm (2 1/2 in.)	[c]	7.2	10.6	19.3	34.0
50 mm (2 in.)	3.6	5.7	8.4	15.3	27.0
37.5 mm (1 1/2 in.)	2.7	4.3	6.3	11.5	20.2
25.0 mm (1 in.)	1.8	2.9	4.2	7.7	13.5
19.0 mm (3/4 in.)	1.4	2.2	3.2	5.8	10.2
12.5 mm (1/2 in.)	0.89	1.4	2.1	3.8	6.7
9.5 mm (3/8 in.)	0.67	1.1	1.6	2.9	5.1
4.75 mm (No. 4)	0.33	0.54	0.80	1.5	2.6

[a] Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter; 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

[b] The sieve area for round sieves is based on an effective diameter 12.7 mm (1/2 in.) less than the nominal frame diameter, because M 92 permits the sealer between the sieve cloth and the frame to extend 6.35 mm (1/4 in.) over the sieve cloth. Thus the effective sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm (7.5 in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm (1/4 in.).

[c] Sieves indicated have less than five full openings and should not be used for sieve testing.

8.4. Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike 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, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203.2-mm (8-in.) diameter sieves to verify the sufficiency of sieving.

8.5. Unless a mechanical sieve shaker is used, hand sieve particles obtained on the 75 mm (3 in.) by determining the smallest sieve opening through which each particle will pass by rotating the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

8.6. Determine the mass of each size increment on a scale or balance conforming to the requirements specified in Section 6.1 to the nearest 0.1 percent of the total original dry sample mass. The total mass of the material after sieving should check closely with the total original dry mass of the sample placed on the sieves. If the two amounts differ by more than 0.3 percent, based on the total original dry sample mass, the results should not be used for acceptance purposes.

9. CALCULATION

9.1. Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 percent on the basis of the total mass of the initial dry sample. If the same test sample was first tested by T 11, include the mass of material finer than 75-µm (No. 200) sieve by washing in the sieve analysis calculation; and use the total dry sample mass prior to washing in T 11 as the basis for calculating all the percentages.

9.1.1. When sample increments are tested as provided in Section 7.6, total the masses of the portion of the increments retained on each sieve, and use these masses to calculate the percentage as in Section 9.1.

9.2. Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100; 150 µm (No. 100), 300 µm (No. 50), 600 µm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm ($^3/_8$ in.), 19.0 mm ($^3/_4$ in.), 37.5 mm ($1^1/_2$ in.), and larger, increasing the ratio of 2 to 1.

10. REPORT

10.1. *Depending upon the form of the specifications for use of the material under test, the report shall include one of the following*:

10.1.1. Total percentage of material passing each sieve, or

10.1.2. Total percentage of material retained on each sieve, or

10.1.3. Percentage of material retained between consecutive sieves.

10.2. Report percentages to the nearest whole number, except if the percentage passing the 75-µm (No. 200) sieve is less than 10 percent, it shall be reported to the nearest 0.1 percent.

10.3. Report the fineness modulus, when required, to the nearest 0.01.

11. PRECISION AND BIAS

11.1. *Precision*—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by T 27 and ASTM C136. The data are based on the analyses of the test results from 65 to 233 laboratories that tested 18 pairs of coarse aggregate proficiency test samples and test results from 74 to 222 laboratories that tested 17 pairs of fine aggregate proficiency test samples (Samples No. 21 through 90). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

Table 2—Estimates of Precision

	Total Percentage of Material Passing		Standard Deviation (1s), %[a]	Acceptable Range of Two Results (d2s), %[a]
Coarse Aggregate:[b]	100	≥95	0.32	0.9
Single-operator precision	<95	≥85	0.81	2.3
	<85	≥80	1.34	3.8
	<80	≥60	2.25	6.4
	<60	≥20	1.32	3.7
	<20	≥15	0.95	2.7
	<15	≥10	1.00	2.8
	<10	≥5	0.75	2.1
	<5	≥2	0.53	1.5
	<2	0	0.27	0.8
Multilaboratory precision	100	≥95	0.35	1.0
	<95	≥85	1.37	3.9
	<85	≥80	1.92	5.4
	<80	≥60	2.82	8.0
	<60	≥20	1.97	5.6
	<20	≥15	1.60	4.5
	<15	≥10	1.48	4.2
	<10	≥5	1.22	3.4
	<5	≥2	1.04	3.0
	<2	0	0.45	1.3
Fine Aggregate:				
Single-operator precision	100	≥95	0.26	0.7
	<95	≥60	0.55	1.6
	<60	≥20	0.83	2.4
	<20	≥15	0.54	1.5
	<15	≥10	0.36	1.0
	<10	≥2	0.37	1.1
	<2	0	0.14	0.4
Multilaboratory precision	100	≥95	0.23	0.6
	<95	≥60	0.77	2.2
	<60	≥20	1.41	4.0
	<20	≥15	1.10	3.1
	<15	≥10	0.73	2.1
	<10	≥2	0.65	1.8
	<2	0	0.31	0.9

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670.

[b] The precision estimates are based on aggregates with nominal maximum size of 19.0 mm ($^3/_4$ in.).

11.1.1. The precision values for Fine Aggregate in Table 2 are based on nominal 500-g test samples. Revision of ASTM C136 in 1994 permitted the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 3, which indicate only minor differences due to test sample size.

Note 6—The values for Fine Aggregate in Table 2 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

Table 3—Precision Data for 300-g and 500-g Fine Aggregate Test Samples

Fine Aggregate Proficiency Sample	Sample	Number		Within Laboratory		Among Laboratories	
Test Result	Size	of Labs	Average	1s	d2s	1s	d2s
AASHTO T 27/ASTM C136:							
Total material passing the 4.75-mm (No. 4) sieve (%)	500 g	285	99.992	0.027	0.066	0.037	0.104
	300 g	276	99.990	0.021	0.060	0.042	0.117
Total material passing the 2.36-mm (No. 8) sieve (%)	500 g	281	84.10	0.43	1.21	0.63	1.76
	300 g	274	84.32	0.39	1.09	0.69	1.92
Total material passing the 1.18-mm (No. 16) sieve (%)	500 g	286	70.11	0.53	1.49	0.75	2.10
	300 g	272	70.00	0.62	1.74	0.76	2.12
Total material passing the 600-µm (No. 30) sieve (%)	500 g	287	48.54	0.75	2.10	1.33	3.73
	300 g	276	48.44	0.87	2.44	1.36	3.79
Total material passing the 300-µm (No. 50) sieve (%)	500 g	286	13.52	0.42	1.17	0.98	2.73
	300 g	275	13.51	0.45	1.25	0.99	2.76
Total material passing the 150-µm (No. 100) sieve (%)	500 g	287	2.55	0.15	0.42	0.37	1.03
	300 g	270	2.52	0.18	0.52	0.32	0.89
Total material passing the 75-µm (No. 200) sieve (%)	500 g	278	1.32	0.11	0.32	0.31	0.85
	300 g	266	1.30	0.14	0.39	0.31	0.85

11.2. *Bias*—Because there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

[1] Similar but not identical to ASTM C136-06.

Standard Method of Test for

Mechanical Analysis of Extracted Aggregate

AASHTO Designation: T 30-15

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

Mechanical Analysis of Extracted Aggregate

AASHTO Designation: T 30-15

1. SCOPE

1.1. This method covers a procedure for the determination of the particle-size distribution of fine and coarse aggregates extracted from asphalt mixtures using sieves with square openings.

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

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
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 35, Superpave Volumetric Design for Asphalt Mixtures
- R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
- T 164, Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
- T 255, Total Evaporable Moisture Content of Aggregate by Drying
- T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

2.2. *ASTM Standard*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. SIGNIFICANCE AND USE

3.1. This method is used to determine the grading of aggregates extracted from asphalt mixtures. The results are used to determine compliance of the particle-size distribution with applicable requirements and to provide necessary data for control of the production of various aggregates to be used in asphalt mixtures.

4. APPARATUS

4.1. *Balance*—A Class G2 balance meeting the accuracy requirements of M 231.

4.2. *Sieves*—Conforming to the requirements of M 92.

4.3. *Mechanical Sieve Shaker*—A mechanical sieving device, if used, shall continually reorient the particles on the sieving surface. The sieving action shall meet the requirements for sieving adequacy described in Section 7 in a reasonable time period (Note 1).

Note 1—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg (44 lb) or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, because a large sieving area is needed for practical sieving of a large nominal size coarse aggregate. Use of the same device for a smaller size of coarse aggregate or fine aggregate will likely result in loss of a portion of the sample.

4.4. *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5ºC (230 ± 9ºF).

4.5. *Wetting Agent*—Any dispersing agent, such as dishwashing detergent, that will promote separation of the fine materials.

4.6. *Container*—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.

4.7. *Spoon or Mixing Utensil*—Or similar device for agitating the sample during the washing procedure.

4.8. *Mechanical Washing Apparatus (Optional)*—A mechanical washing apparatus (Note 2).

Note 2—The use of some mechanical washing equipment with certain material types may cause degradation of the sample, impacting the results of the particle size analysis. To determine if a particular mechanical washing apparatus causes significant degradation, prepare a known aggregate blend gradation in the laboratory using washed and graded aggregate from individual aggregate stockpiles similarly to preparing an aggregate trial blend gradation specified in R 35. Mechanically wash and then grade the prepared aggregate blend sample. Compare the mechanically washed grading results to the known gradation of the laboratory-prepared aggregate blend for each sieve size. If the determined percentage passing each sieve for mechanical washing differs by more than the acceptable range of two results between laboratories given in Table 2, the mechanical washing apparatus should not be used.

5. CALIBRATIONS, STANDARDIZATIONS, AND CHECKS

5.1. Unless otherwise specified, follow the requirements and intervals for equipment calibrations, standardizations, and checks found in R 18.

5.2. Follow the procedures for performing equipment calibration, standardizations, and checks found in R 61.

6. SAMPLE

6.1. The sample shall consist of the entire lot or representative sample of aggregate obtained according to T 164 or T 308 from which the binder material has been extracted.

7. PROCEDURE

7.1. Dry the sample, if necessary, until further drying at 110 ± 5ºC (230 ± 9ºF) does not alter the mass by more than 0.1 percent (Note 3). Determine and record the mass of the sample to the nearest 0.1 g.

Note 3—Samples obtained from T 164 or T 308 should be dried to constant mass as part of the procedures within those standards. If the procedures described herein are completed immediately

following the procedures in either of those methods, it will not be necessary to dry the sample again. If more than 24 h pass between the completion of T 164 or T 308 and the beginning of this test procedure, if the sample is stored in a high-humidity environment, or has otherwise been subjected to moisture, the sample should be dried again to constant mass.

7.1.1. If the sample consists of aggregate obtained from T 164, add the mass of mineral matter contained in the extracted asphalt binder to the mass of the dry sample and record this value as the initial specimen mass (Note 4). The procedure for determination of the mineral matter content of the extracted asphalt is described in T 164.

Note 4—If the asphalt mixture was extracted in accordance with T 164, Method E, for plant control purposes, a mineral matter determination may not have been completed. In this case, record the mass determined in Section 7.1 as the initial specimen mass.

7.1.2. If the sample consists of aggregate obtained from T 308, the mass determined in Section 7.1 shall agree with the mass of aggregate remaining after ignition (M_f from T 308) within 0.1 percent. If the variation exceeds 0.1 percent, the results of this test should not be used for acceptance purposes. Record the mass determined in Section 7.1 as the initial specimen mass.

7.2. Place the test sample in a container and cover it with water. Add a sufficient amount of wetting agent to assure a thorough separation of the material finer than the 75-µm (No. 200) sieve from the coarser particles. Add the wetting agent (Note 5). Agitate the contents of the container vigorously and immediately decant the wash water over a nest of two sieves consisting of a 2.00-mm (No. 10) or 1.18-mm (No. 16) sieve superimposed on a 75-µm (No. 200) sieve (Note 6). The use of a large spoon or similar device is recommended to aid the process of agitating the contents of the container. Limit agitation by mechanical washing equipment to a maximum of 10 min.

Note 5—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water, the quality of the detergent, and the agitation process. Excessive suds may overflow the sieves and carry some material with them.

Note 6—When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation.

7.3. Vigorously agitate the sample, bringing the particles finer than the 75-µm (No. 200) sieve into suspension. Decant the suspension over the sieve nest in order to completely separate the fine particles from the coarse particles. Use care to avoid, as much as possible, the decantation of the coarse particles of the sample onto the sieve nest. Repeat the operation until the wash water is clear. Do not overflow or overload the 75-µm (No. 200) sieve.

7.4. Return all material retained on the nested sieves to the container. Dry the washed aggregate in the container to constant mass in accordance with T 255 and determine its mass to the nearest 0.1 percent.

7.5. Sieve the aggregate over various sieve sizes, including the 75-µm (No. 200) sieve as required by the specification covering the asphalt mixtures. Additional sieve sizes may be used to regulate the amount of material on a sieve to meet the requirements of Section 7.6. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by a mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 7.7.

7.6. Limit the quantity of material on a given sieve so that all particles have the opportunity to reach sieve openings a number of times during the sieving operation. Do not exceed a mass of 7 kg/m^2 (4 g/in.^{2}) retained per sieving surface on any sieve with openings smaller than 4.75 mm (No. 4) at the completion of the sieving operation (Note 7). Do not exceed a mass in kg of the product of

2.5 × (sieve opening in mm) × (the effective or clear sieving surface area, m^2) for sieves with openings 4.75 mm (No. 4) and larger. For sieves with openings 4.75 mm (No. 4) and larger, this mass is shown in Table 1 for five sieve-frame dimensions in common use. Do not cause permanent deformation of the sieve cloth due to overloading.

Note 7—The 7 kg/m^2 (4 g/$in.^2$) amounts to 200 g for the usual 203-mm (8-in.) diameter sieve [with effective or clear sieving surface diameter of 190.5 mm ($7^1/_2$ in.)] or 450 g for a 305-mm (12-in.) diameter sieve [with effective or clear sieving surface diameter of 292.1 mm ($11^1/_2$ in.)]. The amount of material retained on a sieve may be regulated by: (1) the introduction of a sieve with larger openings immediately above the given sieve, (2) testing the sample in a number of increments, or (3) testing the sample over a nest of sieves with a larger sieve-frame dimension.

Table 1—Maximum Allowable Mass of Material Retained on a Sieve, kg

Sieve Opening Size	Nominal Dimensions of Sieve[a]				
	203.2-mm, dia[b]	254-mm, dia[b]	304.8-mm, dia[b]	350 by 350, mm	372 by 580, mm
	Sieving Area, m^2				
	0.0285	0.0457	0.0670	0.1225	0.2158
125 mm (5 in.)	[c]	[c]	[c]	[c]	67.4
100 mm (4 in.)	[c]	[c]	[c]	30.6	53.9
90 mm ($3^1/_2$ in.)	[c]	[c]	15.1	27.6	48.5
75 mm (3 in.)	[c]	8.6	12.6	23.0	40.5
63 mm ($2^1/_2$ in.)	[c]	7.2	10.6	19.3	34.0
50 mm (2 in.)	3.6	5.7	8.4	15.3	27.0
37.5 mm ($1^1/_2$ in.)	2.7	4.3	6.3	11.5	20.2
25.0 mm (1 in.)	1.8	2.9	4.2	7.7	13.5
19.0 mm ($^3/_4$ in.)	1.4	2.2	3.2	5.8	10.2
12.5 mm ($^1/_2$ in.)	0.89	1.4	2.1	3.8	6.7
9.5 mm ($^3/_8$ in.)	0.67	1.1	1.6	2.9	5.1
4.75 mm (No. 4)	0.33	0.54	0.80	1.5	2.6

[a] Sieve-frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter; 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

[b] The sieve area for round sieves is based on an effective or clear diameter of 12.7 mm ($^1/_2$ in.) less than the nominal frame diameter, because M 92 permits the sealer between the sieve cloth and the frame to extend 6.35 mm ($^1/_4$ in.) over the sieve cloth. Thus the effective or clear sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm ($7^1/_2$ in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm ($^1/_4$ in.).

[c] Sieves indicated have less than five full openings and should not be used for sieve testing.

7.7. Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 60 s of continuous hand-sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike 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 min, turning the sieve about one-sixth of a revolution at intervals of about 25 strokes. In determining the adequacy of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8-in.) diameter sieves to verify the adequacy of sieving.

8. CALCULATIONS

8.1. Record the mass of material passing each sieve, the mass retained on the next sieve, and the amount passing the 75-µm (No. 200) sieve. The sum of these masses must be within 0.2 percent of the mass after washing. Add the mass of dry material passing the 75-µm (No. 200) sieve by dry sieving to the mass removed by washing, and if applicable, the mass of mineral matter in the asphalt binder, in order to obtain the total passing the 75-µm (No. 200) sieve. Convert the masses

of fractions retained on the various sieves and the total passing the 75-μm (No. 200) sieve to percentages by dividing each by the initial specimen mass determined in Section 7.1.1 or 7.1.2, as applicable.

8.2. For aggregate samples obtained from T 308, apply the aggregate correction factor, as required in T 308, to obtain the final total passing percentages.

9. REPORT

9.1. Report the results of the sieve analysis as follows: (a) total percentages passing each sieve; or (b) total percentages retained on each sieve; or (c) percentages retained between consecutive sieves, depending upon the form of the specifications of the material being tested. Report percentages to the nearest whole number, except for the percentage passing the 75-μm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

10. PRECISION AND BIAS

10.1. *Precision*—The estimates of precision for this test method are listed in Table 1. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by T 30. The data are based on the analyses of the test results from 47 to 190 laboratories that tested 17 pairs of proficiency test samples (Samples No. 1 through 34). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

Table 2—Precision

	Total Percentage of Material Passing a Sieve	Standard Deviation (1s) Percent[a]	Acceptable Range of Two Results—(d2s) Percent[a]
Extracted aggregate:[b]			
Single-operator precision	95 to 100	0.49	1.4
	40 to 94	1.06	3.0
	25 to 39	0.65	1.8
	10 to 24	0.46	1.3
	5 to 9	0.29	0.8
	2 to 4	0.21	0.6
	0 to 1	0.17	0.5
Multilaboratory precision	95 to 100	0.57	1.6
	40 to 94	1.24	3.5
	25 to 39	0.84	2.4
	10 to 24	0.81	2.3
	5 to 9	0.56	1.6
	2 to 4	0.43	1.2
	0 to 1	0.32	0.9

[a] These numbers represent, respectively, the (1s) and (d2s) limits described in ASTM C670.

[b] The precision estimates are based on aggregates with nominal maximum sizes of 19.0 mm ($^3/_4$ in.) to 9.5 mm ($^3/_8$ in.).

10.2. *Bias*—This test method has no bias because the values determined can only be defined in terms of this test method.

11. KEYWORDS

11.1. Coarse aggregate; fine aggregate; particle size; sieves.

Standard Method of Test for

Specific Gravity and Absorption of Fine Aggregate

AASHTO Designation: T 84-13[1]
ASTM Designation: C128-12

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
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Standard Method of Test for

Specific Gravity and Absorption of Fine Aggregate

AASHTO Designation: T 84-13[1]
ASTM Designation: C128-12

AASHTO

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 Standard*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI10, 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 1 kg 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 when 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. 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 C670. 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:

$$C = 0.9975\,V_a + S + W \qquad (1)$$

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:

$$B = 0.9975\,V + W \qquad (2)$$

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:

$$\text{bulk sp gr} = A/\left(B + S - C\right) \qquad (3)$$

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:

$$\text{bulk sp gr} = \frac{S_1\left(\frac{A}{S}\right)}{0.9975\left(R_2 - R_1\right)} \qquad (4)$$

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:

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

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:

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

11. APPARENT SPECIFIC GRAVITY

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

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

12. ABSORPTION

12.1. Calculate the percentage of absorption as follows:

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

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 C128. The significant difference between the methods is that ASTM C128 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.

APPENDIXES

(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 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:

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

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

Or:

$$S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} = \frac{S_s}{1 - \frac{A}{100}(S_s - 1)} \quad \textit{(X1.3)}$$

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

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

[1] This method is technically equivalent to ASTM C128-12.

Standard Method of Test for

Specific Gravity and Absorption of Coarse Aggregate

AASHTO Designation: T 85-14[1]
ASTM Designation: C127-12

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

Specific Gravity and Absorption of Coarse Aggregate

AASHTO Designation: T 85-14[1]
ASTM Designation: C127-12

AASHTO

1. SCOPE

1.1. This method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, bulk specific gravity (saturated surface-dry (SSD)), or apparent specific gravity. The bulk specific gravity (SSD) and absorption are based on aggregate after 15–19 h of soaking in water. This method is not intended to be used with lightweight aggregates.

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 associated with its use. It is the responsibility of the user of 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 43, Sizes of Aggregate for Road and Bridge Construction
- M 80, Coarse Aggregate for Hydraulic Cement Concrete
- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 248, Reducing Samples of Aggregate to Testing Size
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. *ASTM Standard*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI10, 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. SUMMARY OF METHOD

4.1. A sample of aggregate is immersed in water to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and weighed. Subsequently the sample is weighed while submerged in water. Finally the sample is oven-dried and weighed a third time. Using the mass and weight measurements thus obtained and formulas in the method, it is possible to calculate three types of specific gravity and absorption.

5. SIGNIFICANCE AND USE

5.1. 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 (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the bulk specific gravity (oven-dry) is used for computations when the aggregate is dry or assumed to be dry.

5.2. 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.

5.3. 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 the required amount of time to achieve the soaked condition. 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.

5.4. The general procedures described in this method are suitable for determining the absorption of aggregates that have had conditioning other than the required soak, such as boiling water or vacuum saturation. The values obtained for absorption by other methods will be different than the values obtained by the required soak, as will the bulk specific gravity (SSD).

5.5. The pores in lightweight aggregates may or may not become essentially filled with water after the required soaking period. In fact, many such aggregates can remain immersed in water for several days without satisfying most of the aggregates' absorption potential. Therefore, this method is not intended for use with lightweight aggregate.

6. APPARATUS

6.1. *Balance*—Conforming to the requirements of M 231, Class G 5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.

6.2. *Sample Container*—A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm ($1^1/_2$-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.

6.3. *Water Tank*—A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow outlet for maintaining a constant water level.

6.4. *Suspended Apparatus*—Wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length.

6.5. *Sieves*—A 4.75-mm (No. 4) sieve or other sizes as needed (Sections 7.2, 7.3, and 7.4), conforming to M 92.

7. SAMPLING

7.1. Sample the aggregate in accordance with T 2.

7.2. Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in T 248. Reject all material passing a 4.75-mm (No. 4) sieve by dry-sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm (No. 4) sieve (such as for Size No. 8 and 9 aggregates in M 43), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm (No. 4) sieve. Alternatively, separate the material finer than the 4.75-mm (No. 4) sieve and test the finer material according to T 84.

7.3. The minimum mass of test sample to be used is given below. In many instances, it may be desirable to test a coarse aggregate in several separate size fractions; and if the sample contains more than 15 percent retained on the 37.5-mm ($1^1/_2$-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size, mm (in.)	Minimum Mass of Test Sample, kg (lb)
12.5 ($^1/_2$) or less	2 (4.4)
19.0 ($^3/_4$)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 ($1^1/_2$)	5 (11)
50 (2)	8 (18)
63 ($2^1/_2$)	12 (26)
75 (3)	18 (40)
90 ($3^1/_2$)	25 (55)
100 (4)	40 (88)
112 ($4^1/_2$)	50 (110)
125 (5)	75 (165)
150 (6)	125 (276)

7.4. If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with T 27, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75-mm (No. 4) sieve or 2.36-mm (No. 8) sieve when that sieve is used in accordance with Section 7.2.

8. PROCEDURE

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for 1 to 3 h for test samples of 37.5-mm ($1^1/_2$-in.) nominal maximum size, or longer for larger sizes, until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C). Subsequently immerse the aggregate in water at room temperature for a period of 15 to 19 h.

Note 1—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 the values obtained combined for the computation described in Section 9.

8.2. 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 required soaking may also be eliminated.

Note 2—Values for absorption and bulk specific gravity (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 8.1. This is especially true of particles larger than 75 mm (3 in.) because the water may not be able to penetrate the pores to the center of the particle in the required soaking period.

8.3. 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. A moving stream of air may be used to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores during the operation of surface-drying. If the test sample dries past the SSD condition, immerse in

water for 30 min, then resume the process of surface-drying. Determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to the nearest 1.0 g or 0.1 percent of the sample mass, whichever is greater.

8.4. After determining the mass, immediately place the saturated surface-dry test sample in the sample container and determine its mass in water at 23.0 ± 1.7°C (73.4 ± 3°F), having a density of 997 ± 2 kg/m^3. Take care to remove all entrapped air before determining the mass by shaking the container while immersed. Maintain the water level in the bath at the overflow depth to obtain a constant water level throughout the test.

Note 3—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.

8.5. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature 1 to 3 h, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C), and determine the mass. Use this weight for A in the calculations in Section 9.

9. CALCULATIONS

9.1. *Specific Gravity*:

9.1.1. *Bulk Specific Gravity*—Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as follows:

$$\text{bulk sp gr} = A/(B-C) \quad (1)$$

where:

A = mass of oven-dry test sample in air, g;

B = mass of saturated surface-dry test sample in air, g; and

C = mass of saturated test sample in water, g.

9.1.2. *Bulk Specific Gravity (Saturated Surface-Dry)*—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:

$$\text{bulk sp gr (saturated surface-dry)} = B/(B-C) \quad (2)$$

9.1.3. *Apparent Specific Gravity*—Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F), as follows:

$$\text{apparent sp gr} = A/(A-C) \quad (3)$$

9.2. *Average Specific Gravity Values*—When the sample is tested in separate size fractions, the average value for bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity can be computed as the weighted average of the values as computed in accordance with Section 9.1 using the following equation:

$$G = \frac{1}{\frac{P_1}{100G_1} + \frac{P_2}{100G_2} + \cdots \frac{P_n}{100G_n}} \quad (4)$$

where:

G = average specific gravity (All forms of expression of specific gravity can be averaged in this manner.);

$P_1, P_2 \ldots P_n$ = mass percentages of each size fraction present in the original sample; and

$G_1, G_2 \ldots G_n$ = appropriate specific gravity values for each size fraction depending on the type of specific gravity being averaged.

Note 4—Some users of this method may wish to express the results in terms of density. Density may be determined by multiplying the bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity by the density of water (997.5 kg/m^3 or 0.9975 Mg/m^3 or 62.27 lb/ft^3 at 23°C). Some authorities recommend using the density of water at 4°C (1000 kg/m^3 or 1.000 Mg/m^3 or 62.43 lb/ft^3) as being sufficiently accurate. The density terminology corresponding to bulk specific gravity, bulk specific gravity (SSD), and apparent specific gravity has not been standardized.

9.3. *Absorption*—Calculate the percentage of absorption, as follows:

$$\text{absorption, percent} = \left[(B - A) / A \right] \times 100 \qquad (5)$$

9.4. *Average Absorption Value*—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in Section 9.3, weighted in proportion to the mass percentages of the size fractions in the original sample as follows:

$$A = (P_1 A_1 / 100) + (P_2 A_2 / 100) + \cdots (P_n A_n / 100) \qquad (6)$$

where:

A	=	average absorption, percent;
$P_1, P_2 \ldots P_n$	=	mass percentages of each size fraction present in the original sample; and
$A_1, A_2 \ldots A_n$	=	absorption percentages for each size fraction.

10. REPORT

10.1. Report specific gravity results to the nearest 0.001 (Coarse Aggregate meeting M 80 requirements may be reported to the nearest 0.01), and indicate the type of specific gravity, whether bulk, bulk (saturated surface-dry), or apparent.

10.2. Report the absorption result to the nearest 0.1 percent.

10.3. If the specific gravity and absorption values were determined without first drying the aggregate, as permitted in Section 8.2, it shall be noted in the report.

11. PRECISION AND BIAS

11.1. 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 C127. The significant difference between the methods is that ASTM C127 requires a saturation period of 24 ± 4 h, while T 85 requires a saturation period of 15-19 h. This difference has been found to have 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.

Table 1—Precision

	Standard Deviation (1s)[a]	Acceptable Range of Two Results (d2s)[a]
Single-operator precision:		
Bulk specific gravity (dry)	0.009	0.025
Bulk specific gravity (SSD)	0.007	0.020
Apparent specific gravity	0.007	0.020
Absorption,[b] percent	0.088	0.25
Multilaboratory precision:		
Bulk specific gravity (dry)	0.013	0.038
Bulk specific gravity (SSD)	0.011	0.032
Apparent specific gravity	0.011	0.032
Absorption,[b] percent	0.145	0.41

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15-h minimum saturation times and other laboratories using 24 ± 4-h 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 2 percent.

11.2. *Bias*—Because there is no accepted reference material for determining the bias for the procedure in this test method, no statement on bias is being made.

APPENDIXES

(Nonmandatory Information)

X1. DEVELOPMENT OF EQUATIONS

X1.1. The derivation of the equation is apparent from the following simplified cases using two solids. Solid 1 has a mass W_1 in grams and a volume V_1 in milliliters; its specific gravity (G_1) is therefore W_1/V_1. Solid 2 has a mass W_2 and volume V_2, and $G_2 = W_2/V_2$. If the two solids are considered together, the specific gravity of the combination is the total mass in grams divided by the total volume in milliliters:

$$G = (W_1 + W_2) / (V_1 + V_2) \quad (X1.1)$$

Manipulation of this equation yields the following:

$$G = \frac{1}{\frac{V_1 + V_2}{W_1 + W_2}} = \frac{1}{\frac{V_1}{W_1 + W_2} + \frac{V_2}{W_1 + W_2}} \quad (X1.2)$$

$$G = \frac{1}{\frac{W_1}{W_1 + W_2}\left(\frac{V_1}{W_1}\right) + \frac{W_2}{W_1 + W_2}\left(\frac{V_2}{W_2}\right)} \quad (X1.3)$$

However, the mass fractions of the two solids are:

$$\frac{W_1}{(W_1 + W_2)} = \frac{P_1}{100} \quad (X1.4)$$

and:

$$\frac{W_2}{(W_1+W_2)}=\frac{P_2}{100} \qquad (X1.5)$$

and:

$$\frac{1}{G_1}=\frac{V_1}{W_1} \text{ and } \frac{1}{G_2}=\frac{V_2}{W_2} \qquad (X1.6)$$

therefore:

$$G=\frac{1}{\left(\frac{P_1}{100}\right)\left(\frac{1}{G_1}\right)+\left(\frac{P_2}{100}\right)\left(\frac{1}{G_2}\right)} \qquad (X1.7)$$

An example of the computation is given in Table X1.1.

Table X1.1—Example Calculation of Average Values of Specific Gravity and Absorption for a Coarse Aggregate Tested in Separate Sizes

Size Fraction, mm (in.)	Percent in Original Sample	Bulk Specific Gravity (SSD)[a]	Sample Mass Used in Test, g	Absorption, %
4.75 to 12.5 (No. 4 to $^1/_2$)	44	2.72	2213.0	0.4
12.5 to 37.5 ($^1/_2$ to $1^1/_2$)	35	2.56	5462.5	2.5
37.5 to 63 ($1^1/_2$ to $2^1/_2$)	21	2.54	12593.0	3.0

[a] Average specific gravity (SSD)

$$G_{SSD}=\frac{1}{\frac{0.44}{2.72}+\frac{0.35}{2.56}+\frac{0.21}{2.54}}=2.62 \qquad (X1.8)$$

Average absorption:

$$A=(0.44)(0.4)+(0.35)(2.5)+(0.21)(3.0)=1.7\% \qquad (X1.9)$$

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

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:

$$S_s=\left(1+\frac{A}{100}\right)S_d \qquad (X2.1)$$

$$S_a = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \qquad (X2.2)$$

$$S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} \qquad (X2.3)$$

$$= \frac{S_s}{1 - \left(\frac{A}{100}(S_s - 1)\right)}$$

$$A = \left(\frac{S_s}{S_d} - 1\right)100 \qquad (X2.4)$$

$$A = \left(\frac{S_a - S_s}{S_a(S_s - 1)}\right)100 \qquad (X2.5)$$

[1] This method is technically equivalent to ASTM C127-12.

Standard Method of Test for

Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)

AASHTO Designation: T 164-14[1]
ASTM Designation: D2172/D2172M-11

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

Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)

AASHTO Designation: T 164-14[1]
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AASHTO

1. SCOPE

1.1. These methods cover the quantitative determination of asphalt binder in hot mix asphalt (HMA) and HMA pavement samples. Aggregate obtained by these methods may be used for sieve analysis using T 30.

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 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.* Specific hazards are given in Section 8.

Note 1—The results obtained by these methods may be affected by the age of the material tested, with older samples tending to yield slightly lower asphalt binder contents. Best quantitative results are obtained when the test is made on HMA mixtures and pavements shortly after their preparation. It is difficult to remove all the asphalt binder when some aggregates are used; some solvent may remain within the mineral matter affecting the measured asphalt binder content.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- R 59, Recovery of Asphalt Binder from Solution by Abson Method
- T 30, Mechanical Analysis of Extracted Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 110, Moisture or Volatile Distillates in Hot Mix Asphalt (HMA)
- T 168, Sampling Bituminous Paving Mixtures
- T 228, Specific Gravity of Semi-Solid Asphalt Materials
- T 329, Moisture Content of Asphalt Mixtures by Oven Method

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D604, Standard Specification for Diatomaceous Silica Pigment (withdrawn 2003)
- D2111, Standard Test Methods for Specific Gravity and Density of Halogenated Organic Solvents and Their Admixtures

- D4080, Standard Specification for Trichloroethylene, Technical and Vapor-Degreasing Grade
- D6368, Standard Specification for Vapor-Degreasing Solvents Based on normal-Propyl Bromide and Technical Grade normal-Propyl Bromide

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *nominal maximum size (of aggregate)*—one size larger than the first sieve that retains more than 10 percent aggregate.

3.1.2. *constant mass*—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals.

4. SUMMARY OF TEST METHODS

4.1. The HMA is extracted with trichloroethylene, *normal*-propyl bromide, or methylene chloride, using the extraction equipment applicable to the particular method. Terpene extractant may be used in Method A or E. The asphalt binder content is calculated by differences from the mass of the extracted aggregate, moisture content, and mineral matter in the extract. The asphalt binder content is expressed as a mass percent of moisture-free mixtures.

5. SIGNIFICANCE AND USE

5.1. All of the methods can be used for quantitative determinations of asphalt binder in HMA mixtures and pavement samples for specification acceptance, service evaluation, quality control, and research. Each method prescribes the solvents and any other reagents that can be used in the method. R 59 requires that Method A or E (Note 2) and reagent-grade trichloroethylene be used when asphalt binder is recovered from solution.

Note 2—The vacuum extractor, Section 22.1.1, can be modified by a vacuum trap attached to the top of the "end point" sight tube to collect the extract to allow its use for recoveries (Figure 4b).

6. APPARATUS

6.1. *Oven*—Capable of maintaining the temperature at 110 ± 5°C (230 ± 9°F), for warming the sample.

6.2. *Oven*—Capable of maintaining the temperature at 149 to 163°C (300 to 325°F), for drying the sample if the moisture content is not determined.

6.3. *Pan*—Flat, of appropriate size.

6.4. *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.

6.5. *Cylinders*—Graduated, 1000- or 2000-mL capacity.

7. REAGENTS

7.1. *Methylene Chloride*—Technical grade. *Caution*—see Section 8.

7.2. *Normal-Propyl Bromide*—Conforming to ASTM D6368—see Section 8.

7.3. *Trichloroethylene*—Reagent grade (Note 3) or conforming to ASTM D4080—see Section 8.

7.4. *Terpene*—Extractant, shall be nonhalogenated, nontoxic, and shall readily dissolve asphalt binder from HMA and place it into solution. This extractant shall be easily rinsed from the remaining aggregate without forming a gel, and the extractant rinsed from the aggregate shall pass readily through the diatomaceous earth and the filter.

7.5. When asphalt binder is intended to be extracted and then tested for additional properties, a reagent-grade solvent must be used (Note 3).

Note 3—Non-reagent-grade solvents may contain epoxy resins that may affect the properties of the recovered binder. In particular, certain acid modified binders may be affected by non-reagent-grade solvents.

Note 4—Only vented ovens should be used when terpene extractants are used.

8. PRECAUTIONS

8.1. The solvents listed in Section 7 should be used only under a hood or with an effective surface exhaust system in a well-ventilated area, because they are all toxic to some degree, as described in R 16. Trichloroethylene, methylene chloride, and *normal*-propyl bromide in the presence of heat and moisture may form acids that are extremely corrosive to certain metals, particularly when subject to contact over lengthy periods of time. Proper precautions should be taken to not allow these solvents to remain in small quantities in the effluent tanks of aluminum vacuum extractors.

8.2. Trichloroethylene stored in a steel container and in continuous contact with moisture may decompose by dehydrohalogenation to form unsaturated hydrocarbon liquids and hydrogen chloride. Steel drums containing trichloroethylene should be stored in a cool, dry location, kept tightly sealed, and opened as infrequently as possible. Trichloroethylene should be transferred from the drums to clean, dry, brown glass bottles for laboratory use. The hydrogen chloride in decomposed trichloroethylene may harden an asphalt during the extraction and Abson recovery test (R 59).

8.3. All local, state, and federal regulations must be followed when hauling, using, storing, and discarding extractants and rinse water. These requirements include fire ordinances as well as wastewater treatment regulations. The Material Safety Data Sheet should be followed closely to avoid fires and explosions. Storage of extractant-soaked rags should be prohibited.

9. SAMPLING

9.1. Obtain samples in accordance with T 168.

9.2. *Preparation of Test Specimens*:

9.2.1. If the HMA is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan, and warm it in a 110 ± 5°C (230 ± 9°F) oven only until it can be handled or separated. Split or quarter the material until the mass of material required for the test is obtained.

9.2.2. The size of the test sample shall be governed by the nominal maximum aggregate size of the HMA and conform to the mass requirement shown in Table 1 (Note 5).

Table 1—Size of Sample

Nominal Maximum Aggregate Size		Minimum Mass of Sample, kg
mm	in.	
4.75	No. 4	0.5
9.5	3/8 in.	1
12.5	1/2 in.	1.5
19.0	3/4 in.	2
25.0	1 in.	3
37.5	1 1/2 in.	4

Note 5—When the mass of the test specimen exceeds the capacity of the equipment used (for a particular method), the test specimen may be divided into suitable increments, tested, and the results appropriately combined for calculation of asphalt binder content (Section 13).

9.2.3. Unless the HMA sample is free of moisture (Note 7), a test specimen is required for the determination of moisture (Section 10) in the HMA. Take this test specimen from the remaining sample in the HMA immediately after obtaining the extraction test specimen.

Note 6—If the extraction test is being performed only to recover asphalt binder from the HMA and the percent asphalt binder is not being determined, it is unnecessary to determine the moisture content of the HMA.

Table 2—Dimensional Equivalents

mm	in.	mm	in.	mm	in.
0.8	1/32	42.9	1 11/16	155.6	6 1/8
1.6	1/16	44.5	1 3/4	157.2	6 3/16
2.0	5/64	47.6	1 7/8	158.8	6 1/4
3.2	1/8	50.8	2	163.5	6 7/16
4.0	5/32	55.6	2 3/16	165.1	6 1/2
4.8	3/16	56.4	2 7/32	187.3	7 3/8
5.6	7/32	57.2	2 1/4	203.2	8
6.4	1/4	58.7	2 5/16	247.7	9 3/4
7.9	5/16	63.5	2 1/2	254.0	10
9.5	3/8	66.7	2 5/8	257.2	10 1/8
12.7	1/2	71.4	2 13/16	260.4	10 1/4
15.9	5/8	76.2	3	279.4	11
19.1	3/4	88.9	3 1/2	304.8	12
25.4	1	95.3	3 3/4	320.7	12 5/8
28.6	1 1/8	101.6	4	330.2	13
30.2	1 3/16	108.0	4 1/4	342.9	13 1/2
35.7	1 13/32	127.0	5	355.6	14
38.1	1 1/2	138.1	5 7/16	368.3	14 1/2
40.5	1 19/32	149.2	5 7/8	384.2	15 1/8
41.3	1 5/8	152.4	6	393.7	15 1/2
47.6	1 7/8	154.8	6 3/32	406.4	16
0.9 mm	20 gauge	3.2 mm	#8 B&S	26 qt	24.6 L
1.2 mm	18 gauge	4.75 mm	No. 4 mesh		

10. MOISTURE CONTENT

10.1. When required, determine the moisture content of the mixture (Section 9.2.3) in accordance with the procedure described in T 110 or T 329.

Note 7—If recovery of asphalt binder from the solution obtained from the extraction test is not required, the entire test specimen may be dried in an oven at a temperature of 105 to 165°C (221 to 329°F) to constant mass prior to extraction, instead of determining the moisture content.

10.2. Calculate the mass of water (W_2, Section 13) in the extraction test portion by multiplying mass percent water (Section 10.1) by the mass of the extraction test portion (W_1, Section 13).

TEST METHOD A

11. APPARATUS

11.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Method A:

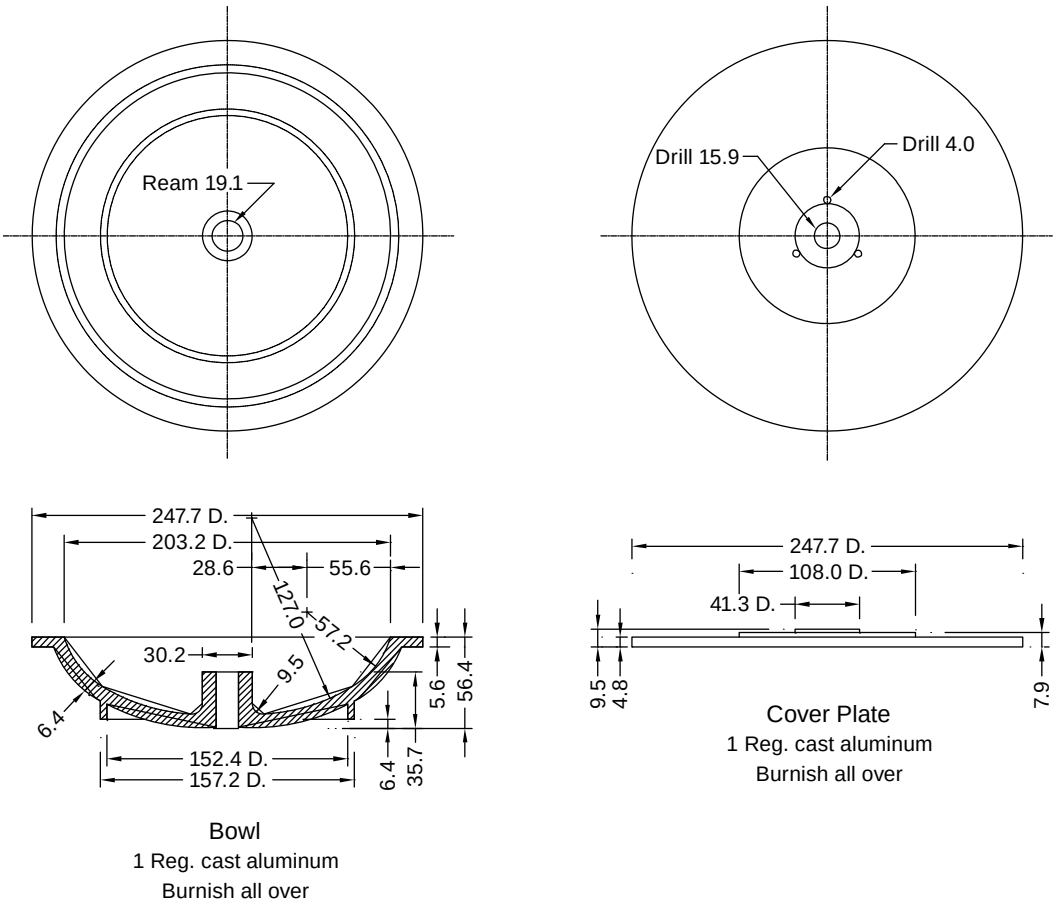
11.1.1. *Extraction Apparatus*—Consisting of a bowl approximating that shown in Figure 1 and an apparatus in which the bowl may be revolved at controlled variable speeds up to 3600 r/min. The speed may be controlled manually or with a preset speed control. The apparatus should be provided with a container for catching the solvent discharged from the bowl and a drain for removing the solvent. The apparatus preferably shall be provided with explosion-proof features and installed in a hood or an effective surface exhaust system to provide ventilation.

Note 8—Similar apparatus of larger size may be used.

11.1.2. *Filter Rings*—Felt or paper, to fit the rim of the bowl.

11.1.3. *Low-Ash Paper Filter Rings*—May be used in place of the felt filter ring (Section 11.1.2). Such filter rings shall consist of low-ash filter paper stock, 1.27 ± 0.13 mm (0.05 ± 0.005 in.) thick. The nominal base weight of the paper shall be 150 ± 14 kg (330 ± 30 lb) for a ream [500 sheets, 635 by 965 mm (25 by 38 in.)]. The ash content of the paper should not exceed 0.2 percent (approximately 0.034 g per ring).

Note 9—Where terpene extractants are used, the gears and shaft should be lubricated frequently.



Note: See Table 2 for dimensional equivalents. All dimensions shown in millimeters unless otherwise noted.

Figure 1—Extraction Unit Bowl (Method A)

12. PROCEDURE

12.1. Determine the moisture content of the material in accordance with Section 10.

12.2. Place the test portion into a bowl.

12.3. Cover the test portion in the bowl with trichloroethylene, methylene chloride, *normal*-propyl bromide, or terpene extractant, and allow sufficient time for the solvent to disintegrate the test portion (not more than 1 h). Place the bowl containing the test portion and the solvent in the extraction apparatus. Dry the filter ring to a constant mass in an oven at 110 ± 5°C (230 ± 9°F), and fit it around the edge of the bowl. Clamp the cover on the bowl tightly, and place an appropriate container under the drain to collect the extract.

12.4. Start the centrifuge revolving slowly, and gradually increase the speed to a maximum of 3600 r/min until the solvent ceases to flow from the drain. Allow the machine to stop; add 200 mL (or more as appropriate for the mass of the sample) of trichloroethylene, methylene chloride, *normal*-propyl bromide, or terpene extractant, and repeat the procedure. Use sufficient solvent additions (not less than three) until the extract is not darker than a light straw color (when viewed against a white background). Collect the extract and the washings in an appropriate container for mineral matter determination.

12.5. Carefully transfer the filter ring and all of the aggregate in the centrifuge bowl into a tared metal pan. Dry in air under a hood until the fumes dissipate, and then to a constant mass in an oven at 110 ± 5°C (230 ± 9°F) (Notes 10 and 11). The mass of the extracted aggregate (W_3) is equal to the mass of the contents in the pan minus the initial dry mass of the filter ring. Brush off mineral matter adhering to the surface of the filter ring, and add it to the extracted aggregate for further testing.

Note 10—The filter and aggregate may be left inside the centrifuge bowl and dried to constant mass in an oven at 110 ± 5°C (230 ± 9°F) and the mass determined.

Note 11—The filter ring may be dried separately to constant mass in an oven at 110 ± 5°C (230 ± 9°F) provided that care is taken not to lose any of the fine material clinging to the filter. If this procedure is used, the aggregate may then be dried to constant mass either in an oven or on a hot plate at 110 ± 5°C (230 ± 9°F).

12.5.1. Use the following alternative procedure when low-ash filter rings are used. Place the aggregate and filter rings in a clean metal pan. Dry as specified above. Carefully fold the dried filter ring and stand it on the aggregate. Burn the filter ring. Determine the mass of the extracted aggregate in the pan (W_3).

Note 12—Because dry aggregate absorbs moisture when exposed to air containing moisture, determine the mass of the extracted aggregate immediately after cooling to a suitable temperature.

12.6. Determine the amount of mineral matter in the extract by one of the procedures specified in Annex A1.

13. CALCULATION OF ASPHALT BINDER CONTENT

$$\text{asphalt binder content, \%} = \frac{(W_1 - W_2) - (W_3 + W_4)}{W_1 - W_2} \times 100 \qquad (1)$$

where:

W_1 = mass of test portion;

W_2 = mass of water in test portion;

W_3 = mass of extracted mineral aggregate; and

W_4 = mass of mineral matter in the extract.

Note 13—When ashless filter rings are not used, add the increase in mass of the felt ring to W_4.

Note 14—When it is desired to express the asphalt binder content as a mass percent of the moisture-free aggregate, substitute the mass $W_3 + W_4$ for the mass $W_1 - W_2$ in the divisor of Equation 1.

TEST METHOD B

14. APPARATUS

14.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Test Method B:

14.1.1. *Extraction Apparatus*—Similar to that shown in Figure 2.

Figure 2—Extraction Apparatus (Method B)

14.1.1.1. *Glass Jar*—Cylindrical, plain, made of heat-resistant glass. The jar shall be free of cracks, scratches, or other evidence of flaws that might cause breakage during heating.

14.1.1.2. *Cylindrical Metal Frames*—One or two. The lower frame shall have legs of sufficient length to support the frame, including the apex of the metal cone and paper cone liner above the solvent level. When two frames are used, the upper frame shall have legs of sufficient length to support the metal cone and paper cone liner at or above the top rim of the lower frame. The legs of the upper frame shall fit securely in the top rim of the lower frame. A bail handle may be provided on the inside of the top rim of each frame for convenient handling. The metal used in fabricating the frames shall be essentially unreactive to the solvents used in the test.

14.1.1.3. *Condenser*—Fabricated with a truncated hemispherical condensing surface and a truncated conical top. Other suitable geometric shapes may also be used, provided they accomplish the condensing and flow functions intended. The material used in fabricating the condenser shall be essentially unreactive to water and to the solvent used and shall be provided with a suitable water inlet and outlet.

14.1.1.4. *Filter Paper*—Medium-grade, fast-filtering. The diameter of the paper shall be such that when folded in accordance with the directions given below, it shall completely line the metal cones in the frames.

14.1.1.5. *Thermal Distributing Protective Pad*—Approximately 3 mm (0.1 in.) thick for use as insulation between the glass jar and hot plates.

14.1.1.6. *Electric Hot Plate*—Thermostatically controlled, of sufficient dimensions and heat capacity to permit refluxing of the solvent as described in Section 16.2.5.

15. PREPARATION OF TEST PORTION

15.1. Prepare a test portion for moisture determination and extraction in accordance with the procedure described in Section 9.

16. PROCEDURE

16.1. *Moisture*:

16.1.1. Determine the moisture content of the HMA (Section 9.2.3) in accordance with the method described in Section 10.

16.2. *Extraction*:

16.2.1. Dry one sheet of filter paper for each frame used to a constant mass in an oven at 110 ± 5°C (230 ± 9°F). Fold each paper on its diameter; fold the ends over, and spread it open to form a proper size to fit inside the metal cones.

16.2.2. Determine the mass of each frame with its filter paper liner to the nearest 0.5 g. Record the mass of each frame.

16.2.3. Place the test portion in the frame(s). If two frames are used, distribute the test portion approximately equally between the two. The top of the test portion must be below the upper edge of the paper liner. Determine the mass of each loaded frame separately to the nearest 0.5 g. Again, record the mass.

16.2.4. Use one of the solvents (Note 15) specified in Section 7.1, 7.2, or 7.3. Pour the solvent into the glass cylinder, and place the bottom frame into it. The solvent level should be below the apex of the one in the lower frame. If two frames are used, place the upper frame in the lower frame, fitting its legs into the holes in the upper rim of the lower frame.

Note 15—Sufficient denatured ethyl alcohol may be poured over the test portion(s) to wet the filter paper. A mixture of 20 percent denatured alcohol and 80 percent trichloroethylene has proven to be a better solvent for some aggregates.

16.2.5. If required, place the thermal insulating pad on the hot plate and then the cylinder on the pad. Cover the condenser. Circulate a gentle, steady stream of cool water through the condenser. Adjust the temperature of the hot plate so that the solvent will boil gently and a steady stream of condensed solvent flows into the cone. If necessary, adjust the temperature of the hot plate to maintain the solvent stream at a rate necessary to keep the test portions in the cone(s) completely covered with condensed solvent. Take care not to allow condensed solvent to overflow the filter cone(s). Continue the refluxing until the solvent flowing from the lower cone is a light straw color (when viewed against a white background). At this point, turn off the hot plate and allow the apparatus to cool enough to handle; turn off the condenser and remove it from the cylinder.

16.2.6. Remove the frame assembly from the cylinder. Allow it to dry in air (hood), and then dry it to a constant mass in an oven at 110 ± 5°C (230 ± 9°F) (Note 9).

16.2.7. Determine the mineral matter in the extraction solution by one of the procedures specified in Annex A1.

17. CALCULATION OF ASPHALT BINDER CONTENT

17.1. Calculate the percentage of asphalt binder in the test portion in accordance with the procedure described in Section 13.

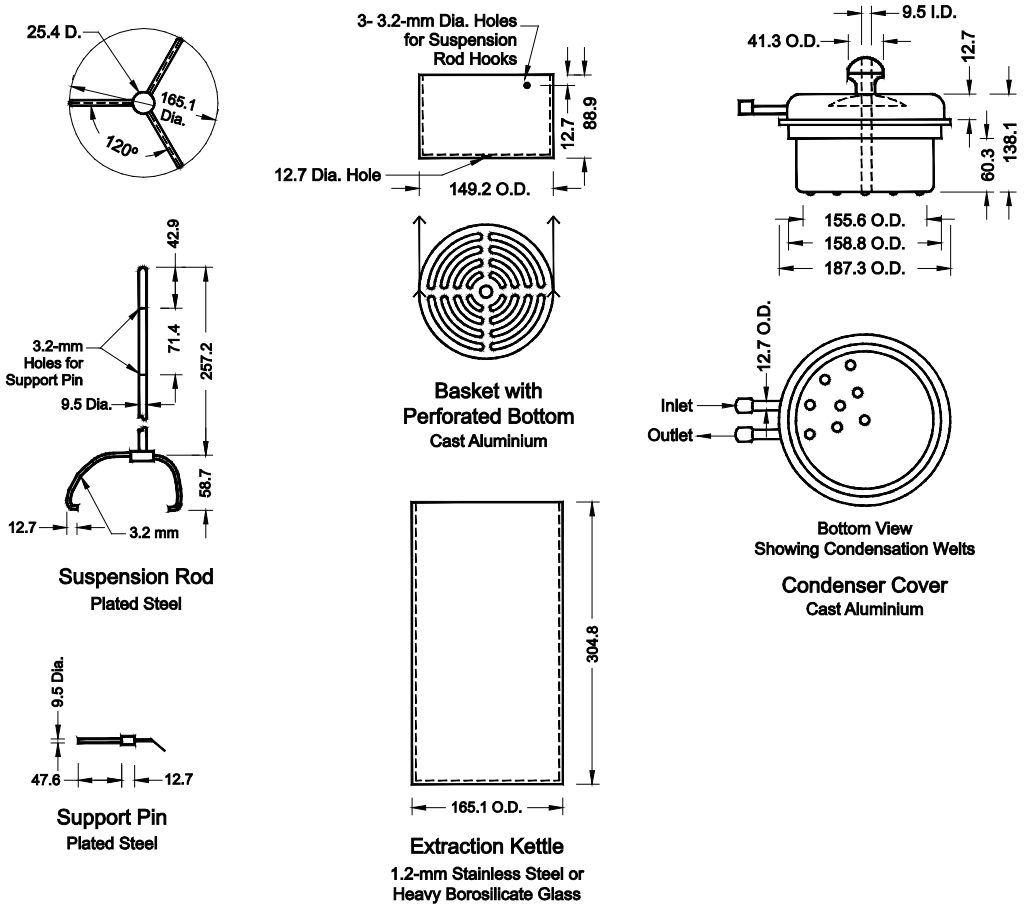
TEST METHOD D

18. APPARATUS

18.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Test Method D:

18.1.1. *Extraction Apparatus*—As shown in Figure 3, consisting of an extraction kettle of metal or borosilicate glass, fitted with a perforated basket and a condenser top. The underside of the condenser shall be covered with numerous rounded knobs to distribute the condenser solvent uniformly over the surface of the sample. The suspension of the basket shall be arranged to support the basket 13 mm ($^1/_2$ in.) above the bottom of the kettle, for immersion of the test portion in the solvent, and at least 75 mm (3 in.) above the bottom of the kettle for refluxing (Note 8).

18.1.2. *Cloth Filter Sacks*—With an elastic hem for lining the basket.



Note: All dimensions shown in millimeters unless otherwise noted.

Figure 3—Extractor Unit (Method D)

19. PREPARATION OF TEST PORTIONS

19.1. Prepare test portions for moisture determination and extraction in accordance with the procedure described in Section 9.

20. PROCEDURE

20.1. *Moisture*:

20.1.1. Determine the moisture content of the HMA (Section 9.2.3) in accordance with the method described in Section 10.

20.2. *Extraction*:

20.2.1. Insert a filter sack in the extraction basket, and determine the mass with the tare pan to determine the total tare mass. Place the test portion in the filter sack, and determine the total mass. Calculate the mass of the test portion.

20.2.2. Attach the suspension rod to the loaded basket, and set the assembly into the extraction kettle. Pour approximately 600 mL of solvent (Section 7.1, 7.2, or 7.3) over the test portion. Set the condenser cover in place on the kettle. Provide a flow of cold water through the condenser lid. Raise the basket to immersion level—for example 13 mm ($^1/_2$ in.) above the bottom of the kettle—by inserting the support pin through the upper hole of the suspension rod. Place the extractor on the hot plate and adjust the heating rate so that the solvent is maintained at a gentle boil, avoiding vigorous boiling, which might wash fines over the sides of the basket.

20.2.3. Continue heating with the test portion in the immersion position for 15 to 30 min, and then raise the basket to refluxing level. Increase the heat, and maintain active boiling until the solvent dripping from the basket appears to be a light straw color when viewed against a white background. If a stainless steel kettle is used, lift out the basket and the condenser cover assembly for examination of the solvent.

20.2.4. Remove the extractor from the hot plate, and allow it to cool for several minutes. Lift out the basket and condenser assembly. Cover the kettle; remove the filter sack, and distribute its contents into the tared pan in which the mass of the test portion was originally determined. Place the filter sack on top of the recovered aggregate. Dry on a steam bath and then in an oven at 110 ± 5°C (230 ± 9°F) to constant mass. Transfer the extract solution to a 1000-mL graduate. Wash the extractor clean with solvent, and add the washings to the extract solution.

20.2.5. Determine the mineral matter in the extract solution by one of the procedures specified in Annex A1.

21. CALCULATION OF ASPHALT BINDER CONTENT

21.1. Calculate the percentage of asphalt binder in the test portion in accordance with the procedure described in Section 13.

TEST METHOD E

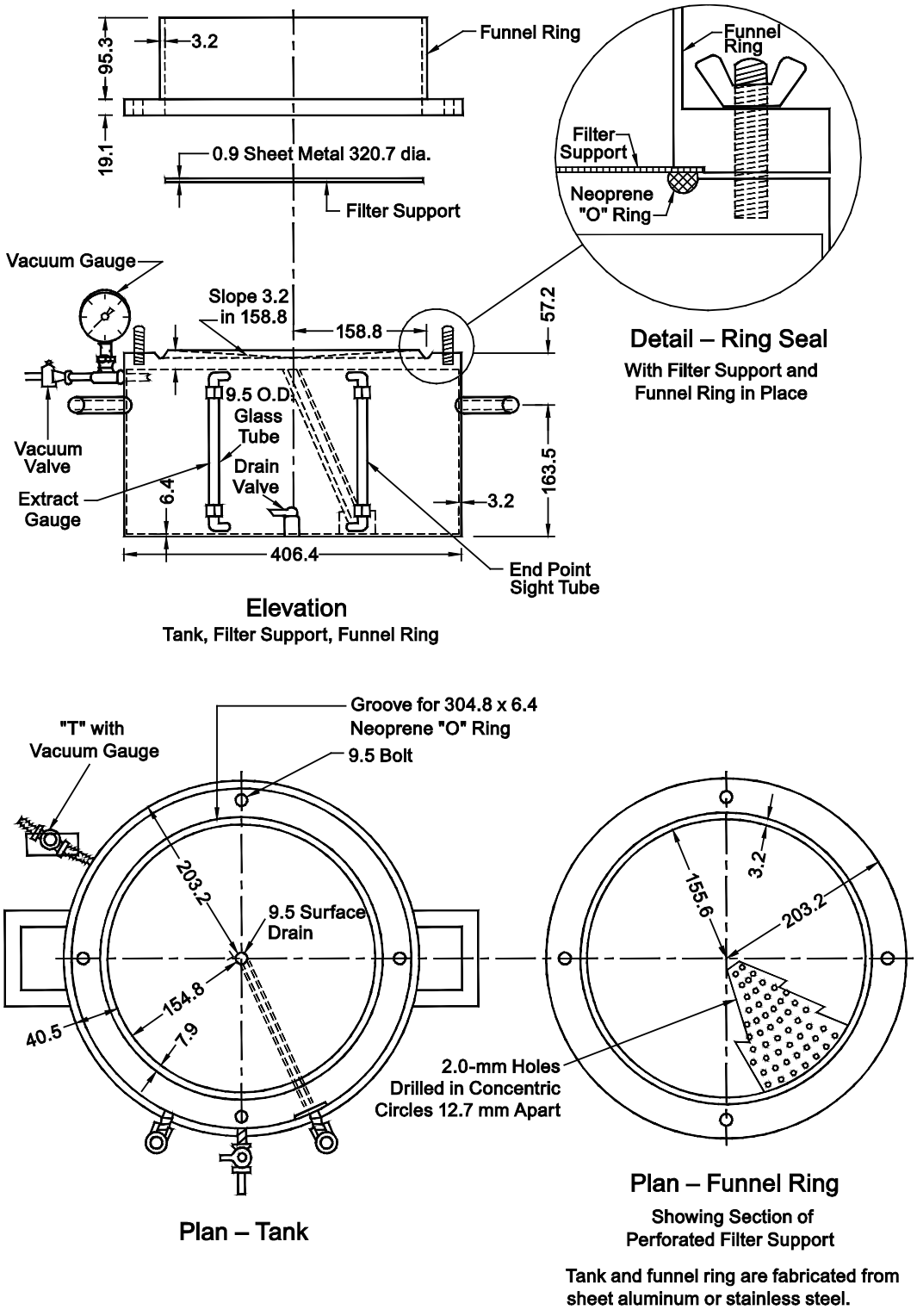
22. APPARATUS

22.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Test Method E:

22.1.1. *Vacuum Extractor*—Complete with the vacuum pump, gasket, rubber tubing, filter paper, support plate, and funnel ring. The dimensional equivalents and apparatus shown in Table 3, and Figures 4a, 4b, and 4c and similar designs, are suitable.

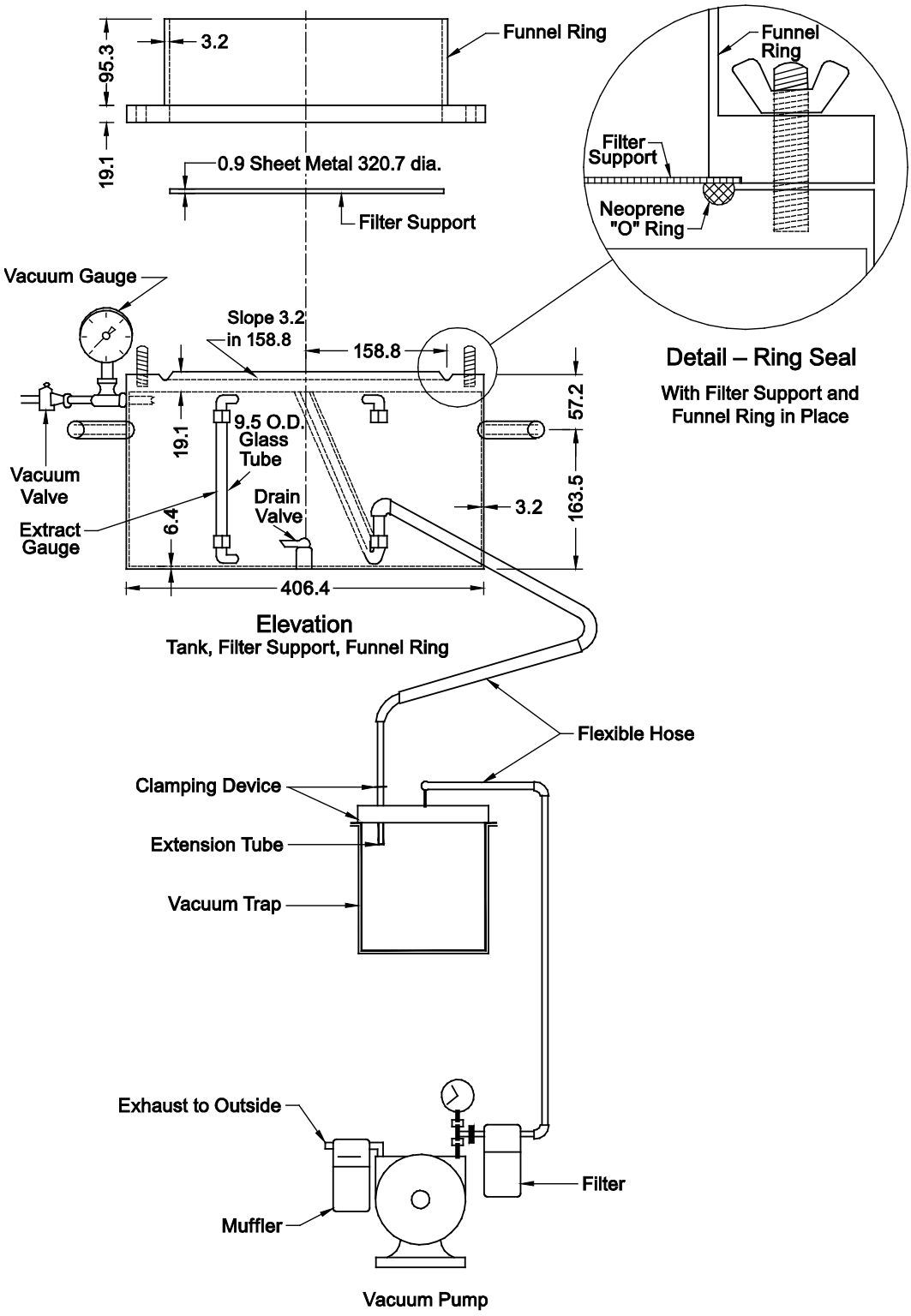
Table 3—Dimensional Equivalents

in.	mm	in.	mm
16	406	$2^{1}/_{4}$	57
$12^{5}/_{8}$	321	$1^{19}/_{32}$	40
12	305	$^{3}/_{4}$	19
8	203	$^{1}/_{2}$	12.7
$6^{7}/_{16}$	164	$^{3}/_{8}$	9.5
$6^{1}/_{4}$	159	$^{1}/_{4}$	6.4
$6^{1}/_{8}$	156	$^{3}/_{64}$	1.19
$6^{3}/_{32}$	155	0.060	1.52
$3^{3}/_{4}$	95		



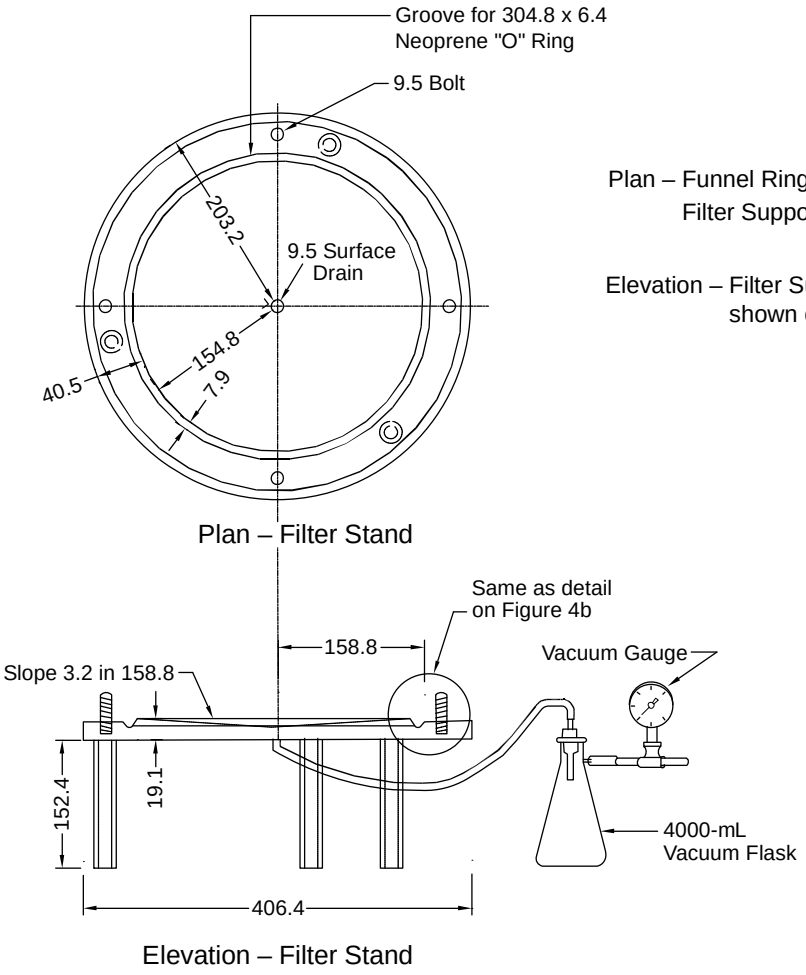
Note: See Table 3 for dimensional equivalents. All dimensions shown in millimeters unless otherwise noted.

Figure 4a—Vacuum Extractor



Note: All dimensions are shown in millimeters unless otherwise noted.

Figure 4b—Vacuum Extractor



Note: All dimensions are shown in millimeters unless otherwise noted.

Figure 4c—Vacuum Extractor

22.1.2. *Filter Paper*—Medium-grade, fast-filtering, 330 mm (13 in.) in diameter.

22.1.3. *Sample Container*—3.8-L (4-qt) capacity or greater.

22.1.4. *Erlenmeyer Flasks*—Glass, two, having a capacity of 4000 mL each.

22.1.5. *Graduate*—Glass, having a capacity of 500 mL.

22.1.6. *Wash Bottle*—Plastic, having a capacity of 500 mL.

22.1.7. *Dial Thermometer*—Having a range from 10 to 82°C (50 to 180°F).

22.1.8. *Mixing Spoon*.

22.1.9. *Spatula.*

22.1.10. *Stiff Bristled Brush.*

22.1.11. *Erlenmeyer Flask*—Glass, having a capacity of 1000 mL.

22.1.12. *Watch Glass*—Having a diameter of approximately 100 mm (4 in.).

22.1.13. *Metal Tongs*—150 to 200 mm (6 to 8 in.) long.

22.1.14. 1.18-mm (No. 16) and 75-µm (No. 200) sieves, 305 mm (12 in.) in diameter (optional).

Note 16—Use apparatus and materials listed under Sections 22.1.11, 22.1.12, 22.1.13, 23.1, and 23.2 only with HMA that is hard to filter, as in Method E-II.

22.1.15. *Stainless Steel Beaker*.

23. REAGENTS AND MATERIALS

23.1. *Diatomaceous Silica Filtering Aid*—Conforming to Type B of ASTM D604.[2]

23.2. *Ethyl Alcohol*—Denatured (optional).

23.3. *Methylene Chloride* (Note 17).

Note 17—Any of the other solvents listed in Section 7 may be substituted for methylene chloride.

24. PREPARATION OF TEST PORTIONS

24.1. Prepare test portions for moisture determination and extraction in accordance with the procedure described in Section 9.

25. PROCEDURE

25.1. Determine the moisture content of the HMA (Section 9.2.3) in accordance with the method described in Section 10.

25.2. *Extraction*:

25.2.1. Place the extraction test portion into the tared stainless steel beaker, and determine the mass (Note 18).

25.2.2. If the test portion is above 54°C (130°F), allow it to cool to a temperature less than 54°C (130°F). When sufficiently cool, pour 200 mL of denatured alcohol, if needed, over the specimen (Note 18). Add approximately 700 mL of extractant, and stir until the asphalt binder is visually in solution (Note 19).

Note 18—Alcohol should not be needed with terpene extractants.

Note 19—If equipment is available, an ultrasonic cleaning tank may be used instead of the beaker (Section 25.2.1) in which to bring the asphalt binder into solution (Section 25.2.2).

25.2.3. Dry the filter paper (more than one filter paper may be used) to constant mass in an oven at 110 ± 5°C (230 ± 9°F), and place the filter paper on the extractor, taking care to center the filter paper and tighten the wing nuts "finger tight" (Note 20).

Note 20—Experience has shown that clogging of the filter may be reduced by decanting the extract solution through nested 1.18-mm (No. 16) and 75-µm (No. 200) sieves onto the filter. When sieves are used, the solution will be decanted onto the 1.18-mm (No. 16) sieve instead of the filter.

25.2.4. Start the vacuum pump and slowly decant extract solution from the sample container onto the filter. When all solution has been removed from the filter paper, the vacuum pump may be stopped or left running.

25.2.5. Cover the sample remaining in the container with extractant, up to 700 mL. Stir gently until the asphalt binder and aggregate fines appear to be in suspension (or start the ultrasonic cleaner if used). Repeat the step in Section 25.2.4.

25.2.6. Repeat Section 25.2.5 until the solution is a light straw color (when viewed against a white background) and the aggregate is visually clean. The flow of solvent may be slowed for color observation by partially opening the vacuum valve and reducing the vacuum. If terpene extractant is used, pour all of the extractant onto the filter, and allow the vacuum to continue until the fluid has passed through the filter. Repeat Sections 25.2.5 and 25.2.4, using water preferably above 43°C (110°F), as many times as necessary to remove the terpene residue from the aggregate and render the rinse water clear. Operate the vacuum pump for a few minutes after the last wash to aid in drying the test portion. Scrape the aggregate away from the side of the funnel ring toward the center of the filter to avoid loss when the ring is removed. Also wash the sides of the funnel ring to remove any fines. Stop the vacuum pump and remove the ring, then brush the clinging aggregate into the tared drying pan. Carefully pick up the filter paper and aggregate by holding the paper on opposite sides and raising it straight up. Transfer the aggregate on the filter paper to the tared drying pan, and brush the clinging aggregate from the filter into the pan. Alternatively, the filter paper and aggregate may be contained separately in tared pans or the aggregate may be contained in a tared pan and the filter paper placed on top of it. In either case, use care to assure that all traces of aggregate in the test sample are transferred to the drying pan(s).

25.2.7. Dry the extracted aggregate and filter to a constant mass in an oven at 110 ± 5°C (230 ± 9°F) (Note 21).

Note 21—See the alternate procedure in Section 12.5.1 when low-ash filter paper is used.

25.2.8. Determine the mass of the filter and aggregate in the pan(s), and record it. Subtract the mass of the filter and pan to determine the mass of the extracted aggregate.

25.2.9. Determine the mineral matter in the extract solution by one of the procedures specified in Annex A1 (Note 22).

Note 22—Sections 25.2.9 and 25.2.15 may be omitted when this method is used only for control of asphalt binder content during HMA production (plant control).

25.2.10. To extract a slow-filtering HMA mixture efficiently, prepare the test portion as described in Sections 25.2.1 and 25.2.2.

25.2.11. Dry the filter paper to constant mass in an oven at 110 ± 5°C (230 ± 9°F), and place the filter paper on the extractor, taking care to center the filter paper and tighten the wing nuts "finger tight" (Note 20).

25.2.12. Weigh between 50 and 200 g of oven-dried diatomaceous silica filtering aid into a 1000-mL Erlenmeyer flask; record the mass, and then add 500 mL of extractant. Swirl until the diatomaceous silica is completely in suspension.

25.2.13. Immediately pour the diatomaceous silica and extractant over the filter. Two predried filters separated by an additional 50 to 100 g of diatomaceous earth may be used to retain the minus 75-μm (No. 200) material, if desired, to facilitate improved flow of the liquid. Start the vacuum pump, and let it run until the pad formed by the diatomaceous silica is surface dry and begins to crack slightly (Note 23).

Note 23—Some diatomaceous silica may be washed through the filter and included in the mineral matter determination of Section 25.2.15. Blank tests are recommended to determine the amount of diatomaceous silica, if any, lost through the filter. An appropriate correction will be required in the mineral matter mass.

25.2.14. Place the watch glass in the extractor, and slowly decant the extractant from the container over the watch glass (Note 24). Stop the vacuum pump when all the solution has been removed from the filter. Repeat as in Section 25.2.5, except decant the solution onto the watch glass. Complete the procedure as in Section 25.2.6. Also wash the watch glass with extractant to remove any fines onto the filter.

Note 24—When nested sieves are used, the watch glass may be omitted.

25.2.15. Determine the amount of mineral matter in the extract solution by one of the procedures specified in Annex A1 (Note 22).

26. CALCULATION OF ASPHALT BINDER CONTENT (APPLICABLE TO BOTH METHOD E-I AND METHOD E-II)

26.1. Calculate the percentage of asphalt binder in the test portion in accordance with the procedure described in Section 13.

27. PRECISION AND BIAS

27.1. The single-laboratory standard deviation has been found to be 0.18 percent. Therefore, results of two properly conducted tests by the same operator on the same batch should not differ by more than 0.52 percent. These values become 0.21 and 0.58, respectively, when extractant containing 85 percent terpene is used (Notes 25 and 26).

27.2. The multilaboratory standard deviation has been found to be 0.29 percent. Therefore, the results of two properly conducted tests from two different laboratories on samples from the same batch should not differ by more than 0.81 percent. These values become 0.29 and 0.83, respectively, when extractant containing 85 percent terpene is used (Notes 25 and 26).

Note 25—These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670.

Note 26—These precision statements are based on one pair of reference samples with 59 laboratories participating and three laboratory results deleted as outlying observations. The reference samples contained aggregate with 98 percent passing the 9.5-mm ($^3/_8$-in.) screen. All test methods were used in the interlaboratory test program.

ANNEX

(Mandatory Information)

A1. DETERMINING THE AMOUNT OF MINERAL MATTER IN THE EXTRACT

A1.1. *Ashing Method*:

A1.1.1. *Apparatus*:

A1.1.1.1. *Ignition Dish*—At least 125 mL in capacity.

A1.1.1.2. Ignition Furnace or Bunsen Burner.

A1.1.1.3. Steam Bath or Hot Plate.

A1.1.1.4. Desiccator.

A1.1.1.5. *Analytical Balance*—Conforming to the requirements of M 231, Class B.

A1.1.1.6. *Cylinder*—100 mL in capacity.

A1.1.2. *Reagents*:

A1.1.2.1. *Ammonium Carbonate Solution*—Saturated solution of reagent-grade ammonium carbonate [$(NH_4)_2CO_2$].

A1.1.3. *Procedure*:

A1.1.3.1. Determine either the volume or mass of the total extract (W_1). Condition the ignition dish in an ignition furnace or over a Bunsen burner at a dull red heat for a minimum of 10 min; cool it in a desiccator, and determine the mass of the ignition dish to the nearest 0.001 g. Agitate the extract thoroughly, and immediately measure 100 mL or 100 g into the ignition dish. Evaporate to dryness on a steam bath or hot plate. Ash the residue at a dull red heat [500 to 600°C (932 to 1112°F)] and cool it. Determine the mass of the ash, and add 5 mL of saturated ammonium carbonate solution per gram of ash. Digest at room temperature for 1 h. Dry in an oven at 110 ± 5°C (230 ± 9°F) to constant mass; cool in a desiccator, and determine the mass to the nearest 0.001 g (G). Calculate the mass of mineral matter in the total volume of extract (W_4) as follows:

$$W_4 = G\ (W_1/100) \qquad (A1.1)$$

where:

G = ash remaining in the ignition dish to nearest 0.001 g; and

W_1 = total volume, mL (or total mass, g) of extract.

A1.2. *Centrifuge Method*:

A1.2.1. *Apparatus*:

A1.2.1.1. Any suitable high-speed (3000-r/min or higher) centrifuge of the continuous-flow type.[3]

A1.2.1.2. Balance—Conforming to the requirements of M 231, Class G 1.

A1.2.1.3. Funnel or Steam Hood.

A1.2.2. *Procedure*:

A1.2.2.1. Determine the mass of a clean, empty centrifuge cup (or bowl) to the nearest 0.01 g, and place it in the centrifuge. Position a container at the appropriate spout to catch the effluent from the centrifuging operation. Transfer all of the extract (from Method A, B, D, or E as appropriate) to an appropriate (feed) container suitably equipped with a feed control (valve or clamp, etc.). To ensure quantitative transfer of the extract to the feed container, the receptacle containing the extract should be washed several times with small amounts of clean solvent and the washings added to the feed container. Start the centrifuge, and allow it to reach a constant operational speed (e.g., 9000 r/min for the SMM type and 20,000 + r/min for the Sharples type). Open the feed line, and feed the extract into the centrifuge at a rate of 100 to 150 mL/min. After all the extract has passed through the centrifuge, wash the feed mechanism (with the centrifuge still running) with several increments of clean solvent, allowing each increment to run through the centrifuge until the effluent is essentially colorless.

A1.2.2.2. Allow the centrifuge to stop, and remove the cup (or bowl). Clean the outside with fresh solvent. Allow the residual solvent to evaporate in a funnel or steam hood, and then dry the container in an oven controlled at 110 ± 5°C (230 ± 9°F). Cool the container and redetermine the mass to the nearest 0.01 g immediately. The increase in mass is the mass of mineral matter, W_4 (Section 13), in the extract.

A1.3. *Volumetric Method*:

A1.3.1. *Apparatus*:

A1.3.1.1. Flask.

A1.3.1.2. *Water Bath*—Capable of controlling temperature to ±0.1°C (±0.2°F).

A1.3.1.3. *Balance*—Conforming to the requirements of M 231, Class G 2.

A1.3.2. *Procedure*:

A1.3.2.1. Place the extract in a previously tared and calibrated flask. Place the flask in a constant-temperature bath controlled to ±0.1°C (±0.2°F), and allow it to reach the temperature at which the flask was calibrated. When the desired temperature has been reached, fill the flask with solvent at the same temperature. Bring the level of the liquid in the flask up to the neck; insert the stopper, making sure the liquid overflows the capillary, and remove the flask from the bath. Wipe the flask dry; determine the mass to the nearest 0.1 g, and record the result as the mass of the contents of the flask, M_1.

Note A1—Instead of using a controlled temperature bath, the temperature of the extract may be measured and the necessary corrections to the volume of the flask and the density of the asphalt binder and solvent made.

A1.3.2.2. After the extracted aggregate has dried to a constant mass and cooled, determine the mass to the nearest 0.1 g. Record the mass of the initial sample minus the mass of the extracted aggregate as the mass of the asphalt binder and fines in the extract, M_2.

A1.3.2.3. Calculate the volume of asphalt and fines in the extract as follows:

$$V_1 = V_2 - \frac{(M_1 - M_2)}{G_1} \quad (A1.2)$$

where:

V_1 = volume of asphalt and fines in the extract, mL;
V_2 = volume of the flask, mL;
M_1 = mass of the contents of the flask, g;
M_2 = mass of the asphalt binder and fines in the extract (or mass of the initial sample minus the mass of the extracted aggregate), g; and
G_1 = specific gravity of the solvent determined to the nearest 0.001 in accordance with ASTM D2111.

A1.3.2.4. Calculate the mass of fines in the extract as follows:

$$W_4 = K(M_2 - G_3 V_1) \quad (A1.3)$$

where:

W_4 = mass of mineral matter in the extract;
K = $\frac{G_2}{G_2 - G_3}$;
G_2 = specific gravity of fines as determined in accordance with T 84;
G_3 = specific gravity of asphalt binder as determined in accordance with T 228;
M_2 = as given in Section A1.3.2.3; and
V_1 = as given in Section A1.3.2.3.

[1] This method is similar to ASTM D2172/D2172M-11.
[2] Celite 110, manufactured by Johns-Manville, has been found satisfactory for this purpose; however, all filtering aids should be presieved through a 75-µm (No. 200) sieve when the gradation test on the aggregate is to be performed.
[3] The Sharples Supercentrifuge and the SMM continuous-flow centrifuge have been found suitable for this method.

Standard Method of Test for

Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

AASHTO Designation: T 166-13

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 Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

AASHTO Designation: T 166-13

AASHTO

1. SCOPE

1.1. This method of test covers the determination of bulk specific gravity (G_{mb}) of specimens of compacted hot mix asphalt (HMA).

1.2. This method should not be used with samples that contain open or interconnecting voids or absorb more than 2.0 percent of water by volume, as determined in Sections 7.2 or 10.2 herein. If the sample contains open or interconnecting voids or absorbs more than 2.0 percent of water by volume, then T 275 or T 331 should be used.

1.3. The bulk specific gravity (G_{mb}) of the compacted HMA may be used in calculating the unit mass of the mixture.

Note 1—The values for bulk specific gravity (G_{mb}) obtained from T 275 or T 331 may differ. Care should be exercised when comparing test results from T 275 and T 331.

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

1.5. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all 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*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 275, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

2.2. *ASTM Standards:*

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D7227/D7227M, Standard Practice for Rapid Drying of Compacted Asphalt Specimens Using Vacuum Drying Apparatus

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *bulk specific gravity (of solids)* (G_{mb})—the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of the expression shall be:

bulk specific gravity (G_{mb}) at x/y °C *(1)*

where:

x = temperature of the material; and

y = temperature of the water.

3.1.2. *constant mass*—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals when using oven drying, or by more than 0.05 percent when weighed after at least two drying cycles of the vacuum-drying apparatus required in ASTM D7227/D7227M.

4. TEST SPECIMENS

4.1. Test specimens may be either laboratory-compacted HMA or sampled from HMA pavements.

4.2. *Size of Specimens*—It is recommended that: (1) the diameter of cylindrically compacted or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one and one-half times the maximum size of the aggregate.

4.3. Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

4.4. Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

4.6. If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.

METHOD A

5. APPARATUS

5.1. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231. The weighing device shall be equipped with a suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of the scale pan of the weighing device.

5.2. *Suspension Apparatus*—The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

5.3. *Water Bath*—For immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level.

6. PROCEDURE

6.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying. As an alternative to oven drying to constant mass, drying the sample according to ASTM D7227/D7227M may be used. When using ASTM D7227/D7227M to achieve constant mass, perform the drying procedure at least twice, with a mass determination after each drying cycle.

6.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 2). Immerse each specimen in the water bath at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 min, and record the immersed mass as *C*. Remove the specimen from the water bath; damp-dry the specimen by blotting it with a damp towel, and determine the surface-dry mass as *B* as quickly as possible *(the entire operation is not to exceed 15 s)*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually.

Note 2—If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass *C* can be taken, then the surface-dry mass *B*, and finally the dry mass *A*.

Note 3—Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

7. CALCULATION

7.1. Calculate the bulk specific gravity (G_{mb}) of the specimen as follows:

$$\text{bulk specific gravity} = \frac{A}{B - C} \qquad (2)$$

where:

A = mass of the specimen in air, g;
B = mass of the surface-dry specimen in air, g; and
C = mass of the specimen in water, g.

7.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{percent of water absorbed by volume} = \frac{B - A}{B - C} \times 100 \qquad (3)$$

7.3. If the percent of water absorbed by the specimen as calculated in Section 7.2 exceeds 2.0 percent, use either T 275 or T 331 to determine the bulk specific gravity (G_{mb}).

METHOD B

8. APPARATUS

8.1. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231.

8.2. *Water Bath*—For immersing the specimen in water.

8.3. *Thermometer*—ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

8.4. *Volumeter*[1]—Calibrated to 1200 mL, or an appropriate capacity depending on the size of the test sample. The volumeter shall have a tapered lid with a capillary bore.

9. PROCEDURE

9.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying. As an alternative to oven drying to constant mass, drying using ASTM D7227/D7227M may be used. When using ASTM D7227/D7227M to determine the constant mass, follow the drying procedure at least twice, with a mass determination after each drying procedure.

9.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 2). Immerse the specimen in the water bath at 25 ± 1°C (77 ± 1.8°F), and let it saturate for at least 10 min. At the end of the 10-min period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F), and weigh the volumeter. Designate this mass as *D*. Remove the saturated specimen from the water bath and damp-dry the specimen by blotting with a damp towel (Note 3) as quickly as possible (not to exceed 5 s). Weigh the specimen, and record the surface-dry mass as *B*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen.

9.3. Place the specimen into the volumeter, and let it stand for at least 60 s. Bring the temperature of the water to 25 ± 1°C (77 ± 1.8°F), and cover the volumeter, making certain that some water escapes through the capillary bore of the tapered lid. Wipe the outside of the volumeter dry with a dry, absorbent cloth, and weigh the volumeter and its contents (Note 4). Record this weight as *E*.

Note 4—If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of the saturated, damp-dry specimen *B* can be taken. Then the volumeter containing the saturated specimen and water *E* can be weighed. The dry mass of the specimen *A* can be determined last.

Note 5—Method B is not acceptable for specimens that have more than 6 percent air voids.

10. CALCULATIONS

10.1. Calculate the bulk specific gravity (G_{mb}) of the specimen as follows:

$$\text{bulk specific gravity} = \frac{A}{B + D - E} \qquad (4)$$

where:

A = mass of the dry specimen, g;

B = mass of the surface-dry specimen, g;

D = mass of the volumeter filled with water at 25 ± 1°C (77 ± 1.8°F), g; and

E = mass of the volumeter filled with the specimen and water at 25 ± 1°C (77 ± 1.8°F), g.

10.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{percent of water absorbed by volume} = \frac{B - A}{B + D - E} \times 100 \qquad (5)$$

10.3. If the percent of water absorbed by the specimen as calculated in Section 10.2 exceeds 2.0 percent, use either T 275 or T 331 to determine the bulk specific gravity (G_{mb}).

METHOD C (RAPID TEST)

11. PROCEDURE

11.1. This procedure can be used for testing specimens that are not required to be saved and that contain a substantial amount of moisture. Specimens obtained by coring or sawing can be tested the same day by this method.

11.2. The testing procedure shall be the same as given in Section 6 or 9 except for the sequence of operations. The dry mass A of the specimen is determined last as follows:

11.2.1. Place the specimen in a large, flat-bottom drying pan of known mass. Place the pan and specimen in an oven at 110 ± 5°C (230 ± 9°F). Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than 6.3 mm ($^1/_4$ in.). Place the separated specimen in an oven at 110 ± 5°C (230 ± 9°F), and dry to a constant mass.

11.2.2. Cool the pan and specimen to room temperature at 25 ± 5°C (77 ± 9°F). Determine the mass of the pan and specimen, subtract the mass of the pan, and record as the dry mass, A.

12. CALCULATIONS

12.1. Calculate the bulk specific gravity (G_{mb}) as given in Section 7.1 or 10.1.

13. REPORT

13.1. *The report shall include the following*:

13.1.1. The method used (A, B, or C).

13.1.2. Bulk specific gravity (G_{mb}) reported to the nearest thousandth.

13.1.3. Absorption reported to the nearest hundredth.

14. PRECISION

Table 1—Precision Estimates for T 166

Condition of Test	Standard Deviation (1s)[a]	Acceptable Range of Two Results (d2s)[a]
Single-operator precision	0.002	0.006
Multilaboratory precision	0.006	0.017

[a] These values represent the 1s and 2ds limits described in ASTM C670.

Note: Based on interlaboratory study described in NCHRP Research Report 9-26 Phase 2 involving 150-mm-diameter specimens, 20 laboratories, three materials (9.5-mm, 12.5-mm, and 19.0-mm mixtures), and two replicates.

[1] Suitable aluminum volumeters of different sizes are available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA 16127; and Rainhart Co., 604 Williams St., Austin, TX 78765.

Designation: D979/D979M – 15

Standard Practice for Sampling Bituminous Paving Mixtures[1]

This standard is issued under the fixed designation D979/D979M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers sampling of bituminous paving mixtures at points of manufacture, storage, delivery, or in place.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *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 *ASTM Standards:*[2]

D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

D2234/D2234M Practice for Collection of a Gross Sample of Coal

D2726 Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures

D3665 Practice for Random Sampling of Construction Materials

D5361 Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing

D5444 Test Method for Mechanical Size Analysis of Extracted Aggregate

D6307 Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method

D6925 Test Method for Preparation and Determination of the Relative Density of Asphalt Mix Specimens by Means of the Superpave Gyratory Compactor

D6926 Practice for Preparation of Bituminous Specimens Using Marshall Apparatus

D6927 Test Method for Marshall Stability and Flow of Asphalt Mixtures

E105 Practice for Probability Sampling of Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

2.2 *AASHTO Standard:*[3]

R 47 Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *field sample, n*—a quantity of the material to be tested of sufficient size to provide an acceptable estimate of the average quality of a unit.

3.1.2 *increment, n*—part of a sample.

3.1.3 *lot, n*—a sizable isolated quantity of bulk material from a single source, assumed to have been produced by the same process (for example, a day's production or a specific mass or volume).

3.1.4 *test portion, n*—a quantity of the material of sufficient size extracted from the larger field sample by a procedure designed to ensure accurate representation of the field sample, and thus of the unit sampled.

3.1.5 *unit, n*—a batch or finite subdivision of a lot of bulk material (for example, a truck load or a specific area covered).

4. Significance and Use

4.1 *General:*

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and are the direct responsibility of Subcommittee D04.30 on Methods of Sampling.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

4.1.1 Sampling is equally as important as the testing, and the sampler shall take every precaution to obtain samples that will yield an acceptable estimate of the nature and conditions of the materials which they represent.

4.1.2 Samples for the development of preliminary data are obtained by the party responsible for the development of the data. Samples for control of the product at the source of manufacture or storage, or at the site of use, are obtained by the manufacturer, contractor, or other parties responsible for accomplishing the work. Samples for tests to be used in acceptance or rejection decisions by the purchaser are obtained by the purchaser or his authorized representative.

4.1.3 This standard shall not be used for the sampling of compacted bituminous paving mixtures. Practice D5361 shall be used.

5. Apparatus

5.1 *Container*—A bucket, pan, box, or other vessel of a sufficient size to contain the sample.

5.2 *Release Agent*—A non-stick product that promotes an easy separation of the bituminous paving mixture from the sampling tools without degrading the material being sampled.

5.3 *Sampling Tool*—A shovel, scoop, or other device used to obtain samples.

5.4 *Truck Sampling Device (optional)*—A mechanical apparatus that enables the user to retrieve material from the bed of a truck without standing in the bed of the truck. An example of one type of truck sampling device is shown in Fig. 1.

6. Procedure

6.1 *Inspection*—The material shall be inspected to determine discernible variations. The seller shall provide equipment needed for safe and appropriate inspection and sampling.

6.2 *Release Agents*—The user and producer of the bituminous paving mixtures must mutually agree upon the use of a release agent. If used, the approved release agent shall be lightly applied to the sampling tools and truck sampling device. Diesel fuel shall not be used.

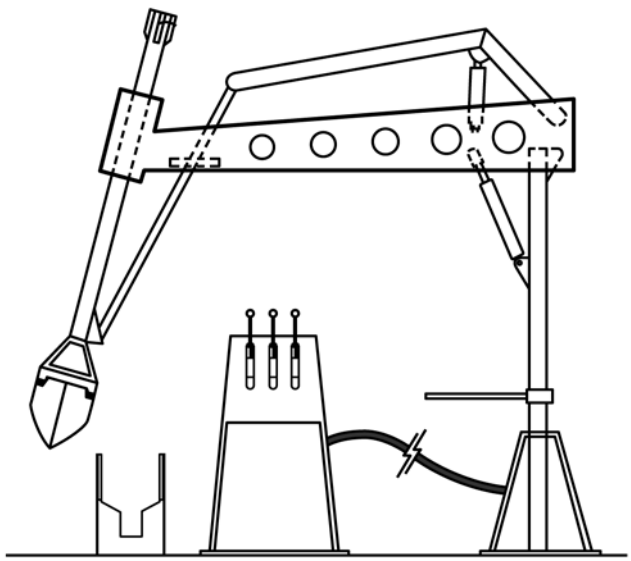

FIG. 1 Example of One Type of Truck Sampling Device

6.3 *Sampling*—The procedures for selecting locations or times for sampling are described in Practice D3665.

6.3.1 *Sampling from a Conveyor Belt*—Stop the conveyor belt. Randomly select at least three areas of approximately equal size on the belt for sampling. In each of the locations to be sampled, insert templates, the shape of which conform to the shape of the belt. From the selected areas obtain approximately equal increments of material which will form a sample whose quantity equals or exceeds the minimum recommended in 6.4.2. Carefully scoop all material between templates into a suitable container.

6.3.2 *Sampling from Truck Transports*—By a random method, select the units to be sampled from the production of materials delivered. Obtain at least three approximately equal increments. Avoid sampling the extreme top surface. Select at random from the unit being sampled and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2. The sample may be obtained by collecting the increments with a truck sampling device, scoop, or shovel.

NOTE 1—Users should refer to the manufacturer's instructions to learn how to properly operate and maintain a truck sampling device, if used.

6.3.3 *Sampling from the Roadway Prior to Compaction*—When only one sample is to be taken, obtain at least three approximately equal increments, selected at random from the unit being sampled, and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.3.1 When three or more samples are to be taken in order to evaluate a lot of material, utilize a random method to determine the locations to be sampled. Select a sample, consisting of approximately three equal increments, from each location, assuring the quantity of each sample exceeds the minimum recommended in 6.4.2.

6.3.3.2 Take all increments or samples from the roadway for the full depth of the material, taking care to exclude any underlying material. When necessary, place templates on the existing roadway to exclude any underlying material. Clearly mark the specified area from which each increment or sample is to be removed. Templates which are placed before the mixture is spread will be a definite aid securing increments of approximately equal mass.

6.3.4 *Sampling from a Skip Conveyor Delivering Mixture to Bin Storage*—Select the units to be sampled from the skip conveyor by a random method based on the bin's storage capacity. Stop the skip conveyor immediately following pug mill discharge. Dig a furrow 150 mm [6 in.] in depth extending from the top to the bottom of the pile. Obtain three approximately equal increments from the top, middle, and bottom of the furrow depositing each increment in a container. The combined increments should form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.5 *Sampling from a Funnel Device Feeding a Conveyor for Mixture Delivery to Storage*—Select the units to be sampled

from the funnel device by a random method based on the bin's maximum storage capacity. Obtain at least three approximately equal increments of material for each sample by passing a bucket or pan or other suitable container across the full flow of materials as it drops from the funnel device onto the conveyor. The combined portions should form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.6 *Sampling from Bituminous Cold Mix Stockpiles*—Cold mixes that are in a stockpile for some time may develop a crust on the surface of the pile. This crust should be removed to a depth of 100 mm, over an area of one square meter, to expose the unweathered mix. Stir the exposed stockpile and obtain three approximately equal samples selected at random from the unit being sampled, and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 6.4.2.

6.3.6.1 When three or more samples are to be taken, sample in accordance with 6.3.3.1.

6.4 *Number and Quantities of Field Samples:*

6.4.1 The number of field samples (obtained by one of the methods described in 6.3) required depends on the criticality of, and variation in, the properties to be measured. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples from the production should be sufficient to give the desired confidence in test results.

NOTE 2—Guidance for determining the number of samples required to obtain the desired level of confidence in test results may be found in Practices D2234/D2234M, E105, E122, and E141.

NOTE 3—The unit to be represented by a single field sample should not be so large as to mask the effects of significant variability within the unit. Nor should a unit be so small as to be affected by the inherent variability between small portions of any bulk material.

NOTE 4—A unit of bulk material composed of graded aggregate or aggregate mixtures might consist of a full truckload. If it were possible, the entire load might be tested as a practical matter. A field sample is composed of three or more increments chosen at random from the material as it is loaded or unloaded from the truck. Research has shown that such a procedure permits an acceptable estimate to be made of the average gradation that might be measured from 15 or 20 increments from the truck.

NOTE 5—Significant variability within a lot of material, where it might exist, should be indicated by statistical measures, such as the standard deviation between units selected at random from within the lot.

6.4.2 The quantities of the material in the sample depend on the type and number of tests to which the material is to be subjected, and sufficient material must be obtained to provide for the proper execution of these tests. Standard control and acceptance tests are covered by ASTM standards and specify the portion of the field sample required for each specific test. Table 1 provides a guide of the minimum amounts of bituminous mixture that will be needed for routine testing for Test Methods D6307, D5444, D2041, D2726, D6925, and D6927, and Practice D6926. If there are to be additional tests, the sample size must be increased. If there are fewer tests to be performed, adjust the size of the sample accordingly. Extract test portions from the field sample by quartering or splitting in a similar manner to AASHTO Standard Practice R 47 or as required by other applicable test methods.

TABLE 1 Guide for Estimating Minimum Sample Quantity

Maximum Size of Aggregates[A]	Uncompacted Mixture	
	Approximate Mass min, kg [lb]	Approximate Volume L [Gal]
2.36-mm (No. 8)	10 [22]	8 [2]
4.75-mm (No. 4)	10 [22]	8 [2]
9.5-mm (⅜-in.)	16 [35]	12 [3]
12.5-mm (½-in.)	20 [45]	15 [4]
19.0-mm (¾-in.)	20 [45]	15 [4]
25.0-mm (1-in.)	24 [52]	18 [5]
37.5-mm (1½-in.)	30 [66]	22 [6]
50-mm (2-in.)	35 [75]	22 [6]

[A] The maximum size of aggregate is the largest sieve size listed in the applicable specification upon which any material is permitted to be retained.

7. Shipping Samples

7.1 Transport samples in containers so constructed as to preclude loss or contamination of any part of the sample, or damage to the contents from mishandling during shipment.

7.2 Samples shall have individual identification attached giving the information required by the sample user. Typical information that may be useful could include, but not necessarily be limited to, the following:

7.2.1 Job for which the material is to be used, giving project number, highway route number, county, and other pertinent geographical information,

7.2.2 Source of sample, including for plant-mixed samples the name of owner or operator of plant, location of plant, type of plant, size of batch, and identification of bitumen and mineral aggregates used in the mixture,

7.2.3 Point at which sampled, for samples taken from roadway, both by station number and location transversely in pavement; also whether sampled from completed pavement, windrow, etc.,

7.2.4 Quantity represented,

7.2.5 By whom sampled and title,

7.2.6 Date of most recent mixing, if road-mixed,

7.2.7 Date sampled,

7.2.8 By whom submitted and address,

7.2.9 Purpose for which sample was taken, and

7.2.10 To whom report is to be made.

8. Keywords

8.1 asphalt paving mixture; bituminous paving mixture; mechanical truck sampling device; sampling

Standard Method of Test for

Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)

AASHTO Designation: T 209-12

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

Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)

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AASHTO

1. SCOPE

1.1. This test method covers the determination of the theoretical maximum specific gravity/gravity mix maximum (G_{mm}) and density of uncompacted hot mix asphalt (HMA) at 25°C (77°F).

Note 1—The precision of the method is best when the procedure is performed on samples that contain aggregates that are completely coated. In order to assure complete coating, it is desirable to perform the method on samples that are close to the optimum asphalt binder content.

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*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
- T 168, Sampling Bituminous Paving Mixtures

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D4311/D4311M, Standard Practice for Determining Asphalt Volume Correction to a Base Temperature

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *density, as determined by this test method*—the mass of a cubic meter of the material at 25°C (77°F) in SI units, or the mass of a cubic foot of the material at 25°C (77°F) in inch-pound units.

3.1.2. *residual pressure, as employed by this test method*—the pressure in a vacuum vessel when vacuum is applied.

3.1.3. *specific gravity, as determined by this test method*—the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. SUMMARY OF TEST METHOD

4.1. A weighed sample of oven-dry HMA in the loose condition is placed in a tared vacuum container. Sufficient water at a temperature of 25 ± 0.5°C (77 ± 0.9°F) is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum container to 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). At the end of the vacuum period, the vacuum is gradually released. The volume of the HMA sample is obtained either by immersing the vacuum container with the sample into a water bath and determining the mass (Section 13.1) or by filling the vacuum container level full of water and determining the mass in air (Section 13.2). At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 25°C (77°F) is calculated. If the temperature employed is different than 25°C (77°F), an appropriate correction is applied.

5. SIGNIFICANCE AND USE

5.1. The theoretical maximum specific gravities and densities of HMA are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt materials.

5.1.1. These properties are used to calculate percent air voids in compacted HMA.

5.1.2. These properties provide target values for the compaction of HMA.

5.1.3. These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in HMA.

6. APPARATUS

6.1. Follow the procedures for performing equipment calibrations, standardizations, and checks found in R 61.

6.2. *Vacuum Container*:

6.2.1. The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of 0.075-mm (No. 200) wire mesh to minimize the loss of fine material.

6.2.2. The capacity of the vacuum container should be between 2000 and 10 000 mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.2.3. *Vacuum Bowl*—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4. *Vacuum Flask for Mass Determination in Air Only (Section 13.2)*—A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.2.5. *Pycnometer for Mass Determination in Air Only*—A glass, metal, or plastic pycnometer.

6.3. *Balance*—A balance conforming to the requirements of M 231, Class G 2. The balance shall be standardized at least every 12 months.

6.3.1. For the mass determination-in-water method (Section 13.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

6.4. *Vacuum Pump or Water Aspirator*—Capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mmHg).

6.4.1. When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6.5. *Vacuum Measurement Device*—Residual pressure manometer[1] or vacuum gauge to be connected directly to the vacuum vessel and capable of measuring residual pressure down to 4.0 kPa (30 mmHg) or less (preferably to zero). The gauge shall be standardized at least annually and be accurate to 0.1 kPa (1 mmHg). It shall be connected at the end of the vacuum line using an appropriate tube and either a "T" connector on the top of the vessel or a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer shall not be situated on top of the vessel.

Note 2—A residual pressure of 4.0 kPa (30 mmHg) absolute pressure is approximately equivalent to a 97 kPa (730 mmHg) reading on a vacuum gauge at sea level.

Note 3—Residual pressure in the vacuum container, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum container.

Note 4—An example of a correct arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum container that otherwise would enter the oil in the vacuum pump and decrease the pump's ability to provide adequate vacuum. Insertion of a valve to isolate the line to each vacuum chamber can reduce wear on the bleeder valve atop each chamber and assist in tracing sealing leaks.

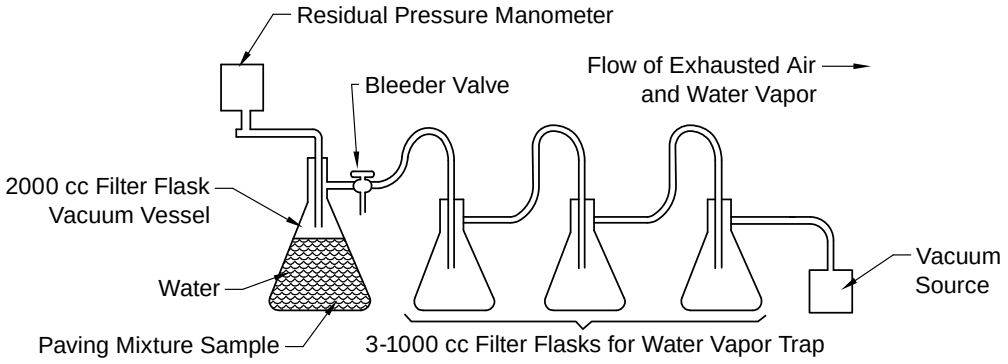

Figure 1—Example of Correct Arrangement of Testing Apparatus

6.6. *Bleeder Valve*—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.

6.7. *Thermometric Device (Mass Determination in Air)*—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F), of suitable range with subdivisions of 0.5°C (1°F). The thermometric device shall be standardized at the test temperature at least every 12 months.

6.8. *Water Bath*:

6.8.1. For vacuum bowls, a water bath capable of maintaining a constant temperature between 20 and 30°C (68 and 86°F) is required. (See Appendix X1 for a method for correcting the theoretical maximum specific gravity to 25°C (77°F) when measurements are made at temperatures other than 25°C (77°F)).

6.8.2. *Thermometric Device (Mass Determination in Water)*—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F) shall be used to measure the temperature of the water bath. The thermometric device shall be standardized at least every 12 months.

6.8.3. When using the mass determination-in-water technique (Section 13.1), the water bath must be suitable for immersion of the suspended container with its deaerated sample.

6.9. *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 135 ± 5°C (275 ± 9°F) or 105 ± 5°C (221 ± 9°F).

6.9.1. *Thermometric Device*—A liquid-in-glass thermometer or other thermometric device accurate to 3°C (5°F) shall be used to measure the temperature of the oven. The thermometric device shall be standardized at least every 12 months.

6.10. *Protective Gloves*—Used when handling glass equipment under vacuum.

7. SAMPLING

7.1. Field samples shall be obtained in accordance with T 168. When necessary, reduce field samples or samples prepared or produced in a laboratory in accordance with R 47.

7.2. The size of the sample shall conform to the following requirements. Samples larger than the capacity of the container may be tested a portion at a time.

Table 1—Minimum Sample Sizes

Nominal Maximum Aggregate Size, mm	Minimum Sample Size, g
37.5 or greater	4000
19 to 25	2500
12.5 or smaller	1500

8. STANDARDIZATION OF FLASKS, BOWLS, AND PYCNOMETERS

8.1. For the mass determination-in-water method (Section 13.1), standardize the vacuum bowls for temperature correction by determining the mass of each container when immersed in water over the range of water bath temperatures likely to be encountered in service (Figure 2).

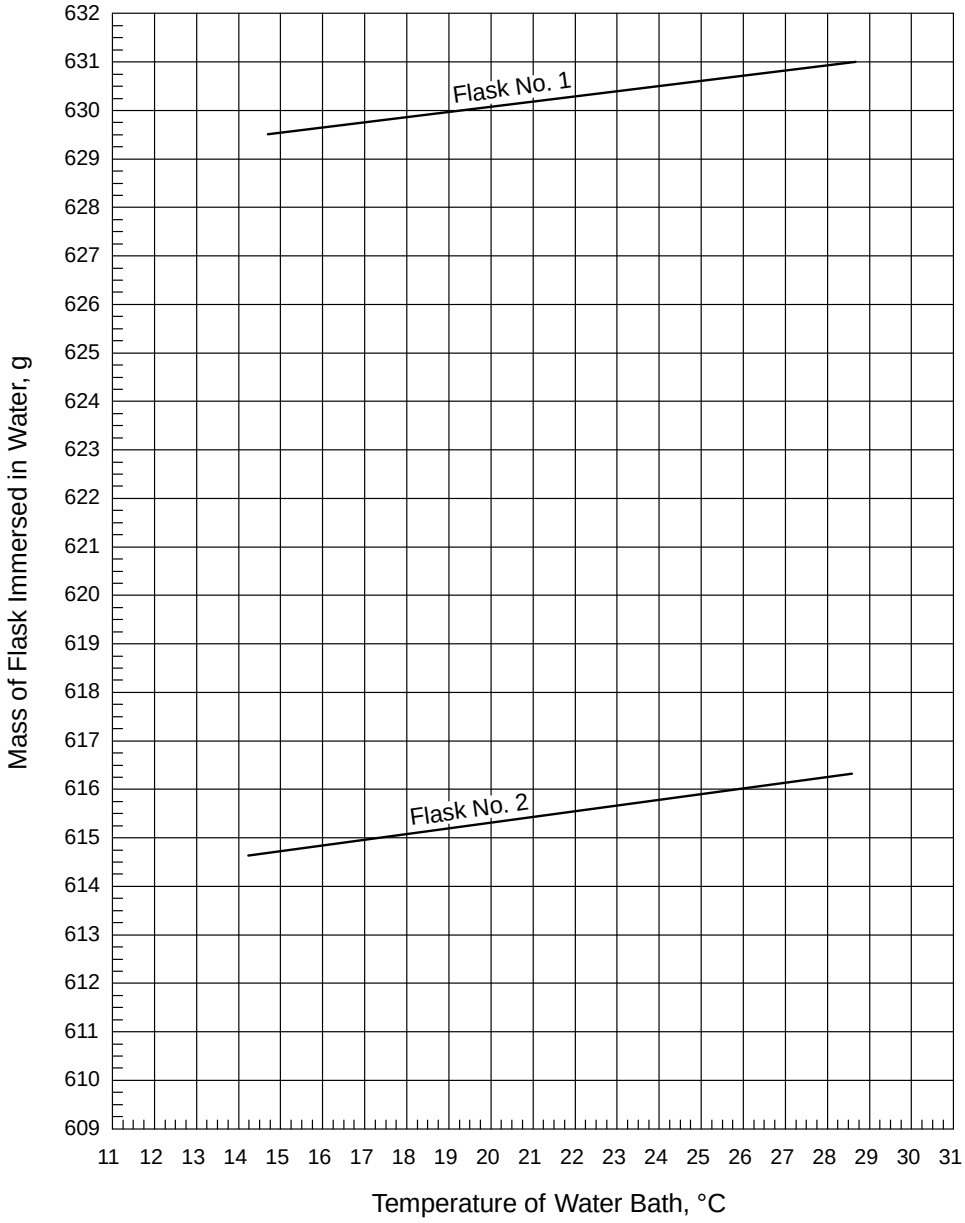

Figure 2—Example Standardization Curve for Volumetric Flask

8.2. For the mass determination-in-air method (Section 13.2), standardize the volumetric flasks or pycnometers for temperature correction by determining the mass of the container when filled with water over the range of water bath temperatures likely to be encountered in service (Figure 3). When standardized at 25 ± 0.5°C (77 ± 0.9°F), designate this mass as *D*. Accurate filling may be ensured by the use of a glass cover plate.

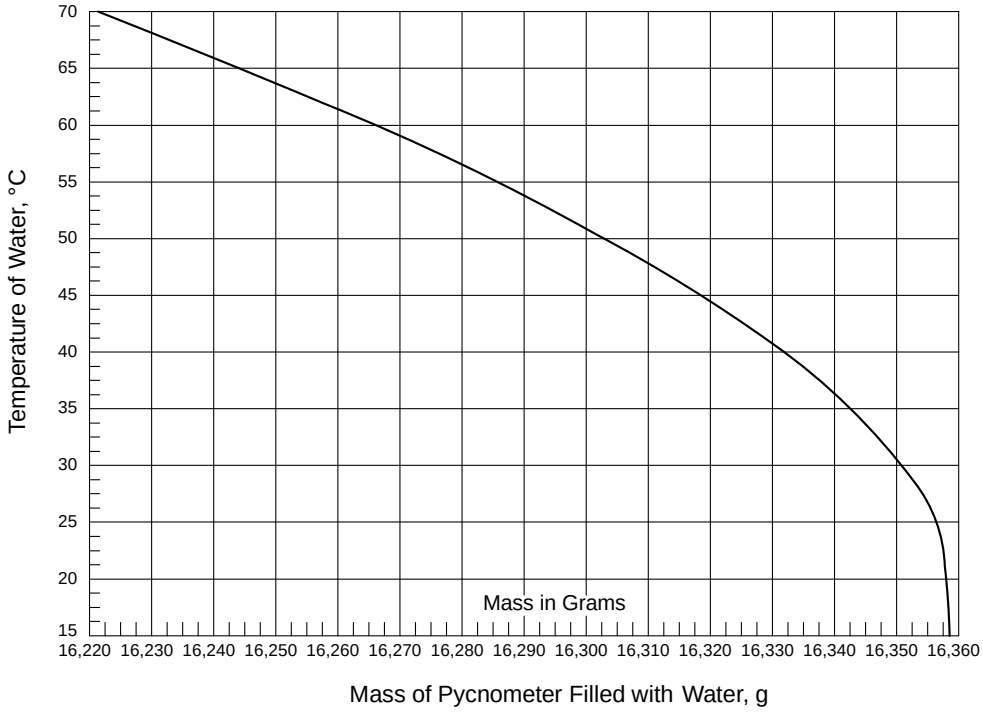

Figure 3—Example Standardization Curve for Pycnometer

8.3. Standardize the large-size plastic pycnometer by accurately determining the mass of water required to fill it over a range of temperature from about 20 to 65°C (70 to 150°F), and construct a standardization curve of mass versus temperature as shown in Figure 3. Care should be taken to follow exactly the same procedure in standardization as in conducting a test.

8.3.1. The following filling procedure may be used for the model with a latched lid and vented stopper: The domed lid is latched in place and the pycnometer nearly filled with water. Leave about 50 mm (2 in.) empty. The release of air bubbles may be facilitated by applying vacuum and by dropping first one side then the other of the pycnometer about 10 mm ($^1/_2$ in.) above a hard, flat surface. This vacuum application and bubble release procedure should take about 10 min so that the temperature equilibrium between the shell and the water approximates that attained when performing a test. The final amount of water is then gently poured in until the level is about halfway up the neck. Any air bubbles caught against the dome that cannot be released by jarring or by swirling the water may be "pricked" or pushed to the surface with a bent wire or other suitable device. Insert the vented stopper using only enough force to just seat the stopper and immediately wipe the excess water off the top.

8.3.2. For the models with a quick-disconnect vacuum line and unlatched lid, the filling procedure is as follows: With the inlet valve closed, apply a vacuum of about 30 kPa (225 mmHg). Open the inlet valve slowly letting water in until the level reaches 25 mm (1 in.) below the top of the dome and close the valve. Continue applying vacuum and release the bubbles by jarring and rapping the vessel with a rubber mallet. Slowly open the inlet valve and allow more water in until the water overflows into the aspirator (vacuum) line and then close the valve. This vacuum application and bubble release procedure should take about 10 min so that the temperature equilibrium between the shell and the water approximates that attained when performing a test. Disconnect the vacuum line by pulling it out at the quick-disconnect joint below the gauge.

8.3.3. Wipe the outside of the pycnometer dry, determine the mass of the full pycnometer, and measure the water temperature.

Note 5—The shape of the standardization curve is a function of two opposing factors that can be rationally defined. As the temperature is increased, the container itself expands (adding mass—"Pycnometer" line in Figure 4) and the density of the contained water decreases (resulting in loss of mass—"Water" line in Figure 4). These relationships are shown in Figure 4 for a typical large-size pycnometer. The "Water" curve may be constructed by multiplying the volume at 25°C (77°F) by the difference between the density of water at 25°C (77°F), which is 0.9970, and the density of water at the standardization temperature (see Equation 1).

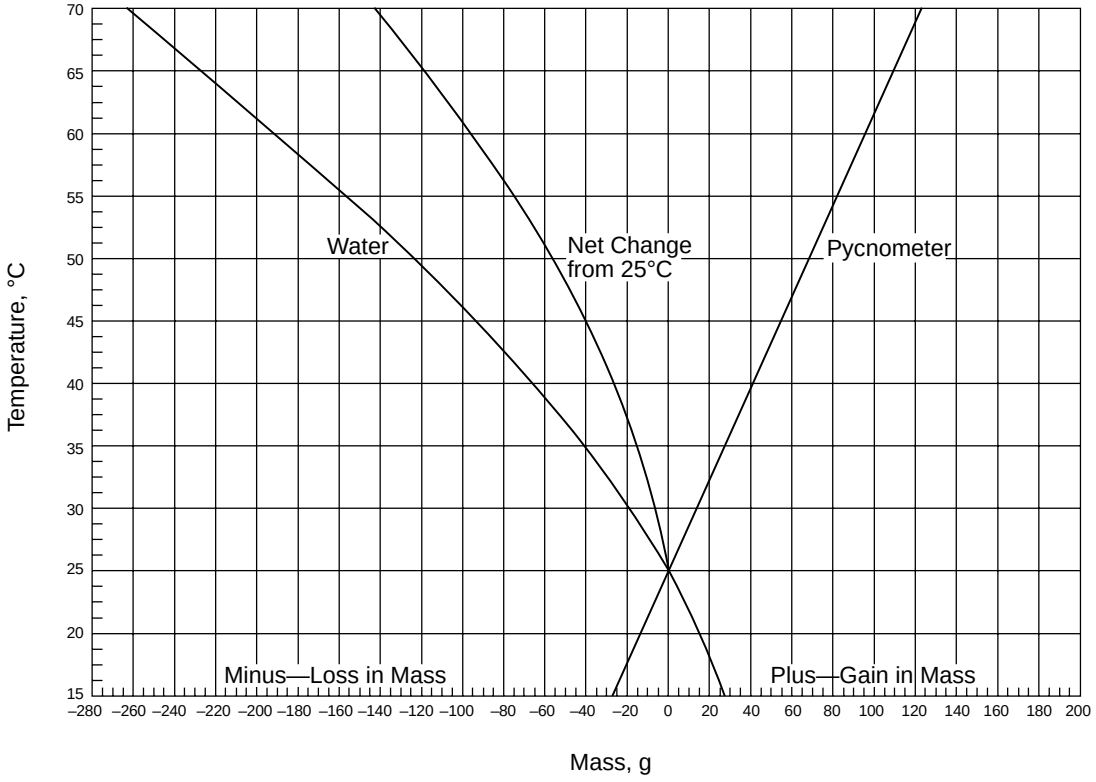

Figure 4—Effect of Change in Density of Water and Volume of Pycnometer with Change in Temperature

$$\text{difference due to water expansion} = V_{25}(0.9970 - dw)$$

Since $V_{25} = W_{25}/0.9970$

$$V_{25}(0.9970 - dw) \text{ reduces to } W_{25}\left(1 - \frac{dw}{0.9970}\right) \qquad (1)$$

where:

V_{25} = volume of water to fill a container at 25°C (77°F), cm^3;
W_{25} = mass of water to fill a container at 25°C (77°F), g; and
dw = density of water at the standardization temperature, Mg/m^3.

The rate of change in capacity of the container due to thermal expansion of the pycnometer itself is essentially constant over the temperature range from 20 to 65°C (70 to 150°F). Thus, the "Pycnometer" line in Figure 4 can be drawn through the 0 at 25°C (77°F) point knowing only the slope of the straight line relationship. The slope can be established by averaging at least five standardization mass determinations at some elevated temperature, adding the loss due to water expansion and subtracting the mass at 25°C (77°F), W_{25}, to give the gain in capacity due to

expansion of the container. The difference in mass divided by the difference in temperature is the slope of the "Pycnometer" line. For a polycarbonate pycnometer of about 13 500-mL capacity, the slope thus established was 2.75 g/°C (1.53 g/°F). This value is believed to be typical and reasonably constant.

The bending of the standardization curve (Figure 3) due to these offsetting thermal factors thus minimizes experimental error due to temperature effects in the normal working range, 25°C (77°F), for both the volumetric flask and the pycnometer containers. Defining the standardization curve makes it possible to correct for temperature, rather than "bringing the container and sample to temperature," thereby eliminating the cost of a water bath and making it feasible to improve accuracy by testing larger samples and to materially reduce the testing time.

8.4. While standardization of the flask or either pycnometer needs to be performed only once, the standardization should be checked occasionally, particularly at 25°C (77°F). The equipment must be kept clean and free from any accumulation that would change the mass if the volume standardization is to remain constant. Care should be taken to use only neutral solvents, especially with plastic containers; glass vessels should not be subjected to high vacuum if they are scratched or damaged.

9. SAMPLE PREPARATION

9.1. Separate the particles of the HMA sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm ($^1/_4$ in.). If an HMA sample is not sufficiently soft to be separated manually, place it in a pan, and warm it in an oven until it can be separated as described.

9.2. Samples prepared in a laboratory shall be conditioned and dried in an oven at 135 ± 5°C (275 ± 9°F) for a minimum of 2 h or as appropriate to match the mix design procedure being used. Longer drying time may be necessary for the sample to achieve a constant mass (mass repeats within 0.1 percent). HMA that has not been prepared in a laboratory with oven-dried aggregates shall be dried to a constant mass at a temperature of 105 ± 5°C (221 ± 9°F). This drying and conditioning operation shall be combined with any warming described in Section 9.1.

Note 6—The minimum 2 h time in the oven is specified as the short-term conditioning time for laboratory-prepared specimens. The short-term conditioning at the specified temperature is especially important when absorptive aggregates are used. This short-term conditioning will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced HMA should not be short-term conditioned because absorption takes place during production.

9.3. Cool the sample to room temperature, and place it in a tared and standardized flask, bowl, or pycnometer. The sample is to be placed directly into a vacuum container. A container within a container is not to be used. Determine the mass and designate the net mass of the sample as *A*. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

Note 7—The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001 percent or 0.2 g in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.

TEST METHOD A—MECHANICAL AGITATION

10. APPARATUS

10.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Method A:

10.1.1. *Mechanical Shaker*—Shaker for removing air from asphalt mix.

11. PROCEDURE

11.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents using the mechanical device during the vacuum period. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

11.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mmHg) per second and proceed with one of the mass determination methods in Section 13.

TEST METHOD B—MANUAL AGITATION

12. PROCEDURE

12.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period by vigorously shaking at intervals of about 2 min. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

12.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mmHg) per second and proceed with one of the mass determination methods in Section 13.

13. MASS DETERMINATION

13.1. *Mass Determination in Water*—Suspend the container and contents in the water bath and determine the mass after a 10 ± 1 min immersion. Measure the water bath temperature, and if different from 25 ± 1°C (77 ± 2°F), correct the mass to 25°C (77°F) using the standardization temperature adjustment developed in Section 8.1. Designate the mass of the sample in water at 25°C (77°F) as *C*.

Note 8—Instead of using a chart like Figure 2 to establish the mass correction for the temperature of the vacuum vessel submerged by itself in the water bath, this correction can be easily established by rapidly and completely emptying the vacuum container immediately following the final mass determination, and then without delay, determining the mass of the vessel by itself when totally submerged in the water bath.

13.2. *Mass Determination in Air*—Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of 25 ± 1°C (77 ± 2°F). Determine the mass of the container and

contents, completely filled, in accordance with Section 8.2 within 10 ± 1 min after completing Section 11.1 or 12.1. Designate this mass as *E*.

Note 9—See Appendix X1 for correcting the theoretical maximum specific gravity when measurements are made at temperatures other than 25°C (77°F).

14. CALCULATION

14.1. Calculate the theoretical maximum specific gravity (G_{mm}) of the sample at 25°C (77°F) as follows:

14.1.1. *Mass Determination in Water*:

$$\text{theoretical maximum specific gravity} = \frac{A}{A - C} \qquad (2)$$

where:

A = mass of the oven-dry sample in air, g; and

C = mass of the sample in water at 25°C (77°F), g.

14.1.2. *Mass Determination in Air*:

$$\text{theoretical maximum specific gravity} = \frac{A}{A + D - E} \qquad (3)$$

where:

A = mass of the oven-dry sample in air, g;

D = mass of the container filled with water at 25°C (77°F), g; and

E = mass of the container filled with the sample and water at 25°C (77°F), g.

14.1.3. *Large-Size Plastic Pycnometer Determinations*:

14.1.3.1. If the test temperature is between 22.2 and 26.7°C (72 and 80°F), Equation 3 may be used to calculate specific gravity (G_{mm}) within a minor amount of error due to thermal effects (0.001 points or less).

14.1.3.2. If the test temperature differs significantly from 25°C (77°F), correct for thermal effects as follows:

$$\text{specific gravity} = \frac{A}{(A + F) - (G + H)} \times \frac{dw}{0.9970} \qquad (4)$$

where:

A = mass of the oven-dry sample in air, g;

F = mass of the pycnometer filled with water at the test temperature (Figure 3), g;

G = mass of the pycnometer filled with water and the sample at the test temperature, g;

H = correction for thermal expansion of asphalt (Figure 5), g;

dw = density of water at the test temperature, Curve D in Figure 6, Mg/m^3; and

0.9970 = density of water at 25°C (77°F), Mg/m^3.

The ratio (dw/0.9970) is Curve R in Figure 6.

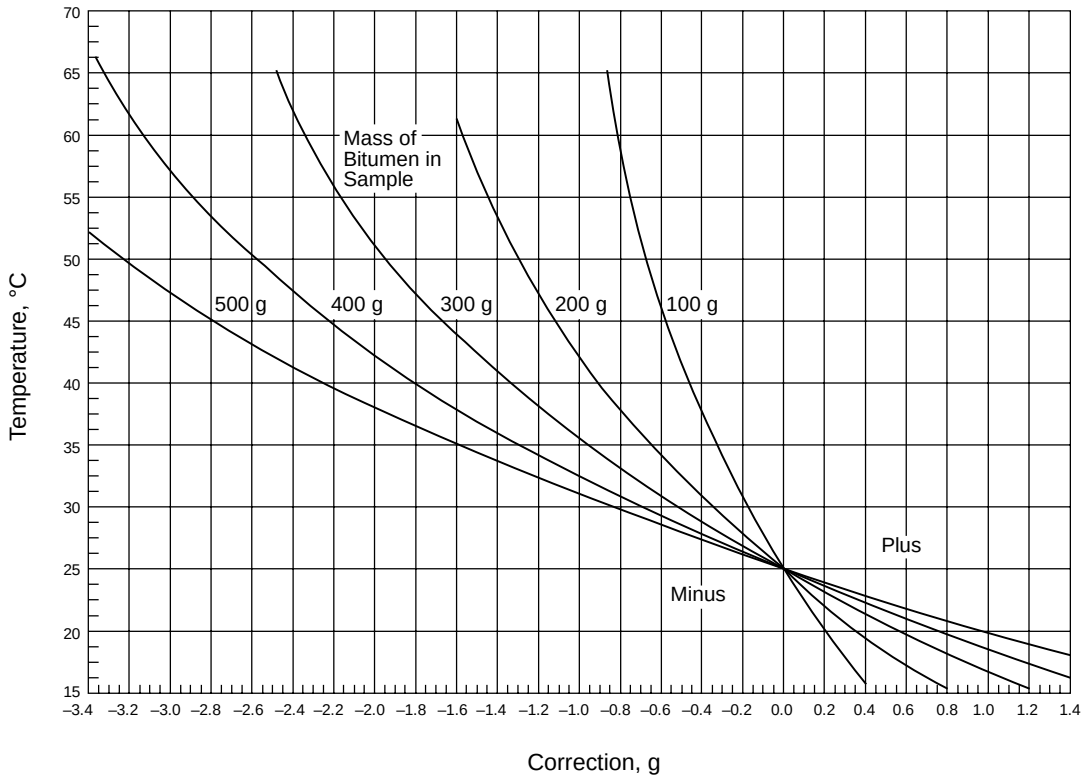

Figure 5—Correction Curves for Expansion of Asphalt, *H*, in Equation 4

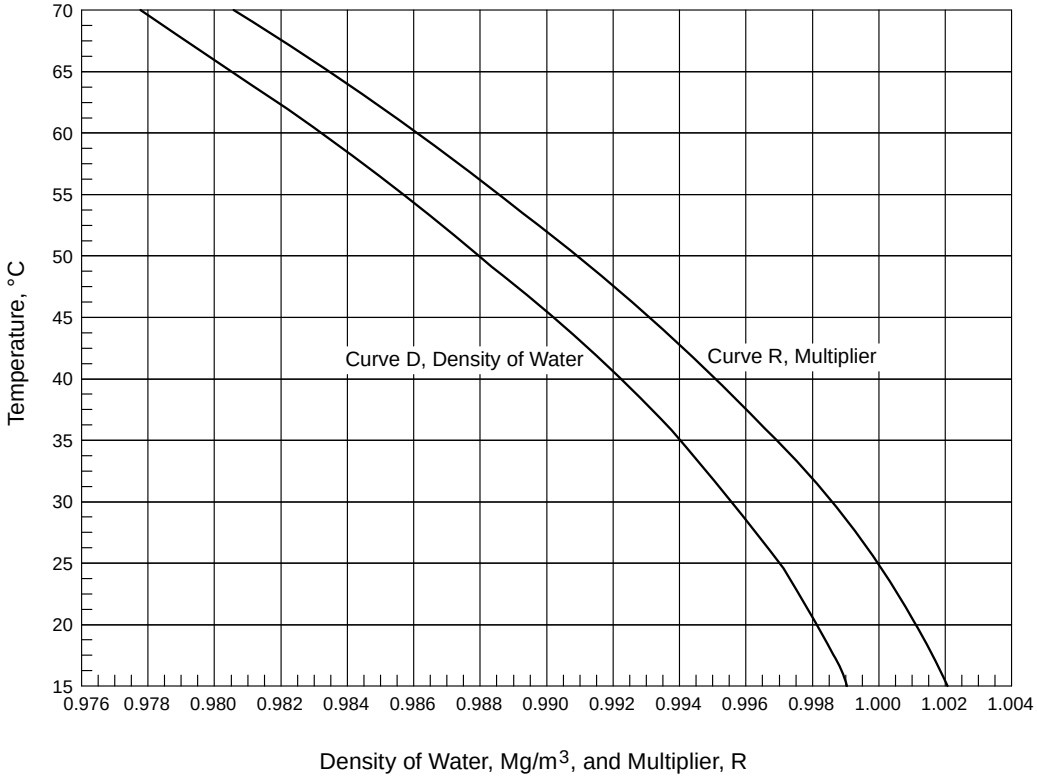

Figure 6—Curves D and R for Equation 4

Note 10—This general procedure for correcting for thermal effects should also be applicable to corresponding measurements made with other suitable containers.

Note 11—When samples are tested a portion at a time, differences between the maximum specific gravities for each portion should be within the precision statements listed in Section 17. If the values are within the precision statements, the specific gravities for each portion shall be averaged. If the values are outside the precision statements, the test shall be performed again.

14.2. *Theoretical maximum density (G_{mm}) at 25°C (77°F)*:

14.2.1. Calculate the corresponding theoretical maximum density (G_{mm}) at 25°C (77°F) as follows:

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 997.1 kg/m^3 in SI units.

or

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 62.245 lb/ft^3 in inch-pound units.

where:

The density of water at 25°C (77°F) = 997.1 kg/m^3 in SI units or 62.245 lb/ft^3 in inch-pound units.

15. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE

Note 12—Experiments indicate that this supplemental procedure has an insignificant effect on the test results if the HMA contains individual aggregate with a water absorption below 1.5 percent.

15.1. If the pores of the aggregates are not thoroughly sealed by an asphalt film, they may become saturated with water during the application of vacuum. To determine if this condition has occurred, proceed as follows after completing Section 13.1 or 13.2. Drain the water from the sample. To prevent the loss of fine particles, decant the water through a towel held over the top of the container. Break several large pieces of aggregate and examine the broken surfaces for wetness.

15.2. If the aggregate has absorbed water, spread the sample before an electric fan to remove the surface moisture. Determine the mass at 15-min intervals, and when the loss in mass is less than 0.05 percent for this interval, the sample may be considered to be surface dry. This procedure requires about 2 h and shall be accompanied by intermittent stirring of the sample. Break conglomerations of HMA by hand. Take care to prevent loss of the HMA particles.

15.3. To calculate the specific gravity of the sample, substitute the final surface-dry mass determined in Section 15.2 for *A* in the denominator of Equation 2 or 3 as appropriate.

16. REPORT

16.1. *Report the following information*:

16.1.1. G_{mm} and density of the HMA to the nearest 0.001 for specific gravity or nearest 1 kg/m^3 (0.1 lb/ft^3) for density as follows: sp gr 25/25°C (77/77°F) or density at 25°C (77°F);

16.1.2. Type of HMA;

16.1.3. Size of the sample;

16.1.4. Number of samples;

16.1.5. Type of container; and

16.1.6. Type of procedure.

17. PRECISION

17.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table:

Table 2—Precision Estimates

Test and Type Index	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)
Test results obtained without use of Section 15		
Method A [a]		
Single-operator precision	0.0051	0.014
Multilaboratory precision	0.0084	0.024
Method B [b]		
Single-operator precision	0.0064	0.018
Multilaboratory precision	0.0103	0.029

[a] Basis of estimate: 1 replicate, 1 material, 344 laboratories.

[b] Basis of estimate: 1 replicate, 1 material, 134 laboratories.

17.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. Multilaboratory precision has not been verified for 4500-mL or larger pycnometers.

17.3. The values in Column 3 are the acceptable range for two tests. When more than two results are being evaluated, the range given in Column 3 must be increased. Multiply the standard deviation(s) in Column 2 by the multiplier given in Table 1 of ASTM C670 for the number of actual tests.

Example for three tests: $0.004 \times 3.3 = 0.013$.

Additional guidance and background is given in ASTM C670.

APPENDIX

(Nonmandatory Information)

X1. THEORETICAL MAXIMUM SPECIFIC GRAVITY FOR LOOSE HMA

X1.1. *Scope*:

X1.1.1. This appendix has two objectives:

X1.1.1.1. To indicate a method for correcting the theoretical maximum specific gravity to 25°C (77°F) when measurements are made at temperatures other than 25°C (77°F).

X1.1.1.2. To indicate the range of temperature in °C above or below 25°C (77°F) within which no temperature correction is required, because the measured theoretical maximum specific gravity values are shown to be 0.0004 or less away from the value determined at 25°C (77°F).

X1.2. *Indicated Values*:

X1.2.1. The following example values are indicated for the theoretical maximum specific gravity of a loose HMA sample:

X1.2.1.1. Mass of the loose HMA sample = 1251.3 g.

X1.2.1.2. Volume of the loose HMA sample at 25°C (77°F) = 492.77 mL.

X1.2.1.3. Asphalt binder content = 5.0 percent of total mix.

X1.2.1.4. Specific gravity of the asphalt at 25°C (77°F) = 1.029.

X1.2.1.5. Combined bulk specific gravity of the aggregate = 2.714.

X1.2.1.6. Cubical coefficient of expansion of the asphalt binder at 20°C (68°F) = 6.2×10^{-4} mL/mL/°C (ASTM D4311/D4311M).

X1.2.1.7. Cubical coefficient of expansion of the aggregate at 20°C (68°F) = 2.2×10^{-5} mL/mL/°C.[2]

X1.3. *Basis of Calculation for 1 g of Loose HMA at 20°C (68°F)*:

X1.3.1. Mass of the asphalt binder = 0.05 g.

X1.3.2. Volume of the asphalt binder = 0.05/1.029 = 0.0486 mL.

X1.3.3. Mass of the aggregate = 0.95 g.

X1.3.4. Volume of the aggregate = 0.95/ 2.714 = 0.3500 mL.

X1.3.5. Volume of the asphalt binder plus aggregate in 1 g of loose HMA at 20°C (68°F) = 0.0486 + 0.3500 = 0.3986 mL.

X1.4. *Basis of Calculation for Volume Change of 1 g of Loose HMA for1°C (2°F) from 20°C (68°F)*:

X1.4.1. Volume change for the asphalt binder = $6.2 \times 10^{-4} \times 0.0486 = 0.3013 \times 10^{-4}$ mL = 3.0130×10^{-5} mL.

X1.4.2. Volume change for the aggregate = $2.2 \times 10^{-5} \times 0.3500 = 0.77 \times 10^{-5}$ mL.

X1.4.3. Volume change for 1 g of loose HMA for 1°C (2°F) change in temperature from 20°C (68°F) = $3.0130 \times 10^{-5} + 0.7700 \times 10^{-5} = 3.7830 \times 10^{-5}$ mL.

X1.5. *Volume Correction*:

X1.5.1. For a difference in water temperature of 1°C (2°F) above or below 20°C (68°F), a correction to the volume of water displaced by 1 g of loose HMA can be made by the following equation:

$$\text{correction} = \Delta T \times K_T \times V_T \text{ mL} \qquad (X1.1)$$

where:

ΔT = 1°C (2°F);

K_T = volume change of 1 g of loose HMA for a 1°C (2°F) change in temperature above or below 20°C (68°F) = 3.7830×10^{-5} mL; and

V_T = volume of water for a corresponding 1251.3-g mass of loose HMA at a test temperature of 20°C (68°F) = 492.77 mL.

Substituting these values into the equation gives the following:

Correction = $1 \times 3.7830 \times 10^{-5} \times 492.77 = 0.01864$ mL/g at 20°C (68°F).

X1.6. Table X1.1 illustrates an example of the influence of temperature corrections. For a measured volume and a given mass of HMA tested at specific temperatures, this table relates these influences to the specific gravity of the HMA.

Table X1.1—Influence of Temperature Corrections to a Measured Volume at 20°C of a Given Mass of Loose Paving Mixture, to Provide the Required Theoretical Maximum Specific Gravity at 25°C

Temperature, °C	Volume of HMA at 20°C (68°F), mL	Volume Correction for Temp Change	Corrected Volume of HMA at 20°C (68°F), mL	Mass of HMA, g	Specific Gravity of HMA
1	*2*	*3*	*4 = 2 + 3*	*5*	*6 = 5/4*
31	492.77	0.2046	492.975	1251.3	2.5383
30[a]	492.77	0.1860	492.956	1251.3	2.5384
29[a]	492.77	0.1674	492.937	1251.3	2.5385
28[a]	492.77	0.1488	492.919	1251.3	2.5386
27[a]	492.77	0.1302	492.900	1251.3	2.5386
26[a]	492.77	0.1116	492.882	1251.3	2.5387
25[a]	492.77	0.0930	492.863	1251.3	2.5388
24[a]	492.77	0.0744	492.844	1251.3	2.5389
23[a]	492.77	0.0558	492.826	1251.3	2.5390
22[a]	492.77	0.0372	492.807	1251.3	2.5391
21[a]	492.77	0.0186	492.789	1251.3	2.5392
20	492.77	0.0000	492.772	1251.3	2.5393
19	492.77	–0.0186	492.751	1251.3	2.5394

[a] Range less than 0.0005.

Notes: Strictly speaking, the above table shows that the specific gravity for this particular mix, as measured at 20°C (68°F), just fails to meet the corrected theoretical maximum specific gravity at 25°C (77°F), 2.5388 versus 2.5393, that is, by 0.0005, and that a temperature correction would be required. If the measurement for volume had been made at 21°C (70°F), the table indicates that no temperature correction would have been necessary, because the measurement at 21°C (70°F) would have satisfied the theoretical maximum specific gravity at 25°C (77°F), 2.5388 versus 2.5392, a difference of less than 0.0005.

[1] Sargent Welch, 39745 Gauge-Vacuum, Mercury Prefilled (or equivalent).
[2] Krebs and Walker, *Highway Materials*, McGraw-Hill, Inc., 1971, p. 274.

Standard Method of Test for

Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus

AASHTO Designation: T 245-15

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

Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus

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AASHTO

1. SCOPE

1.1. This method covers the measurement of the resistance to plastic flow of cylindrical specimens of asphalt mixture loaded on the lateral surface by means of the Marshall apparatus. This method is for use with mixtures containing asphalt binder or asphalt cutback and aggregate up to 25.4-mm (1-in.) maximum size.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- R 68, Preparation of Asphalt Mixture Specimens by Means of the Marshall Compactor
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 275, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens

3. APPARATUS

3.1. *Breaking Head (Figure 1)*—Shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm (2 in.) accurately machined. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.

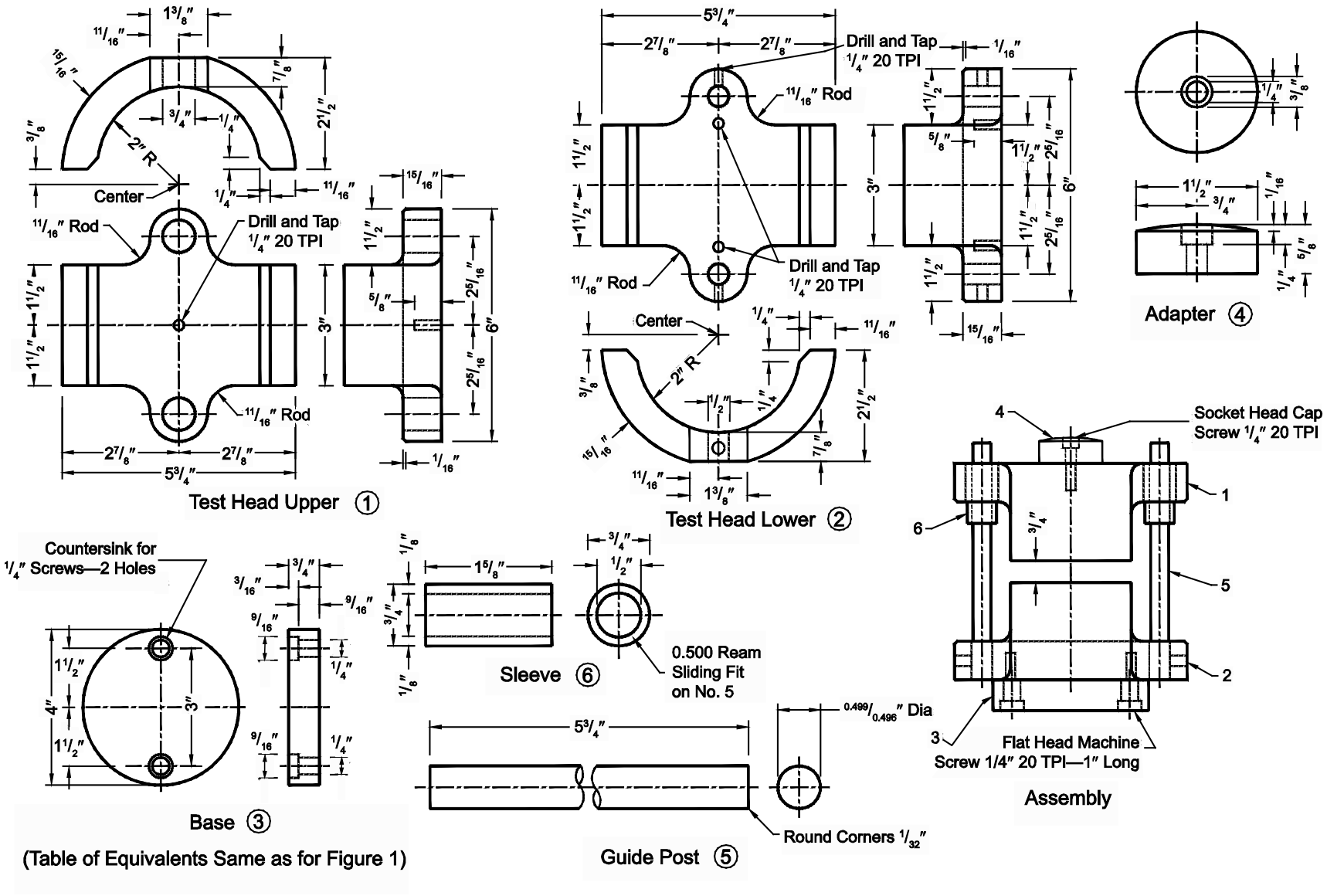


Figure 1—Breaking Head

3.2. *Loading Jack*—The loading jack (Figure 2) shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm (2 in.)/min. An electric motor may be attached to the jacking mechanism.

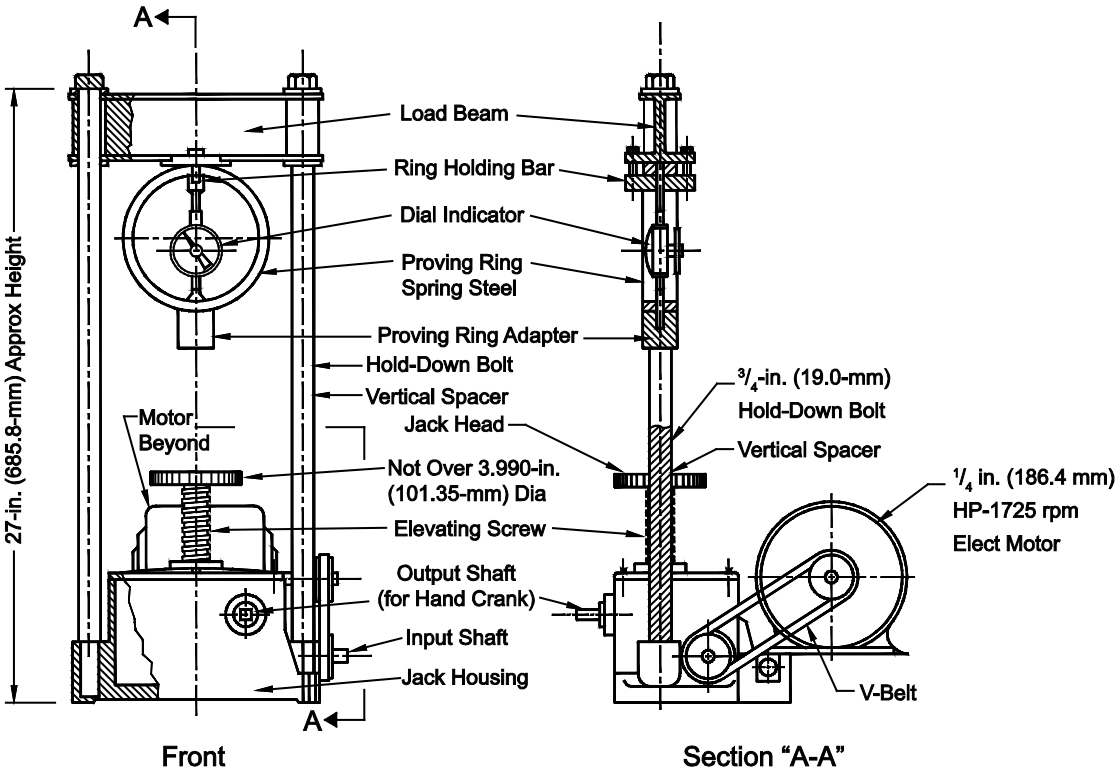


Figure 2—Loading Jack

Note 1—Instead of the loading jack, a mechanical or hydraulic testing machine may be used, provided the rate of movement can be maintained at 50.8 mm (2 in.)/min while the load is applied.

3.3. *Ring Dynamometer Assembly*—One-ring dynamometer (Figure 2) of 22.2-kN (5000-lb) capacity and sensitivity of 44.5 N (10 lb) up to 4.45 kN (1000 lb) and 111.2 N (25 lb) between 4.45 and 22.2 kN (1000 and 5000 lb) shall be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm (0.0001 in.) increments. Upper and lower ring dynamometer attachments are required for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head. Instead of the ring dynamometer assembly, any suitable load-measuring device may be used, provided the capacity and sensitivity satisfy the above requirements.

3.4. *Flowmeter*—The flowmeter shall consist of a guide sleeve and a gauge. The activating pin of the gauge shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve shall slide freely over the guide rod of the breaking head. The flowmeter gauge shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gauge shall be in 0.25-mm (0.01-in.) divisions. Instead of the flowmeter, a micrometer dial or stress–strain recorder graduated in 0.25 mm (0.01 in.) increments may be used to measure flow.

3.5. *Ovens or Hot Plates*—Ovens or hot plates shall be provided for heating aggregates, asphalt material, specimen molds, compaction hammers, and other equipment to the required mixing and

molding temperatures. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 2.8°C (5°F). Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

3.6. *Water Bath*—The water bath shall be at least 152.4 mm (6 in.) deep and shall be thermostatically controlled so as to maintain the bath at 60 ± 1°C (140 ± 2°F) or 37.8 ± 1°C (100 ± 2°F). The tank shall have a perforated false bottom or be equipped with a shelf for supporting specimens 50.8 mm (2 in.) above the bottom of the bath.

3.7. *Air Bath*—The air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1°C (77° ± 2°F).

3.8. *Thermometers*—For water and air baths sensitive to 0.2°C (0.4°F) with a range sufficient to determine the specified bath temperature.

3.9. *Vernier Calipers*—Calipers readable to 0.1 mm (0.004 in.)

3.10. *Miscellaneous—Gloves*—For handling hot equipment and other gloves for removing specimens from water bath.

4. TEST SPECIMENS

4.1. *Number and Dimension of Specimens*—Three cylindrical specimens, 101.6 ± 0.1 mm (4.0 ± 0.05 in.) in diameter and ranging from 25.4 mm (1.0 in.) to 76.2 mm (3.0 in.) tall, are recommended. Prepare specimens in accordance with AASHTO R 68.

4.2. *Roadway Core Specimens*—Core specimens meeting the dimensional requirements of Section 4.1 may be collected in accordance with D5361/D5361M.

5. PROCEDURE

5.1. Measure specimen height in accordance with ASTM D3549/D3549M.

5.2. Bring the specimens prepared with asphalt cement to the specified temperature by immersing in the water bath 30 to 40 min or placing in the oven for 2 h. Maintain the bath or oven temperature at 60 ± 1°C (140 ± 1.8°F) for the asphalt binder specimens. Bring the specimens prepared with asphalt cutback to the specified temperature by placing them in the air bath for a minimum of 2 h. Maintain the air bath temperature at 25 ± 1°C (77 ± 1.8°F). Thoroughly clean the guide rods and the inside surfaces of the test heads prior to performing the test, and lubricate the guide rods so that the upper test head slides freely over them. The testing-head temperature shall be maintained between 21.1 to 37.8°C (70 to 100°F) using a water bath when required. Remove the specimen from the water bath, oven, or air bath, and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine. Place the flowmeter, where used, in position over one of the guide rods and adjust the flowmeter to zero while holding the sleeve firmly against the upper segment of the breaking head. Hold the flowmeter sleeve firmly against the upper segment of the breaking head while the test load is being applied.

5.3. Apply the load to the specimen by means of the constant rate of movement of the loadjack or testing-machine head of 50.8 mm (2 in.) per minute until the maximum load is reached and the load decreases as indicated by the dial. Record the maximum load noted on the testing machine or converted from the maximum micrometer dial reading. Release the flowmeter sleeve or note the micrometer dial reading, where used, the instant the maximum load begins to decrease. Note and record the indicated flow value or equivalent units in twenty-five hundredths of a millimeter

(hundredths of an inch) if a micrometer dial is used to measure the flow. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 s.

Note 2—For core specimens, correct the load when thickness is other than 63.5 mm ($2^1/_2$ in.) by using the proper multiplying factor from Table 2.

Table 1—Stability Correlation Ratios[a,b]

Volume of Specimen, cm^3	Approximate Thickness of Specimen, in.	mm	Correlation Ratio
200 to 213	1	25.4	5.56
214 to 225	$1^1/_{16}$	27.0	5.00
226 to 237	$1^1/_8$	28.6	4.55
238 to 250	$1^3/_{16}$	30.2	4.17
251 to 264	$1^1/_4$	31.8	3.85
265 to 276	$1^5/_{16}$	33.3	3.57
277 to 289	$1^3/_8$	34.9	3.33
290 to 301	$1^7/_{16}$	36.5	3.03
302 to 316	$1^1/_2$	38.1	2.78
317 to 328	$1^9/_{16}$	39.7	2.50
329 to 340	$1^5/_8$	41.3	2.27
341 to 353	$1^{11}/_{16}$	42.9	2.08
354 to 367	$1^3/_4$	44.4	1.92
368 to 379	$1^{13}/_{16}$	46.0	1.79
380 to 392	$1^7/_8$	47.6	1.67
393 to 405	$1^{15}/_{16}$	49.2	1.56
406 to 420	2	50.8	1.47
421 to 431	$2^1/_{16}$	52.4	1.39
432 to 443	$2^1/_8$	54.0	1.32
444 to 456	$2^3/_{16}$	55.6	1.25
457 to 470	$2^1/_4$	57.2	1.19
471 to 482	$2^5/_{16}$	58.7	1.14
483 to 495	$2^3/_8$	60.3	1.09
496 to 508	$2^7/_{16}$	61.9	1.04
509 to 522	$2^1/_2$	63.5	1.00
523 to 535	$2^9/_{16}$	65.1	0.96
536 to 546	$2^5/_8$	66.7	0.93
547 to 559	$2^{11}/_{16}$	68.3	0.89
560 to 573	$2^3/_4$	69.9	0.86
574 to 585	$2^{13}/_{16}$	71.4	0.83
586 to 598	$2^7/_8$	73.0	0.81
599 to 610	$2^{15}/_{16}$	74.6	0.78
611 to 625	3	76.2	0.76

[a] The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5-mm ($2^1/_2$-in.) specimen.

[b] Volume-thickness relationship is based on a specimen diameter of 101.6 mm (4 in.).

6. REPORT

6.1. *The report shall include the following information*:

6.1.1. Type of sample tested (laboratory sample or pavement core specimen);

Note 3—For core specimens, the height of each test specimen in millimeters (or inches) shall be reported.

6.1.2. Average maximum load in pounds-force (or newtons) of at least three specimens, corrected when required;

6.1.3. Average flow value, in twenty-five hundredths of a millimeter (hundredths of an inch), of three specimens; and

6.1.4. Test temperature.

7. PRECISION AND BIAS

7.1. Criteria for judging the acceptability of Marshall stability and flow test results obtained by this method are shown in Table 3.

Table 3—Precision Estimates

Test and Type of Index		Coefficient of Variation, % of mean[a]	Acceptable Range of Two Test Results, % of mean[a]
Marshall stability	Within laboratory precision	6	16
	Between laboratory precision	16	43
Marshall flow	Within laboratory precision	9	26
	Between laboratory precision	20	58

[a] These values represent the 1s percent and d2s percent limits as described in ASTM C670.

7.2. The precision estimates noted in Table 3 are based on specimens compacted with mechanical and manual hammers and include dense graded mixtures with limestone and gravel aggregates, and different asphalt binders.

8. KEYWORDS

8.1. Asphalt; binder; cutback; cylindrical specimens; Marshall apparatus; mixtures; plastic flow; stability.

9. REFERENCES

9.1. ASTM. D5361/D5361M, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing.

9.2. ASTM. E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves.

Standard Method of Test for

Reducing Samples of Aggregate to Testing Size

AASHTO Designation: T 248-14[1]
ASTM Designation: C702/C702M-11

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

Reducing Samples of Aggregate to Testing Size

AASHTO Designation: T 248-14[1]
ASTM Designation: C702/C702M-11

AASHTO

1. SCOPE

1.1. These methods cover the reduction of large samples of aggregate to the appropriate size for testing, employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.

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

1.3. *This standard does not purport to address 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.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- T 2, Sampling of Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate

2.2. *ASTM Standard*:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates

3. TERMINOLOGY

3.1. *Definitions*—the terms used in this standard are defined in ASTM C125.

4. SIGNIFICANCE AND USE

4.1. Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. The methods described in this standard provide for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality. These methods are conducted in such a manner that the smaller test sample portion will be representative of the larger sample and, thus, of the total supply. The individual test methods provide for minimum masses of material to be tested.

4.2. Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as, for example, in the case of an aggregate having relatively few large-sized particles in

the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced-size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced-size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

4.3. Failure to carefully follow the procedures in these methods could result in providing a nonrepresentative sample to be used in subsequent testing.

5. SELECTION OF METHOD

5.1. *Fine Aggregate*—Samples of fine aggregate that are drier than the saturated surface-dry condition (Note 1) shall be reduced in size by a mechanical splitter according to Method A. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

5.1.1. If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, the sample may be moistened to achieve this condition, thoroughly mixed, and then the sample reduction performed.

Note 1—The method of determining the saturated surface-dry condition is described in T 84. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated surface-dry.

5.1.2. If use of Method A is desired and the sample has free moisture on the particle surfaces, the entire sample may be dried to at least the surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then the sample reduction performed. Alternatively, if the moist sample is very large, a preliminary split may be made using a mechanical splitter having wide chute openings 38 mm ($1^1/_2$ in.) or more to reduce the sample to not less than 5000 g. The portion so obtained is then dried, and reduction to test sample size is completed using Method A.

5.2. *Coarse Aggregates*—Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

5.3. *Combined Coarse and Fine Aggregate*—Samples that are in a dry condition may be reduced in size by either Method A or Method B. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B. When Method A is desired and the sample is damp or shows free water, dry the sample until it appears dry or until clumps can be easily broken by hand (Note 2). Dry the entire sample to this condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduce the sample. The miniature stockpile Method C is not permitted for combined aggregates.

Note 2—The dryness of the sample can be tested by tightly squeezing a small portion of the sample in the palm of the hand. If the cast crumbles readily, the correct moisture range has been obtained.

6. SAMPLING

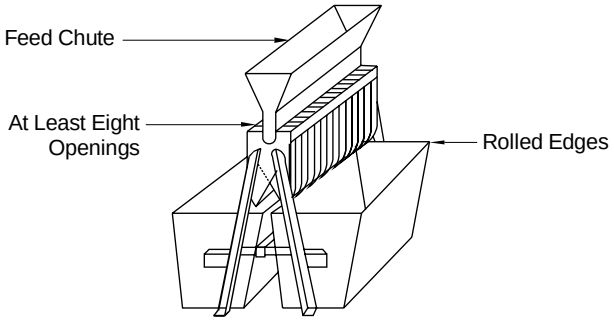
6.1. The samples of aggregate obtained in the field shall be taken in accordance with T 2, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of field sample listed in T 2 is usually adequate. When additional tests are to be conducted, the

user shall determine that the initial size of the field sample is adequate to accomplish all intended tests. Similar procedures shall be used for aggregate produced in the laboratory.

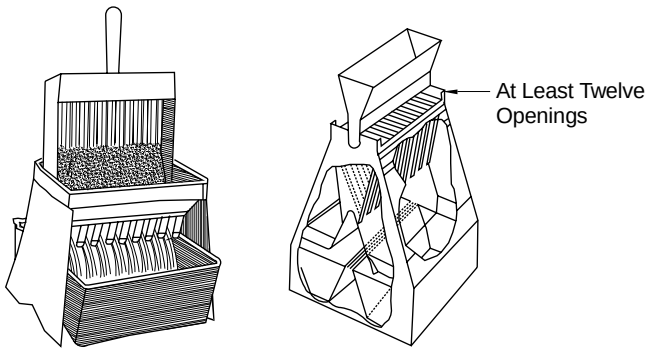
METHOD A—MECHANICAL SPLITTER

7. APPARATUS

7.1. *Sample Splitter*—Sample splitters shall have an even number of equal-width chutes, but not less than a total of eight for coarse aggregate, or twelve for fine aggregate, which discharge alternatively to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 percent larger than the largest particles in the sample to be split (Note 3). For dry fine aggregate in which the entire sample will pass the 9.5-mm ($^3/_8$-in.) sieve, the minimum width of the individual chutes shall be at least 50 percent larger than the largest particles in the sample and the maximum width shall be 19 mm ($^3/_4$ in.). The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straightedged pan, which has a width equal to or slightly less than the overall width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material. (See Figure 1.)



(a) Large Sample Splitter for Coarse Aggregate



(b) Small Sample Splitters for Fine Aggregate

Note: (a) may be constructed as either closed or open type. Closed type is preferred.

Figure 1—Sample Splitters (Riffles)

Note 3—Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 37.5 mm ($1^1/_2$ in.).

8. PROCEDURE

8.1. Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will 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 receptacles below.

8.2. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

METHOD B—QUARTERING

9. APPARATUS

9.1. Apparatus shall consist of a straightedge; straightedged scoop, shovel or trowel; a broom or brush; and a canvas blanket or tear-resistant tarp approximately 2 by 2.5 m (6 by 8 ft).

10. PROCEDURE

10.1. Use either the procedure described in Section 10.1.1 or 10.1.2, or a combination of both.

10.1.1. Place the original sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size. (See Figure 2.)

10.1.2. As an alternative to the procedure in Section 10.1.1 or when the floor surface is uneven, the field sample may be placed on a canvas blanket or tear-resistant tarp and mixed with a shovel or trowel as described in Section 10.1.1, leaving the sample in a conical pile. As an alternative to mixing with the shovel or trowel, lift each corner of the blanket or tarp and pull it over the sample toward the diagonally opposite corner, causing the material to be rolled. After the material has been rolled a sufficient number of times (a minimum of four times), so that it is thoroughly mixed, pull each corner of the blanket or tarp toward the center of the pile so the material will be left in a conical pile. Flatten the pile as described in Section 10.1.1. Divide the sample as described in Section 10.1.1, or insert a stick or pipe beneath the blanket or tarp and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick, leaving a fold of the blanket 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 equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket or tarp. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size. (See Figure 3.)

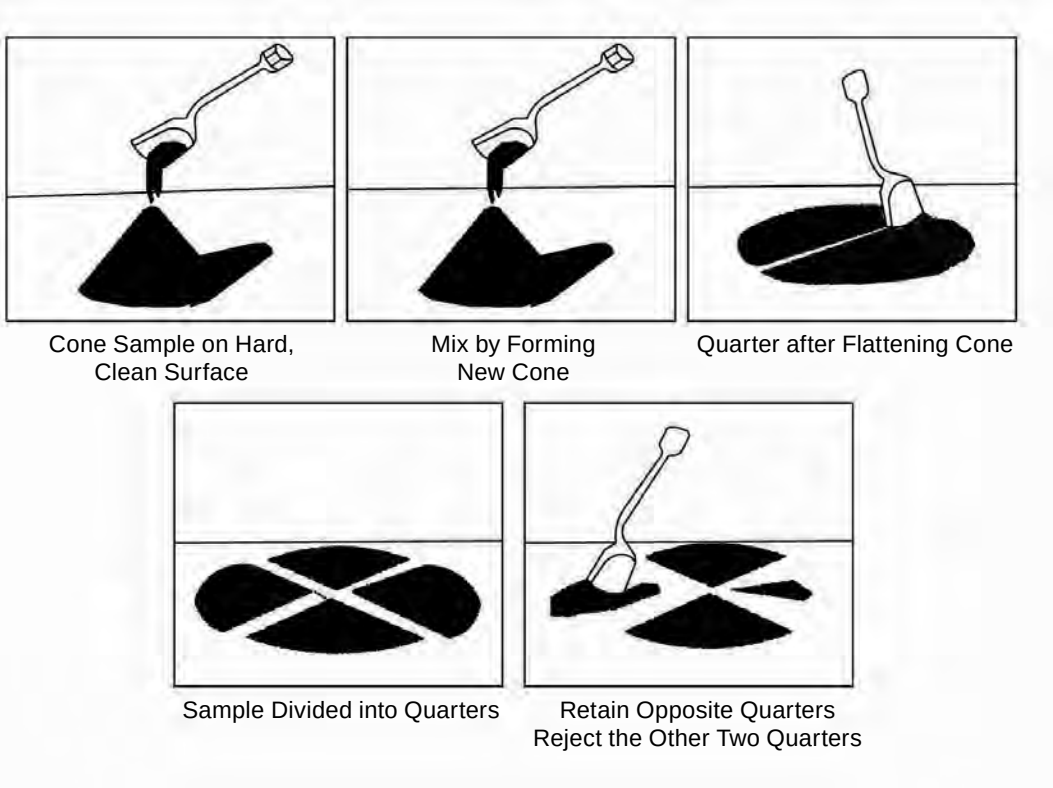


Figure 2—Quartering on a Hard, Clean, Level Surface

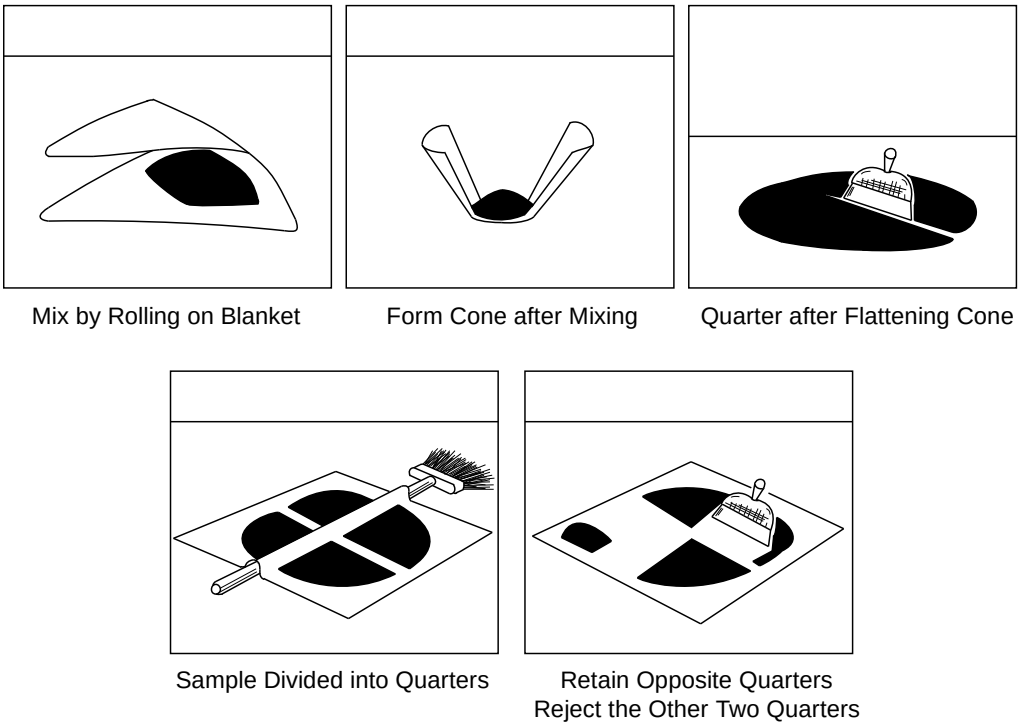


Figure 3—Quartering on a Canvas Blanket or Tear-Resistant Tarp

METHOD C—MINIATURE STOCKPILE SAMPLING (DAMP FINE AGGREGATE ONLY)

11. APPARATUS

11.1. Apparatus shall consist of a straightedge; straightedged scoop, shovel, or trowel for mixing the aggregate; and either a small sampling thief, small scoop, or spoon for sampling.

12. PROCEDURE

12.1. Place the original sample of damp fine aggregate on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. If desired, the conical pile may be flattened to a uniform thickness and diameter by pressing the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the sampling devices described in Section 11.1.

[1] Technically equivalent but not identical to ASTM C702/C702M-11.

Standard Method of Test for

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2012)[1]
ASTM Designation: C566-97(2004)

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

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2012)[1]
ASTM Designation: C566-97(2004)

AASHTO

1. SCOPE

1.1. This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

1.2. The values stated in SI units are to be regarded as the standard. The values stated in parentheses are provided for information only.

1.3. *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*. For specific precautionary statements, see Sections 5.3.1, 7.2.1, and 7.3.1.

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 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate

2.2. *ASTM Standards*:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. TERMINOLOGY

3.1. *Definitions*—For definitions of terms used in this test method, refer to ASTM C125.

4. SIGNIFICANCE AND USE

4.1. This test method is sufficiently accurate for usual purposes such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In rare cases where aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled-temperature oven.

4.2. Large particles of coarse aggregate, especially those larger than 50 mm (2 in.), will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large-size particles.

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. *Source of Heat*—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C (230 ± 9°F). Where close control of the temperature is not required (see Section 4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3. *Sample Container*—A container not affected by the heat, and of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one-fifth of the least lateral dimension.

5.3.1. **Precaution**—When a microwave oven is used, the container shall be nonmetallic.

Note 1—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan with heat lamps or oven. Note precaution in Section 5.3.1.

5.4. *Stirrer*—A metal spoon or spatula of convenient size.

6. SAMPLE

6.1. Sampling shall generally be accomplished in accordance with T 2, except the sample size may be as stated in Table 1.

Table 1—Sample Size for Aggregate

Nominal Maximum Size of Aggregate, mm (in.)[a]	Mass of Normal Weight Aggregate Sample, Min., kg[b]
4.75 (0.187) (No. 4)	0.5
9.5 ($^3/_8$)	1.5
12.5 ($^1/_2$)	2
19.0 ($^3/_4$)	3
25.0 (1)	4
37.5 ($1^1/_2$)	6
50 (2)	8
63 ($2^1/_2$)	10
75 (3)	13
90 ($3^1/_2$)	16
100 (4)	25
150 (6)	50

[a] Based on sieves meeting M 92.

[b] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m^3 (determined using T 19M/T 19) and dividing by 1600.

6.2. Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

7. PROCEDURE

7.1. Determine the mass of the sample to the nearest 0.1 percent.

7.2. Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1. **Caution**: When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs, it can damage the microwave oven.

7.3. When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1. **Warning**: Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4. The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 percent additional loss in mass.

7.5. Determine the mass of the dried sample to the nearest 0.1 percent after it has cooled sufficiently not to damage the balance.

8. CALCULATION

8.1. Calculate total evaporable moisture content as follows:

$$p = 100(W - D)/D \qquad (1)$$

where:

p = total evaporable moisture content of sample, percent;
W = mass of original sample, g; and
D = mass of dried sample, g.

8.2. Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with T 85, Test for Specific Gravity and Absorption of Coarse Aggregate, or T 84, Test for Specific Gravity and Absorption of Fine Aggregate.

9. PRECISION AND BIAS

9.1. *Precision*:

9.1.1. The within-laboratory single-operator standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.2. The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.3. Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

Note 2—These numbers represent, respectively, the 1s and d2s limits as described in ASTM C670.

9.2. *Bias*:

9.2.1. When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1. The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between –0.07 percent and +0.20 percent.

9.2.1.2. The bias of moisture tests on a second aggregate material has been found to have a mean of less than +0.01 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between –0.14 percent and +0.14 percent.

9.2.1.3. The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 percent. The bias of individual test values overall from both aggregate materials has been found with 95 percent confidence to lie between –0.12 percent and +0.18 percent.

9.2.2. Test data used to derive the above bias statement were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

Note 3—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program, which is fully described in the National Research Council Report SHRP-P-619. The samples tested that relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface-dry.

10. KEYWORDS

10.1. Aggregate; drying; moisture content.

[1] This method is technically equivalent with ASTM C566-97(2004), except for the balance statement in Section 5.1.

Standard Method of Test for

Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

AASHTO Designation: T 305-14

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

Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

AASHTO Designation: T 305-14

AASHTO

1. SCOPE

1.1. This test method covers the determination of the amount of draindown material in an uncompacted asphalt mixture sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport, and placement of the mixture. The test is particularly applicable to mixtures such as porous asphalt (open-graded friction course) and Stone Matrix Asphalt (SMA).

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 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
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- T 245, Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *draindown material*—For the purpose of this test method, draindown material is considered to be that portion of material that separates itself from the sample as a whole and is deposited outside the wire basket during the test. The draindown material may be composed of either asphalt binder or a combination of asphalt binder and fine aggregate.

3.1.2. *draindown*—The process by which draindown material separates itself from the sample as a whole.

4. SUMMARY OF METHOD

4.1. A sample of the asphalt mixture to be tested is prepared in the laboratory or obtained from field production. The sample is placed in a wire basket, which is positioned on a plate or other suitable container of known mass. The sample, basket, and plate or container are placed in a forced-draft

oven for 1 h at a preselected temperature. At the end of 1 h, the basket containing the sample is removed from the oven, along with the plate or container and the mass of the plate or container is determined. The amount of draindown material is then calculated.

5. SIGNIFICANCE AND USE

5.1. This test method can be used to determine whether the amount of draindown material measured for a given asphalt mixture is within acceptable levels. The test provides an evaluation of the draindown potential of an asphalt mixture during mixture design or during field production. This test is primarily used for mixtures with high coarse aggregate content such as porous asphalt (open-graded friction course) and SMA.

6. APPARATUS

6.1. *Forced-Draft Oven*—Capable of maintaining the temperature in a range from 120 to 175°C (250 to 350°F). The oven should maintain the set temperature to within ±2°C (±3.6°F).

6.2. *Plates*—Or other suitable containers of appropriate size. The plates or containers used should be of appropriate durability to withstand the oven temperatures. Cake pans or pie tins are examples of suitable types of containers.

6.3. *Standard Basket*—Meeting the dimensions shown in Figure 1. The basket shall be constructed using standard 6.3-mm (0.25-in.) sieve cloth as specified in M 92.

6.4. *Balance*—Accurate to 0.1 g.

6.5. *Other apparatus*—Spatulas, trowels, bowls, and mixer as needed.

7. SAMPLE PREPARATION

7.1. *Laboratory-Prepared Samples*:

7.1.1. *Number of Samples*—For each mixture tested, the draindown characteristics should be determined at two different temperatures. The two temperatures should be the anticipated plant production temperature, as well as 15°C (27°F) above that temperature (Note 1). For each temperature, duplicate samples should be tested. Thus for one asphalt mixture, a minimum of four samples will be tested.

Note 1—When using the test as part of the mixture design procedure, the test should be performed at two temperatures in order to determine the potential effect that plant temperature variation may have on the mixture during production. When the test is used in the field during production, it should be necessary to perform the test at the plant production temperature only.

7.1.2. Dry the aggregate to a constant mass in accordance with T 255, and sieve it into the appropriate size fractions as indicated in T 245.

7.1.3. Determine the anticipated plant production temperature or select a mixing temperature in accordance with T 245.

7.1.4. Place into separate pans for each test sample the amount of each size fraction required to produce completed mixture samples having a mass of 1200 ± 200 g. The aggregate fractions shall be combined such that the resulting aggregate blend has the same gradation as the job mix formula. Place the aggregate samples in an oven and heat them to a temperature not to exceed the mixing temperature established in Section 7.1.3 by more than approximately 28°C (50°F).

7.1.5. Heat the asphalt binder to the temperature established in Section 7.1.3.

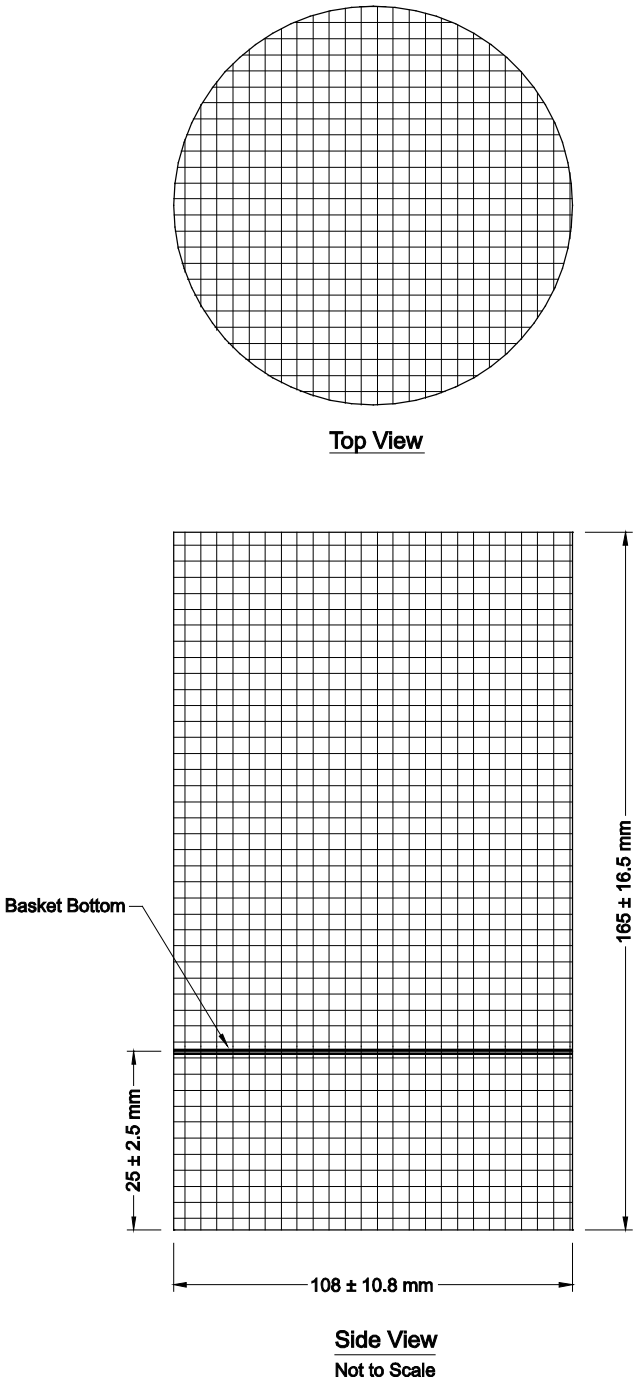


Figure 1—Wire Basket Assembly

7.1.6. Place the heated aggregate in the mixing bowl. Add any stabilizers (Note 2) and thoroughly mix the dry components. Form a crater in the aggregate blend and add the required amount of asphalt binder. The amount of asphalt binder shall be such that the final sample has the same asphalt content as the job mix formula. At this point, the temperature of the aggregate and asphalt binder shall be within the limits of the mixing temperature established in Section 7.1.3. Using a spatula (if mixing by hand) or a mixer, mix the aggregate (and stabilizer, if any) and asphalt binder quickly until the aggregate is thoroughly coated.

Note 2—Some types of stabilizers, such as fibers or some polymers, must be added directly to the aggregate prior to mixing with the asphalt binder. Other types of stabilizers must be added directly to the asphalt binder prior to blending with the aggregate.

7.2. *Plant-Produced Samples*:

7.2.1. *Number of Samples*—For plant-produced samples, duplicate samples should be tested at the plant production temperature.

7.2.2. Samples may be obtained during plant production by sampling the mixture at any appropriate location, such as the trucks prior to the mixture leaving the plant. Samples obtained during actual production should be reduced to the proper test sample size by R 47.

Note 3—Caution should be exercised when sampling from surge or storage bins because draindown may already have taken place.

8. PROCEDURE

8.1. Transfer the hot laboratory-produced or plant-produced uncompacted mixture sample to a tared wire basket as described in Section 6.3. Place the entire sample in the wire basket. Do not consolidate or otherwise disturb the sample after transferring it to the basket. Determine the mass of the sample to the nearest 0.1 g. Care should be exercised to ensure that the sample does not cool more than 25°C (77°F) below the test temperature. (See Section 8.2.)

8.2. Determine and record the mass of a plate or other suitable container to the nearest 0.1 g. Place the basket on the plate or container and place the assembly into the oven at the temperature as determined in Section 7.1.1 or 7.2.1 for 60 ± 5 min. If the sample has cooled more than 25°C (77°F) below the test temperature, the test should be conducted for 70 ± 5 min.

8.3. After the sample has been in the oven for the time specified in Section 8.2, remove the basket and plate or container from the oven. Determine and record the mass of the plate or container plus draindown material to the nearest 0.1 g.

9. CALCULATIONS

9.1. Calculate the percent of mixture that drained by subtracting the initial plate or container mass from the final plate or container mass and dividing this value by the initial total sample mass. Multiply the result by 100 to obtain a percentage.

$$\frac{M_f - M_i}{M_t} \times 100 = \text{percent of mixture that drained or percent draindown}$$

where:

M_f = final plate or container mass;

M_i = initial plate or container mass; and

M_t = initial total sample mass.

10. REPORT

10.1. Report the average percent draindown (average percent of mixture that drained) at each of the test temperatures.

Standard Method of Test for

Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

AASHTO Designation: T 308-10 (2015)

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

Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

AASHTO Designation: T 308-10 (2015)

1. SCOPE

1.1. This test method covers the determination of asphalt binder content of hot mix asphalt (HMA) by ignition at temperatures that reach the flashpoint of the binder in a furnace. The means of specimen heating may be the convection method or the direct infrared (IR) irradiation method. The aggregate remaining after burning can be used for sieve analysis using T 30.

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 associated with its use. It is the responsibility of the user of 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 231, Weighing Devices Used in the Testing of Materials
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- R 66, Sampling Asphalt Materials
- T 2, Sampling of Aggregates
- T 30, Mechanical Analysis of Extracted Aggregate
- T 168, Sampling Bituminous Paving Mixtures
- T 248, Reducing Samples of Aggregate to Testing Size
- T 329, Moisture Content of Asphalt Mixtures by Oven Method

2.2. *ASTM Standard*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *Other Documents*:

- Manufacturer's Instruction Manual
- NCHRP Final Report, NCHRP Project No. 9-26, Phase 3

3. SUMMARY OF TEST METHOD

3.1. The asphalt binder in the HMA is ignited using the furnace equipment applicable to the particular method. This procedure covers two methods. Method A requires an ignition furnace with an internal balance. Method B requires an ignition furnace with an external balance.

3.2. The asphalt binder content is calculated as the difference between the initial mass of the HMA and the mass of the residual aggregate, with adjustments for an asphalt binder correction factor and the moisture content. The asphalt binder content is expressed as a mass percent of the moisture-free mixture. This method may be affected by the type of aggregate in the mixture. Accordingly, to optimize accuracy, correction factors for asphalt binder and aggregate will be established by testing a set of correction factor specimens for each type of HMA. Correction factors must be determined before any acceptance testing is performed.

4. SIGNIFICANCE AND USE

4.1. This method can be used for quantitative determinations of asphalt binder content and gradation in HMA and pavement specimens for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for gradation analysis according to T 30.

5. APPARATUS

5.1. *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). The furnace chamber dimensions shall be adequate to accommodate a specimen size of 3500 g. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and, when set up properly, shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan with the capability to pull air through the furnace to expedite the test and reduce the escape of smoke into the laboratory.

5.1.1. For Method A, the furnace shall also have an internal balance thermally isolated from the furnace chamber and accurate to 0.1 g. The balance shall be capable of weighing a 3500-g specimen in addition to the specimen baskets. A data collection system will be included so that the 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 specimen 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 asphalt binder content (percent), test time, and test temperature. The furnace shall provide an audible alarm and indicator light when the specimen mass loss does not exceed 0.01 percent of the total specimen mass for 3 consecutive min. The furnace shall also allow the operator to change the ending mass loss percentage to 0.02 percent.

5.2. *Specimen Basket Assembly*—Consisting of specimen basket(s), catch pan, and an assembly guard to secure the specimen basket(s) to the catch pan.

5.2.1. *Specimen Basket(s)*—Of appropriate size to allow the specimens to be thinly spread and allow air to flow through and around the specimen particles. Sets with two or more baskets shall be nested. The specimen shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.

Note 1—Screen mesh or other suitable material with maximum and minimum openings of 2.36 mm (No. 8) and 0.600 mm (No. 30), respectively, has been found to perform well.

5.2.2. *Catch Pan*—Of sufficient size to hold the specimen basket(s) so that aggregate particles and melting asphalt binder falling through the screen are caught.

5.3. *Oven*—Capable of maintaining 110 ± 5°C (230 ± 9°F).

5.4. *Balance*—Of sufficient capacity and conforming to the requirements of M 231, Class G 2.

5.5. *Safety Equipment*—Safety glasses or face shield, dust mask, high-temperature gloves, long-sleeved jacket, a heat-resistant surface capable of withstanding 650°C (1202°F), and a protective cage capable of surrounding the specimen baskets during the cooling period.

5.6. *Miscellaneous Equipment*—A pan larger than the specimen basket(s) for transferring the specimen after ignition, spatulas, bowls, and wire brushes.

6. SAMPLING

6.1. Obtain samples of freshly produced HMA in accordance with T 168.

6.2. The specimen shall be the end result of reducing a larger sample in accordance with R 47.

6.3. 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 it is workable. Do not leave the specimen in the oven for an extended period of time. Excessive heating may cause detrimental effects such as asphalt draindown or oxidation.

6.4. The size of the test specimen shall be governed by the nominal-maximum aggregate size of the HMA and shall conform to the mass requirement shown in Table 1. When the mass of the specimen exceeds the capacity of the equipment used, the specimen may be divided into suitable increments, tested, and the results appropriately combined for calculation of the asphalt binder content (using a weighted average). Specimen sizes shall not be more than 500 g greater than the minimum recommended specimen mass.

Note 2—Large specimens of fine mixes tend to result in incomplete ignition of asphalt binder.

Table 1—Mass Requirements

Nominal-Maximum Aggregate Size,[a] mm	Sieve Size	Minimum Mass of Specimen, g
4.75	No. 4	1200
9.5	3/8 in.	1200
12.5	1/2 in.	1500
19.0	3/4 in.	2000
25.0	1 in.	3000
37.5	1 1/2 in.	4000

[a] Nominal-maximum aggregate size—one size larger than the first sieve to retain more than 10 percent.

TEST METHOD A—INTERNAL BALANCE

7. TEST PROCEDURES

7.1. *Test Initiation*:

7.1.1. For the convection-type furnace, preheat the ignition furnace to 538°C (1000°F) or to the temperature determined by the correction factor process in the Annex. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

7.1.2. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.

7.2. Oven dry the HMA specimen to a constant mass at a temperature of 110 ± 5°C (230 ± 9°F), or determine the moisture content of a companion specimen according to T 329.

7.3. Enter into the ignition furnace, or manually record, the asphalt binder correction factor for the specific mix to be tested, as determined in the Annex.

7.4. Determine and record the mass of the specimen basket assembly to the nearest 0.1 g.

7.5. Prepare the specimen as described in Section 6. Place the specimen basket(s) in the catch pan. Evenly distribute the specimen in the basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

7.6. Determine and record the total mass of the specimen and specimen basket assembly at room temperature to the nearest 0.1 g. Calculate and record the initial mass of the specimen, M_i (total mass minus the mass of the specimen basket assembly).

7.7. Input the initial mass of the specimen, M_i, in whole grams into the ignition furnace controller. Verify that the correct mass has been entered.

7.8. Open the chamber door and place the specimen basket assembly in the furnace, carefully positioning the specimen basket assembly so it is not in contact with the furnace walls. Close the chamber door and verify that the specimen mass (including the basket assembly) displayed on the furnace scale equals the total mass recorded in Section 7.6 within ±5 g. Differences greater than 5 g or failure of the furnace scale to stabilize may indicate that the specimen basket assembly is contacting the furnace wall.

Note 3—Due to the extreme heat of the furnace, the operator should wear safety equipment—high-temperature gloves, face shield, and fire-retardant shop coat—when opening the door to load or unload the specimen.

7.9. Initiate the test by pressing the start/stop button. This operation will lock the specimen chamber and start the combustion blower.

Note 4—The furnace temperature will drop below the set point when the door is opened but will recover with the door closed and when ignition occurs. Specimen ignition typically increases the temperature well above the set point, depending on the specimen size and asphalt binder content.

7.10. Allow the test to continue until the stable light and audible stable indicator indicate the test is complete (the change in mass does not exceed 0.01 percent for 3 consecutive min). Press the start/stop button. This operation will unlock the specimen chamber and cause the printer to print out the test results.

Note 5—An ending mass loss percentage of 0.02 may be substituted when the aggregate exhibits an excessive amount of loss during ignition testing. The precision and bias statement was developed using 0.01 percent. Both precision and accuracy may be adversely affected by using 0.02 percent.

7.11. Open the chamber door, remove the specimen basket assembly, and place it on a cooling plate or block. Place the protective cage over the specimen basket assembly, and allow it to cool to room temperature (approximately 30 min).

7.12. Determine and record the total mass of the specimen and specimen basket assembly after ignition to the nearest 0.1 g. Calculate and record the final mass of the specimen, M_f (total mass minus the mass of the specimen basket assembly).

7.13. Use the corrected asphalt binder content (percent) from the printed ticket. If this value is not corrected, subtract the asphalt binder correction factor. If a moisture content has been determined per T 329, subtract the percent moisture from the asphalt binder content on the printed ticket, and report the resultant value as the corrected asphalt binder content (P_b).

Note 6—Asphalt binder content can also be calculated using Equation 1 from Method B (Section 8.16).

TEST METHOD B—EXTERNAL BALANCE

8. TEST PROCEDURES

8.1. Preheat the ignition furnace to 538°C (1000°F) or the temperature determined by the correction factor process in the Annex.

8.2. Oven dry the HMA specimen to a constant mass at a temperature of 110 ± 5°C (230 ± 9°F), or determine the moisture content of a companion specimen according to T 329.

8.3. Record the asphalt binder correction factor for the specific mix to be tested, as determined by the correction factor process in the Annex.

8.4. Determine and record the mass of the specimen basket assembly to the nearest 0.1 g.

8.5. Prepare the specimen as described in Section 6. Place the specimen baskets in the catch pan. Evenly distribute the specimen in the basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

8.6. Determine and record the total mass of the specimen basket assembly at room temperature to the nearest 0.1 g. Calculate and record the initial mass of the specimen, M_i (total mass minus the mass of the specimen basket assembly).

8.7. Open the chamber door and place the specimen basket assembly in the furnace. Burn the HMA specimen in the furnace for at least 45 min.

Note 7—The appropriate time for the initial burn of an HMA specimen is dependent on the specimen size. For large specimens, the time could be significantly longer than 45 min. See the manufacturer's manual for guidelines.

8.8. Open the chamber door, remove the specimen basket assembly, and place it on a cooling plate or block. Place the protective cage over the specimen basket assembly, and allow it to cool to room temperature (approximately 30 min).

8.9. Determine and record the total mass of the specimen and specimen basket assembly after cooling to the nearest 0.1 g.

8.10. Place the specimen and specimen basket assembly back into the furnace.

8.11. Burn the specimen for at least 15 min after the furnace reaches the set point temperature.

8.12. Open the chamber door, remove the specimen and specimen basket assembly, and place it on a cooling plate or block. Place the protective cage over the specimen basket assembly, and allow it to cool to approximately room temperature (approximately 30 min).

8.13. Weigh and record the total mass of the specimen and specimen basket assembly after cooling to the nearest 0.1 g.

8.14. Repeat Sections 8.10 through 8.13 until the change in measured mass of the specimen after ignition does not exceed 0.01 percent of the initial specimen mass, M_i.

Note 8—An ending mass loss percentage of 0.02 may be substituted when the aggregate exhibits an excessive amount of loss during ignition testing. The precision and bias statement was developed using 0.01 percent. Both precision and accuracy may be adversely affected by using 0.02 percent. After the time required to obtain the specified mass loss has been established for each mixture, repeated mass determinations may not be necessary.

8.15. Calculate and record the final mass of the specimen, M (total mass minus the mass of the specimen basket assembly).

8.16. Calculate the asphalt binder content of the specimen as follows:

$$P_b, \% = \left[\frac{\left(M_i - M_f \right)}{M_i} \times 100 \right] - C_F - MC \qquad (1)$$

where:

P_b = the measured (corrected) asphalt binder content, percent;
M_i = the total mass of the HMA specimen prior to ignition, g;
M_f = the total mass of aggregate remaining after the ignition, g;
C_F = the correction factor, percent by mass of HMA specimen; and
MC = the moisture content of the companion HMA specimen, percent, as determined by T 329. (If the specimen was oven dried prior to initiating the procedure, $MC = 0$.)

9. GRADATION

9.1. Allow the contents of the specimen baskets to cool to room temperature prior to performing the gradation analysis. Empty the contents of the baskets into a flat pan, being careful to capture all material. Use a small wire sieve brush to ensure that any residual fines are removed from the baskets and catch pan.

9.2. Perform the gradation analysis according to T 30.

10. REPORT

10.1. *The report shall include the following*:

10.1.1. Test method (A or B);

10.1.2. Corrected asphalt binder content;

10.1.3. Correction factor;

10.1.4. Temperature compensation factor (if applicable);

10.1.5. Specimen mass;

10.1.6. Moisture content (if determined, per T 329); and

10.1.7. Test temperature.

Note 9—If Method A is performed, attach the original printed ticket to the report.

11. PRECISION AND BIAS

11.1. *Precision*—Criteria for judging the acceptability of ignition burn results for asphalt content obtained by Method A or Method B are given in Table 2.

11.1.1. *Single-Operator Precision*—The figures in Column 2 of Table 2 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table 2, Column 3.

11.1.2. *Multilaboratory Precision*—The figures in Column 2 of Table 2 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table 2, Column 3.

Table 2—Precision Estimates

Condition	Standard Deviation (1s)[a]	Acceptable Range of Two Test Results (d2s)[a]
Single-operator precision		
Asphalt content (%)	0.069	0.196
Multilaboratory precision		
Asphalt content (%)	0.117	0.330

[a] These values represent the 1s and d2s limits described in ASTM C670

Note 10—The precision estimates given in Table 2 are based on the analysis of test results from three pairs of AMRL proficiency samples. The data analyzed consisted of results from 353 to 461 laboratories for each of the three pairs of samples. The analysis included two binder grades:

PG 52-34 and PG 64-22. Average results for asphalt content ranged from 4.049 to 5.098 percent. The details of this analysis are in NCHRP Final Report, NCHRP Project No. 9-26, Phase 3.

Note 11—The precision estimates are based on four aggregate types, four replicates, and twelve laboratories participating with no laboratory results deleted as outlying observations. All four aggregates were tested in surface mixes and had relatively low absorption values.

11.2. *Bias*—Any biases inherent to the ignition oven process used for Test Methods A and B, when testing for asphalt content and aggregate gradation, are accounted for by the determination and application of appropriate correction factors.

ANNEX

(Mandatory Information)

CORRECTION FACTORS

A1. ASPHALT BINDER AND AGGREGATE

A1.1. Asphalt binder content results may be affected by the type of aggregate in the mixture and the ignition furnace. Therefore, asphalt binder and aggregate correction factors must be established by testing a set of correction specimens for each job mix formula (JMF) mix design. Correction factor(s) must be determined before any acceptance testing is completed and repeated each time a change in the mix ingredients or design occurs. 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.

A1.2. *Asphalt Binder Correction Factor*—Certain aggregate types may result in unusually high correction factors (greater than 1.0 percent). Such mixes should be corrected and tested at a lower temperature, as described below. Each ignition furnace will have its own unique asphalt binder correction factor determined in the location where testing will be performed.

A1.3. *Aggregate Correction Factor*—Due to potential aggregate breakdown during the ignition process, an aggregate correction factor will be determined for each ignition furnace in the location where testing will be performed when the following conditions occur: aggregates that have a proven history of excessive breakdown or aggregates from an unknown source.

A2. CORRECTION FACTOR PROCEDURE

A2.1. Obtain samples of aggregate in accordance with T 2.

A2.2. Obtain samples of asphalt binder in accordance with R 66.

Note A1—Include other additives that may be required by the JMF.

A2.3. Prepare an initial, or “butter” mix at the design asphalt binder content. Mix and discard the butter mix prior to preparing any of the correction specimens to ensure an accurate asphalt binder content.

A2.4. Prepare two correction specimens at the JMF design asphalt binder content and gradation. Aggregate used for correction specimens shall be sampled from the material designated for use in

production. An additional "blank" (aggregate only) specimen shall be batched at the JMF gradation. Determine an aggregate gradation in accordance with T 30 on the "blank" specimen.

A2.5. Place the freshly mixed specimens directly into the specimen basket assembly. If specimens are allowed to cool prior to placement in the specimen basket assembly, the specimens must be dried to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Do not preheat the specimen basket assembly.

A2.6. Test the specimens in accordance with Method A or Method B of the procedure.

A2.7. 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.

A2.8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat Section A2.3 through A2.7 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. The asphalt binder correction factor, C_F, is the average of the differences expressed as a percentage by mass of the HMA.

A2.8.1. If the asphalt binder correction factor exceeds 1.0 percent, the test temperature should be lowered to 482 ± 5°C (900 ± 8°F) for a convection-type furnace. If there is no improvement in the correction factor, it is permissible to use the higher temperature.

Note A2—The temperature for determining the asphalt binder content of HMA specimens by this procedure shall be the same temperature determined for the correction specimens.

A2.8.2. For the direct IR irradiation-type 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. Option 1 is designed for aggregate that requires a large asphalt binder correction factor (greater than 1 percent)—typically very soft aggregate (such as dolomite). Option 2 is designed for samples that may not burn completely using the Default burn profile. The burn profile for testing HMA samples shall be the same burn profile selected for correction samples.

A2.9. Perform a gradation analysis on the residual aggregate in accordance with T 30, if required. The results will be utilized in developing an aggregate correction factor and should be calculated and reported to the nearest 0.1 percent.

A2.9.1. From the gradation results, subtract the percent passing each sieve for each specimen from the percent passing each sieve of the "blank" specimen gradation results from Section A2.4.

A2.9.2. Determine the average difference for the two values. If the difference for any single sieve exceeds the allowable difference for that sieve as listed in Table A2.1, 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 T 30, prior to final rounding and reporting. If the 0.075-mm (No. 200) sieve is the only sieve outside the limits in Table A2.1, apply the aggregate correction factor to only the 0.075-mm (No. 200) sieve.

Table A2.1—Permitted Sieving Difference

Sieve	Allowable Difference
Sizes larger than or equal to 2.36 mm (No. 8)	±5.0 percent
Sizes larger than 0.075 mm (No. 200) and smaller than 2.36 mm (No. 8)	±3.0 percent
Sizes 0.075 mm (No. 200) and smaller	±0.5 percent

Standard Method of Test for

Viscosity Determination of Asphalt Binder Using Rotational Viscometer

AASHTO Designation: T 316-13[1]

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

Viscosity Determination of Asphalt Binder Using Rotational Viscometer

AASHTO Designation: T 316-13[1]

AASHTO

1. SCOPE

1.1. This test method outlines the procedure for measuring the viscosity of asphalt binders at elevated temperature from 60 to over 200°C using a Rotational Viscometer apparatus as specified by M 320 and R 29.

1.2. *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 application of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 320, Performance-Graded Asphalt Binder
- R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
- R 66, Sampling Asphalt Materials

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers

3. TERMINOLOGY

3.1. *Definition*:

3.1.1. *viscosity*—the ratio between the applied shear stress and the rate of shear is called the coefficient of viscosity. This coefficient is a measure of the resistance to flow of the liquid. It is commonly called the viscosity. The SI unit of viscosity is the Pascal second (Pa·s).

4. SUMMARY OF METHOD

4.1. This test method can be used to measure the viscosity of asphalt at application temperatures. The torque required to maintain a constant rotational speed of a cylindrical spindle while submerged in an asphalt sample at a constant temperature is used to measure the relative resistance to rotation. The torque and speed are used to determine the viscosity of the binder in Pascal seconds.

5. SIGNIFICANCE AND USE

5.1. This test method can be used to measure the apparent viscosity of asphalt at application temperatures.

5.2. The measured viscosity at elevated temperatures can be used to determine whether the asphalt binder can be handled and pumped at the refinery, terminal, or hot mix plant facility. Measured viscosity from this procedure can be used to develop temperature viscosity charts for estimating mixing and compaction temperatures for use in hot mix asphalt mix design.

6. APPARATUS

6.1. *Oven*—An oven capable of maintaining any desired temperature setting from room temperature to 260°C to within ±3°C.

6.2. *Thermometers*—Thermometers having a range from 60 to over 200°C and readable to 0.2°C.

6.3. *Balance*—A balance with a capacity of 2000 g readable to 0.1 g for determining the mass of asphalt binder.

6.4. *Cylindrical Spindles* of various sizes for measurement of asphalt binders of different viscosities.

6.5. *Rotational Viscometer* capable of measuring the torque required to rotate the selected spindle at a selected constant speed while submerged in asphalt at constant desired test temperature and should display the viscosity in Pascal seconds automatically.

6.6. *Temperature Controller*—A proportional temperature controller capable of maintaining the specimen temperatures ±1.0°C for test temperatures ranging from 60 to 165°C or greater.

7. MATERIALS

7.1. Solvent (such as Mineral Spirits or Varsol) or a degreasing spray cleaner formulated for cleaning the sample holder, spindles, and accessories.

8. HAZARDS

8.1. Use standard laboratory safety procedures required for handling the hot asphalt binder and required safety procedures when cleaning with solvents or degreasers.

9. PREPARATION OF APPARATUS

9.1. The rotational viscometer must be leveled to function properly. A bubble-type level is normally located on top of the viscometer and is adjusted by using leveling screws located on the base. If the torque controller and thermal chamber are separate units, both should be leveled in accordance with the device manufacturer's instructions.

10. CALIBRATION AND STANDARDIZATION

10.1. The accuracy of the rotary transducer is checked using a reference fluid (Newtonian fluid) of known viscosity at various temperatures. The reference fluid shall be certified to be Newtonian in behavior over the full range of expected test temperatures and shear rates. The viscosity measured should be within ±2 percent or the rotary transducer requires recalibration.

10.2. The accuracy of the temperature reading of the temperature controller is checked by placing an asphalt sample in the testing chamber and equilibrating to a given temperature. The indicated temperature shall be verified by using a NIST-traceable measuring device as defined by ASTM E1.

11. PREPARATION OF SAMPLES AND TEST SPECIMENS

11.1. *Preparing Test Samples*—Unaged asphalt and modified asphalt binders are obtained according to R 66.

11.1.1. Anneal the asphalt binder from which the specimen is obtained by heating until sufficiently fluid to pour. Annealing prior to testing removes reversible molecular associations (steric hardening) that may occur during normal storage at ambient temperature.

Note 1—Minimum pouring temperature that produces a consistency equivalent to that of SAE 10W30 motor oil (readily pours but not overly fluid) at room temperature is recommended. The specific temperature will depend on the grade of binder and its prior aging history, if any. Temperatures less than 135°C are desirable; however, temperatures above 135°C may be required for some modified asphalt binders or heavily aged binders.

12. PROCEDURE

12.1. Read and understand the information in the rotational viscometer manufacturer's operating manual before proceeding.

12.2. Turn on the rotational viscometer and proportional temperature controller unit.

12.3. Preheat the sample holder with the sample chamber and the selected cylindrical spindle according to the manufacturer's recommendation.

12.4. Set the proportional temperature controller to desired test temperature.

12.5. Heat the required amount of asphalt binder as recommended by the manufacturer for testing according to Section 11.1.1.

12.6. When the proportional temperature controller reads the desired test temperature, remove the sample holder, and add the required amount of asphalt into the sample chamber.

12.7. Insert the sample chamber into the proportional temperature controller unit.

12.8. Insert a preheated spindle and attach it to the viscometer using the necessary coupling. Gently lower the spindle into the asphalt so that asphalt covers the upper conical portion of the spindle. This procedure may vary based on the manufacturer's recommendations.

12.9. Bring the asphalt sample to the desired temperature within approximately 30 min. Set the viscometer speed at 20 rpm and set the display to read the viscosity in Pascal seconds (Pa·s). This operation may be performed manually or by using a software program. The viscometer speed may be set higher than 20 rpm if it is expected that the observed torque will be out of range at 20 rpm.

12.10. Allow the asphalt sample to equilibrate at the desired test temperature for a minimum of 10 min. Begin the spindle rotation during the 10-min temperature equilibration period. Allow the readings to stabilize before recording any viscosity measurements. If the observed torque is out of range for the selected spindle and speed, change the spindle or speed based on the manufacturer's recommendations for the anticipated viscosity. If a different spindle is used, restart the test with a new sample.

12.11. Start the test after the asphalt sample has reached the specified temperature and equilibrated and the viscosity readings have stabilized, as required in Sections 12.9 and 12.10.

12.12. Measure the viscosity at 1-min intervals for a total of 3 min.

12.13. Follow the procedure in Sections 12.1 to 12.12 for other temperatures.

13. CALCULATION OF RESULTS

13.1. The viscosity is reported as the average of three readings. If the digital output of the rotational viscometer viscosity is in units of centipoise (cP), the following factor is used to convert to Pascal-seconds:

10 P = 1 Pa·s *(1)*

1 cP = 1 mPa·s *(2)*

Multiply viscosity in centipoise by 0.001 to obtain the viscosity in Pa·s.

14. REPORT

14.1. *Report the following information*:

14.1.1. The date and time of the test;

14.1.2. The test temperature to the nearest 1°C;

14.1.3. The speed in rpm;

14.1.4. The size of the spindle used;

14.1.5. The torque in percent; and

14.1.6. The average viscosity in Pa·s.

15. PRECISION AND BIAS

15.1. *Precision*—Criteria for judging the acceptability of viscosity results obtained by this method are given in Table 1.

15.1.1. *Single-Operator Precision (Repeatability)*—The figures in Column 2 of Table 1 are the coefficients of variation that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same

equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results, expressed as a percent of their mean, exceeds the values given in Table 1, Column 3.

15.1.2. *Multilaboratory Precision (Reproducibility)*—The figures in Column 2 of Table 1 are the coefficients of variation that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results, expressed as a percent of their mean, exceeds the values given in Table 1, Column 3.

Table 1—Precision Estimates

Condition	Coefficient of Variation (1s%)[a]	Acceptable Range of Two Test Results (d2s%)[a]
Single-operator precision:		
Average viscosity (Pa·s)	1.2	3.5
Multilaboratory precision:		
Average viscosity (Pa·s)	4.3	12.1

[a] These values represent the 1s% and d2s% limits described in ASTM C670.

Note 2—The precision estimates given in Table 1 are based on the analysis of test results from eight pairs of AMRL proficiency samples. The data analyzed consisted of results from 142 to 202 laboratories for each of the eight pairs of samples. The analysis included five binder grades: PG 52-34, PG 64-16, PG 64-22, PG 70-22, and PG 76-22 (SBS modified). Unmodified binder average viscosity results ranged from 0.272 Pa·s to 0.719 Pa·s. The modified binder average viscosity results ranged from 1.621 Pa·s to 1.638 Pa·s. The details of this analysis are in the final report for NCHRP Project No. 9-26, Phase 3.

Note 3—As an example, two tests conducted on the same material yield viscosity results of 0.500 Pa·s and 0.510 Pa·s, respectively. The average of these two measurements is 0.505 Pa·s. The acceptable range of results is then 3.5 percent of 0.505 Pa·s or 0.018 Pa·s. As the difference between 0.500 Pa·s and 0.510 Pa·s is less than 0.018 Pa·s, the results are within the acceptable range.

15.2. *Bias*—No information can be presented on the bias of the procedure because no material having an accepted reference value is available.

16. KEYWORDS

16.1. Asphalt binder; viscosity.

[1] Formerly AASHTO Provisional Standard TP 48. First published as a full standard in 2002.

Standard Method of Test for

Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

AASHTO Designation: T 331-13[1]
ASTM Designation: D6752/D6752M-11

American Association of State Highway and Transportation Officials
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Standard Method of Test for

Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

AASHTO Designation: T 331-13[1]
ASTM Designation: D6752/D6752M-11

AASHTO

1. SCOPE

1.1. This method covers the determination of bulk specific gravity (G_{mb}) of specimens of compacted hot mix asphalt (HMA) mixtures.

1.2. This method should be used with samples that contain open or interconnecting voids and/or absorb more than 2.0 percent of water by volume, as determined by T 166. An agency may specify this method as an alternative to T 275.

1.3. The bulk specific gravity (G_{mb}) of the compacted HMA may be used in calculating the unit mass of the mixture.

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

1.5. *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*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 245, Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
- T 275, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

2.2. *ASTM Standards*:

- D6752/D6752M, Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method
- D7227/D7227M, Standard Practice for Rapid Drying of Compacted Asphalt Specimens Using Vacuum Drying Apparatus
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers

2.3. *Other Document*:

- FHWA-IF-02-044, NCAT Report No. 02-11, *Bulk Specific Gravity Round-Robin Using the CoreLok™ Vacuum Sealing Device*

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *bulk specific gravity (of solids)*—the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature.

The form of the expression shall be:

Bulk specific gravity at *x*/*y*°C

where:

x = temperature of the material; and

y = temperature of the water.

3.1.2. *constant mass*—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when the mass is determined at 2-h intervals.

4. TEST SPECIMENS

4.1. Test specimens may be either laboratory-compacted HMA mixtures or sampled from HMA pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot mix base.

4.2. *Size of Specimens*—Specimens shall conform to the requirements of T 166.

4.3. Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

4.4. Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

4.6. If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage specimens. Jagged edges or sharp aggregates may puncture the plastic bag. Specimen ends or planar edges may require sawing if the bag does not conform to the specimen in a uniform manner.

5. APPARATUS

5.1. *Bag Cutter*—A knife, scissors, or other types of clipping devices may be used to quickly open bags.

5.2. *Oven*—The oven shall be capable of maintaining the appropriate temperature for drying specimens to a constant mass.

5.3. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231. The weighing device shall be equipped with a suitable suspension apparatus and holder to determine the mass of the specimen while suspended from the center of the scale pan of the weighing device.

5.4. *Plastic Bags*—The two most commonly used sizes of bags are designated as small and large size bags. The small bags shall have a minimum opening of 235 mm (9.25 in.) and a maximum opening of 260 mm (10.25 in.) with a mass of less than 35 g. The large bags shall have a minimum opening of 375 mm (14.75 in.) and a maximum opening of 394 mm (15.5 in.) with a mass of 35 g or more. The bags shall be made of a plastic material that will not adhere to asphalt film and shall be puncture-resistant, capable of withstanding sample temperatures of up to 70°C (158°F), impermeable to water, and contain no air channels for evacuation of air from the bag. The bags shall have a minimum thickness of 0.100 mm (0.004 in.) and a maximum thickness of 0.152 mm (0.006 in.). The manufacturer shall provide the bag correction factor (apparent specific gravity) of the bags (usually located in the operator's manual). See the manufacturer's recommendations to ensure proper handling of bags.

5.5. *Specimen Sliding Plates*—Level and smooth-sided planar filler plates shall be inserted into the chamber to keep the samples of various heights level with the seal bar while being sealed. The plates shall be removable and of the appropriate dimensions to easily fit into the vacuum chamber. A smooth-sided specimen supporting plate shall easily slide on top of the smooth-sided plates. The opposite side of the smooth-sided specimen supporting plate shall have a cushioning membrane to help prevent tears in the plastic bag. The plate shall be large enough to fully support the specimen but small enough to allow movement during the sealing process.

5.6. *Suspension Apparatus*—The wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing.

5.7. *Thermometer*—ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated and conforming to ASTM E1. An electronic temperature measuring device, such as a resistance thermometer or thermocouple, may be used.

5.8. *Vacuum Chamber*—The pump shall be capable of evacuating the sealed and enclosed chamber to 5 mmHg in 60 s at sea level. The chamber shall be large enough to seal samples of 150-by-350-by-150 mm (6-by-14-by-6 in.). A sealing bar of sufficient length to fully seal small and large size bags shall be located inside the chamber. The heat setting shall be set according to the manufacturer's recommendations and the bag composition. The device shall automatically seal the plastic bag and exhaust air back into the chamber in a controlled manner to ensure proper conformance of the plastic bag to the specimen. The air exhaust and vacuum operation time should be calibrated to bring the chamber to atmospheric pressure in 80 to 120 s after completion of the vacuum operation. The vacuum system should be provided with a latch to control chamber door opening.

5.9. *Vacuum Gauge (Standardized)*—The standardized vacuum gauge shall be capable of being placed inside the automatic vacuum sealing device to verify vacuum performance and seal integrity. The gauge shall have a minimum range of 10 to 0 mmHg (10 to 0 torr) and shall be readable to 1 mmHg (1 torr) increments, as a minimum.

5.10. *Water Bath*—For immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level and thermostatically controlled so as to maintain the bath at 25 ± 1°C (77 ± 1.8°F). A heater and circulator may be attached. The circulator shall not be in use while recording sample masses. It is important that the water bath be of sufficient size to ensure sufficient space for the sample and the plastic bag suspension. A water bath with suggested minimum dimensions (length by width by depth) of 610-

by-460-by-460 mm (24-by-18-by-18 in.) or a large cylindrical container has been found to work well for this test method. (See Note 1.)

Note 1—If a cushioned holder is used inside the water bath, it should not have sharp edges. Cushioned holders with sharp edges have been found to puncture the plastic bags. A clip may be attached to the container to hold the plastic bags underwater and to keep edges of the plastic bags from touching the edges of the water bath. Water baths at eye level may help prevent tears in bags and assist in ease of use.

6. PROCEDURE

6.1. *Initial Mass of Specimen in Air*—Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F), or vacuum-dry the specimen according to ASTM D7227/D7227M. Samples saturated with water shall initially be dried overnight and then the mass determined at 2-h drying intervals. Recently compacted laboratory samples that have not been exposed to moisture do not require drying. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the initial dry mass as *A*. It is important that the sample contain less than 5 g of water before it is exposed to vacuum. At high vacuum, water will evaporate, potentially causing the bag around the sample to loosen due to trapped gas, thus resulting in a higher volume determination and a lower bulk specific gravity result.

Note 2—Bulk specific gravity (G_{mb}) determined by this method may be lower, and air voids higher, than the results obtained by T 166. The differences may be more pronounced for coarse and absorptive mixtures. Users of this test method are cautioned to evaluate any alteration in asphalt content or aggregate gradation for mix designs with a positive performance history. If this procedure will be used for control or assurance testing, users are cautioned to follow this procedure during the laboratory mix design.

Note 3—Laboratory-compacted specimens of 3000 to 6000 g may be considered at room temperature equilibrium after 2 h of cooling under a fan. The cooling time may be reduced for smaller specimens or if verified to have no significant differences in properties from those cooled to room temperature equilibrium.

Note 4—Some steps may be performed in conjunction with T 166.

6.2. *Sealing the Specimen*—Select an appropriately sized bag for the specimen. Specimens of 100 mm (4 in.) and 150 mm (6 in.) up to 50 mm (2 in.) in thickness are usually tested with the small bag. Specimens of 150 mm (6 in.) in diameter by 50 mm (2 in.) or greater in thickness will usually be tested with a large bag.

6.2.1. Set the heat-sealing bar temperature according to the bag manufacturer's recommendations.

6.2.2. Inspect the bag for holes and irregularities, then record the bag mass. Place the bag inside the vacuum chamber on top of the specimen sliding plate.

6.2.3. Insert the specimen into the bag with the smoothest plane of the specimen on the bottom. This operation may be done inside the chamber while holding the bag open with one hand over the sliding plate and gently inserting the specimen with the other hand. There should be about 25 mm (1 in.) of slack between the presealed bag end and the specimen.

6.2.4. If needed, filler plates should be added or removed prior to inserting the specimen. Grab the unsealed end of the bag on each side, and gently pull and center it over the seal bar, overlapping the bag at least 25 mm (1 in.).

6.2.5. Ensure that there are no wrinkles in the bag along the seal bar just prior to closing the lid.

6.2.6. Close the lid, and engage the lid-retaining latch. The vacuum pump light will illuminate "red," and the vacuum gauge on the exterior of the chamber will become active, or a digital reading will show the vacuum state. It is normal for the bag to expand or "puff up" during this process.

6.2.7. Once sealed, the "de-vac" valve will open, and air will enter the chamber, causing atmospheric pressure to collapse the bag around the specimen.

6.2.8. Disengage the lid-retaining latch, and carefully remove the sealed specimen from the chamber. Gently pull on the bag at any areas that appear loose. Loose areas indicate a poor seal and the process must then be restarted at Section 6.1 with a new bag and a new initial mass.

6.3. *Sealed Specimen Mass*—Calculate the mass of the sealed specimen in air by summing the masses recorded in Sections 6.1 and 6.2.2. Designate this mass as *B*.

6.4. *Mass of Sealed Specimen in Water*—Quickly weigh the sealed specimen in a water bath at 25 ± 1°C (77 ± 1.8°F). Fully submerge the specimen and bag to ensure no trapped air bubbles exist under the specimen. Ensure that the bag is completely underwater and that it is not touching the edges of the water bath. Designate this mass as *E*.

Note 5—The time between the lid opening after sealing and the time to placement of the specimen into the water bath should not exceed 1 min to reduce the potential for bag leaks.

6.5. *Check*—To ensure a tight seal in the bag, remove the sample from the water, and cut the bag open. Remove the sample from the bag, and determine its mass. Designate this mass as *C*. Compare this mass with initial dry mass determined in Section 6.1 as *A*. If *A* is more than 5 g from the mass of dry specimen *C*, the results from this method may not be accurate. The check passes if less than 0.08 percent is lost or no more than 0.04 percent is gained. A loss indicates sample material loss, and a gain indicates a possible bag leakage problem. Remove the bag, and restart the process at Section 6.1 if this check fails.

6.6. If the specimen may be needed for referee testing, oven-dry the specimen as described in Method C of T 166 or vacuum-dry it according to ASTM D7227/D7227M.

6.7. If the specimen will not be needed for referee testing, oven-dry the specimen as described in Method A of T 166, or vacuum-dry it according to ASTM D7227/D7227M.

7. CALCULATION

7.1. Calculate the bulk specific gravity (G_{mb}) of the specimen as follows. Round and report the value to the nearest 0.001.

$$G_{mb} = \frac{A}{\left[C + (B - A) - E - \left[\frac{B - A}{F}\right]\right]} \quad (1)$$

where:

G_{mb} = specimen bulk specific gravity;
A = initial mass of the dried specimen in air, g;
B = calculated mass of the dry, sealed specimen, g;
C = final mass of the specimen after removal from the sealed bag, g;
E = mass of the sealed specimen underwater, g; and
F = bag correction factor (apparent specific gravity) of the plastic sealing material at 25°C (77°F), provided by the manufacturer.

7.2. Calculate the density of the specimen as follows. Round and report the value to the nearest 1 kg/m³ (lb/ft³).

$$\tilde{n} = G_{mb}\,(\tilde{a}) \qquad (2)$$

where:

G_{mb} = bulk specific gravity of the specimen;

$\tilde{n}$ = density of the specimen, kg/m^3 or lb/ft^3 (pcf); and

$\tilde{a}$ = density of water at 25°C (77°F), (997.0 kg/m^3, 0.997 g/cm^3, or 62.2 lb/ft^3, pcf).

8. VERIFICATION

8.1. *Vacuum System Verification*:

8.1.1. The vacuum settings of the device shall be verified once every 3 months, after repairs, and after shipment or relocation, as a minimum.

8.1.2. Verification shall be performed with an absolute vacuum gauge capable of being placed inside the chamber and reading the vacuum setting of the sealing device.

8.1.3. Place the gauge inside the chamber and record the setting. The gauge should indicate a reading of 10 mmHg (10 torr) or less. The unit should not be used if the gauge reading is above 10 mmHg (10 torr).

8.2. *Plastic Bag Verification*:

8.2.1. The bag correction factor (apparent specific gravity) of the plastic bag provided by the manufacturer shall be verified periodically.

8.2.2. Compact a specimen of 4.75-mm (No. 4) nominal-maximum aggregate size HMA with a Marshall compactor or gyratory compactor (according to T 245 or T 312, respectively) to minimum dimensions of 100 mm (4 in.) in diameter by 60 mm (2.4 in.) thick. The sample should be compacted to produce air voids of 4.0 ± 1.0 percent. Alternatively, compact a specimen of fine-graded 9.5-mm nominal-maximum aggregate size HMA with a Marshall compactor or gyratory compactor (according to T 245 or T 312, respectively) to minimum dimensions of 150 mm (6 in.) in diameter by 100 mm (4 in.) thick. The sample should be compacted to produce air voids of 4.0 ± 1.0 percent.

8.2.3. Using three bags from the same size set of plastic bags and the compacted specimen from Section 8.2.2, follow Section 6 as appropriate; determine the bulk specific gravity (G_{mb}) of the compacted specimen for each individual bag.

8.2.4. Average the three bulk specific gravities (or densities) obtained with each bag.

8.2.5. Determine the bulk specific gravity (G_{mb}) of the same compacted specimen, by T 166.

8.2.6. The average bulk specific gravity (or density) calculated for the HMA specimen using the plastic bags shall be within ±0.020 g/cm^3 (20 kg/m^3) of the bulk specific gravity (or density) as determined by T 166 for the same HMA specimen. If the difference between T 166 and T 331 bulk specific gravities is outside of the required tolerance, dry the sample per the procedures in Section 6.1, and repeat the above verification test. Average the values for the first and second verification tests, and ensure that the difference is less than or equal to 0.02 g/cm³. Contact the manufacturer if this verification test fails.

8.2.7. This section shall be repeated for each bag size.

9. PRECISION

9.1. Criteria for judging the acceptability of bulk specific gravity results obtained by this test method are given in Table 1.

Table 1—Acceptability of Bulk Specific Gravity (G_{mb}) [a]

Test and Type Index	Standard Deviation	Acceptable Range of Two Results
Single-operator precision	0.0124	0.035
Multilaboratory precision	0.0135	0.038

[a] The precision estimates were obtained from *Bulk Specific Gravity Round-Robin Using the CoreLok™ Vacuum Sealing Device* report. The FHWA pooled-fund study report number was FHWA-IF-02-044, NCAT Report No. 02-11.

9.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between results of two properly conducted tests.

[1] Similar, but not identical, to ASTM D6752/D6752M-11.

Standard Method of Test for

Moisture Content of Asphalt Mixtures by Oven Method

AASHTO Designation: T 329-15

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

Moisture Content of Asphalt Mixtures by Oven Method

AASHTO Designation: T 329-15

1. SCOPE

1.1. This method is intended for the determination of moisture content of asphalt mixtures by drying in an oven.

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 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 231, Weighing Devices Used in the Testing of Materials
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- T 168, Sampling Bituminous Paving Mixtures

3. SUMMARY OF TEST METHOD

3.1. A test specimen of asphalt mixture is dried in a forced-air, ventilated, or convection oven to constant mass.

4. APPARATUS

4.1. *Balance or Scale*—2-kg (4.4-lb) capacity, readable to at least 0.1 g and conforming to the requirements of M 231.

4.2. *Forced-Air, Ventilated, or Convection Oven*—capable of maintaining the temperature surrounding the sample at 163 ± 14°C (325 ± 25°F).

4.3. *Sample Container*—The container in which the sample is dried shall be of sufficient size to contain the sample without danger of spilling and to allow the sample to be evenly distributed in a manner that will allow completion of the test in an expeditious manner.

4.4. *Thermometers*—Readable to the nearest 2°C (4°F), for determining temperatures of asphalt mixtures. Armored-glass, dial type, or digital thermometers with metal stems are recommended.

5. SAMPLE

5.1. A sample of asphalt mixture shall be obtained in accordance with T 168.

5.2. The sample shall be reduced in size in accordance with R 47. The size of the test sample shall be a minimum of 1000 g.

6. PROCEDURE

6.1. Determine and record the mass of the sample container including any material used to line the sample container to the nearest 0.1 g.

Note 1—When using paper or other absorptive material to line the sample container, ensure it is dry before determining the initial mass of the sample container.

6.2. Place the test sample in the sample container. Determine and record the temperature of the test sample. To facilitate drying, evenly distribute the test sample in the sample container.

6.3. Determine and record the total mass of the sample container and moist test sample to the nearest 0.1 g.

6.4. Preheat the oven to drying temperature. The drying temperature shall fall within the job mix formula mixing temperature range. If a mixing temperature range is not supplied, a temperature of 163 ± 14°C (325 ± 25°F) will be used.

Note 2—For repeatability between operators and/or laboratories, the difference between drying temperatures for samples should not exceed 9°C (15°F).

6.5. Calculate the mass of the initial, moist test sample by subtracting the mass of the sample container determined in Section 6.1 from the total mass of the sample container and moist test sample determined in Section 6.3.

6.6. Dry the sample initially for 90 ± 5 min and determine its mass. Then continue to dry the sample to constant mass, checking at 30 ± 5-min intervals until further drying does not alter the mass by more than 0.05 percent.

Note 3—The moisture content of test samples and the number of test samples in the oven will affect the rate of drying at any given time. Placing wet test samples in the oven with nearly dry test samples could affect the drying process.

6.7. Cool the sample container and test sample to approximately the same temperature as determined in Section 6.2.

6.8. Determine and record the total mass of the sample container and dry test sample to the nearest 0.1 g.

Note 4—Do not attempt to remove the test sample from the sample container for the purposes of determining the dry mass of the test sample.

6.9. Calculate the mass of the final, dry test sample by subtracting the mass of the sample container determined in Section 6.1 from the total mass of the sample container and dry test sample determined in Section 6.8.

7. CALCULATIONS

7.1. *Calculate moisture content as follows*:

$$\text{moisture content, \%} = \frac{M_i - M_f}{M_f} \times 100 \qquad (1)$$

where:

M_i = mass of the initial, moist test sample, g; and

M_f = mass of the final, dry test sample, g.

Example:

M_i = 1134.9 g

M_f = 1127.3 g

$$\text{moisture content, \%} = \frac{1134.9 \text{ g} - 1127.3 \text{ g}}{1127.3 \text{ g}} \times 100 = 0.67\%$$

7.2. *Calculate the percent change in mass, as described in Section 6.6, as follows*:

$$\text{\% change} = \frac{\left(M_p - M_n\right)}{M_n} \times 100 \qquad (2)$$

where:

M_p = previous mass measurement; and

M_n = new mass measurement.

8. REPORT

8.1. Report the moisture content to the nearest 0.01 percent.

9. KEYWORDS

9.1. Hot mix asphalt; moisture content; oven-drying.

Designation: D4867/D4867M – 09 (Reapproved 2014)

Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures[1]

This standard is issued under the fixed designation D4867/D4867M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers procedures for preparing and testing asphalt concrete specimens for the purpose of measuring the effect of water on the tensile strength of the paving mixture. This test method is applicable to dense mixtures such as those appearing in the Table for Composition of Bituminous Paving Mixtures in Specification D3515. This test method can be used to evaluate the effect of moisture with or without antistripping additives including liquids and pulverulent solids such as hydrated lime or portland cement.

1.2 The values stated in either SI units or inch-pound units in parentheses shall be regarded separately as standard. The values 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 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 *ASTM Standards:*[2]

D979 Practice for Sampling Bituminous Paving Mixtures
D1074 Test Method for Compressive Strength of Bituminous Mixtures
D1561 Practice for Preparation of Bituminous Mixture Test Specimens by Means of California Kneading Compactor
D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
D2726 Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures
D3203 Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
D3387 Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)
D3496 Practice for Preparation of Bituminous Mixture Specimens for Dynamic Modulus Testing (Withdrawn 2010)[3]
D3515 Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures (Withdrawn 2009)[3]
D3549 Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
D3665 Practice for Random Sampling of Construction Materials
D4013 Practice for Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor (Withdrawn 2013)[3]
D4123 Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures (Withdrawn 2003)[3]
D6926 Practice for Preparation of Bituminous Specimens Using Marshall Apparatus

3. Summary of Test Method

3.1 *Potential for Moisture Damage*—The degree of susceptibility to moisture damage is determined by preparing a set of laboratory-compacted specimens conforming to the job-mix formula without an additive. The specimens are compacted to a void content corresponding to void levels expected in the field, usually in the 6 to 8 % range. The set is divided into two subsets of approximately equal void content. One subset is maintained dry while the other subset is partially saturated with water and moisture conditioned. The tensile strength of each subset is determined by the tensile splitting test. The potential for moisture damage is indicated by the ratio of the tensile strength of the wet subset to that of the dry subset.

3.2 *Additive Effect*—The effect of an antistripping additive is determined on a set of specimens containing an additive prepared and tested as described in 3.1. The effect of an additive dosage may be estimated by repeating the tests on sets with different additive dosages.

3.3 *Plant-Produced Mixtures*—The potential for moisture damage or the effectiveness of an additive in a plant-produced

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.22 on Effect of Water and Other Elements on Asphalt Coated Aggregates.

Current edition approved July 1, 2014. Published November 2014. Originally approved in 1988. Last previous edition approved in 2009 as D4867/D4867M – 09. DOI: 10.1520/D4867_D4867M-09R14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

mixture is determined on specimens that are laboratory compacted to expected field-level void content, divided into wet and dry subsets, and evaluated as described in 3.2.

4. Significance and Use

4.1 This test method can be used to test asphalt concrete mixtures in conjunction with mixture design testing to determine the potential for moisture damage, to determine whether or not an antistripping additive is effective, and to determine what dosage of an additive is needed to maximize the effectiveness. This test method can also be used to test mixtures produced in plants to determine the effectiveness of additives under the conditions imposed in the field.

5. Apparatus

5.1 To prepare and compact the specimens use apparatus from any one of the following: Test Methods D1074, and D3387, Practice D3496, or Practices D1561, D4013, and D6926.

5.2 *Vacuum Pump or Water Aspirator* in accordance with Test Method D2041.

5.3 *Manometer or Vacuum Gage* in accordance with Test Method D2041.

5.4 *Container,* preferably Type F, of Test Method D2041.

5.5 *Balance* in accordance with Test Method D2726.

5.6 *Water Baths* Three:

5.6.1 One waterbath in accordance with Test Method D2726.

5.6.2 One bath capable of maintaining a temperature of 60 ± 1.0°C (140 ± 1.8°F) for 24 h, and

5.6.3 One bath capable of maintaining a temperature of 25 ± 1.0°C (77 ± 1.8°F).

5.7 *Mechanical* or *Hydraulic Testing Machine* capable of maintaining the required strain rate and measuring load with equal or better precision.

5.8 *Loading Strips* in accordance with Test Method D4123.

6. Preparation of Laboratory Test Specimens

6.1 Make at least six specimens for each test, three to be tested dry and three to be tested after partial saturation and moisture conditioning.

6.2 Use specimens 100 mm (4 in.) in diameter and 62.5 mm (2.5 in.) high, in general, but specimens of other dimensions may be used if desired. When using aggregate larger than 25 mm (1 in.), use specimens at least 150 mm (6 in.) in diameter.

NOTE 1—The user is cautioned that the specimen diameter has been determined to influence both the tensile strength and the tensile strength ratio. The tensile strength and the tensile strength ratio values may be different for 150–mm specimens compared to 100–mm specimens.

6.3 Prepare mixtures in batches large enough to make at least 3 specimens or, as an alternative, prepare a batch just large enough for 1 specimen. If theoretical maximum specific gravity is to be determined, use a batch large enough or prepare a separate batch to provide a specimen for this purpose.

6.4 When a liquid antistripping additive is used, heat a sufficient quantity of asphalt cement for one batch to 150 ± 6°C (300 ± 10°F) in a closed 1 L (1-qt) can in an oven. Add the required quantity of additive and immediately mix, for approximately 2 min, with a mechanical stirrer approximately 25 mm (1 in.) from the bottom of the container. Maintain the treated asphalt cement at 150 ± 6°C (300 ± 10°F) in the closed can until it is used. Discard the treated asphalt cement if not used the same day it is prepared, or if allowed to cool so that it requires reheating.

6.5 When using a pulverulent solid antistripping additive , use the addition procedure simulating the procedure expected in the field. Follow the procedure specified in either 6.5.1, 6.5.2, or 6.5.3.

6.5.1 When dry powder is added to dry aggregate, dry, batch, and heat the mineral aggregate to 150 ± 6°C (300 ± 10°F). Add the required quantity of additive to the aggregate, and thoroughly mix the entire mass until a uniform distribution of additive is achieved. Take care to minimize the loss of additive to the atmosphere in the form of dust. After mixing, maintain the treated aggregate at the required mixing temperature until it is used.

6.5.2 When dry powder is added to damp aggregate, batch the damp mineral aggregate, and adjust the moisture content of the combined aggregate to the expected field moisture level. Add the required quantity of additive to the damp aggregate, and thoroughly mix the entire mass until a uniform distribution of additive is achieved. Take care to minimize the loss of additive to the atmosphere in the form of dust. After mixing, dry the treated aggregate, heat to the required mixing temperature, and maintain at that temperature until it is used.

6.5.3 When powder slurry is used, add the required quantity of additive to water using the powder to water ratio expected in the field. Take care to minimize the loss of additive to the atmosphere in the form of dust. To prevent settling, continuously mix the resulting slurry until it is used. Batch the damp mineral aggregate, adjust the moisture content as required in 6.5.2, add the required quantity of slurry, and thoroughly mix the entire mass until a uniform distribution of slurry is achieved. After mixing, dry the treated aggregate, heat to the required mixing temperature, and maintain at that temperature until used.

6.6 Proportion, mix, and compact specimens in accordance with one of the following: Test Methods D1074, D3387, Practice D3496, Practices D1561, D4013, or D6926, and 6.6.1 and 6.6.2.

6.6.1 After mixing, stabilize the mixture temperature of each specimen at the required compaction temperature, in a closed container, in an oven for 1 to 2 h. If preparing a multi-specimen batch, split the batch into single-specimen quantities before placing into the oven.

6.6.2 Compact the specimens to 7 ± 1 % air voids, or a void level expected in the field at the time of construction. This void level can be obtained by adjusting the following: the static load in double-plunger compaction; the number of blows in a marshall hammer compaction; the foot pressure, number of

tamps, leveling load, or some combination in kneading compaction; or the number of revolutions in gyratory compaction. Determine the exact procedure by trial for each mixture.

6.6.3 Cool specimens in the mold to room temperature as rapidly as possible in a stream of moving air, extract from molds, then follow the procedure outlined in Section 8 within 24 h.

7. Preparation of Field Specimens

7.1 Select a truck to be sampled in accordance with Practice D3665.

7.2 Secure a sample from the truck at the plant in accordance with Practice D979.

7.3 Stabilize the mixture temperature to approximately the temperature found in the field when rolling begins. Maintain this temperature in a closed container, in an oven if necessary, for approximately the time lapse between mixing and the start of actual rolling.

7.4 Compact the specimens in accordance with 6.6.2, and cool and extract from the molds in accordance with 6.6.3.

7.5 If specimens are not to be compacted in the field laboratory, place the samples in a sealed container, transport to the laboratory, and reheat to the temperature required in 7.3. Proceed with the steps in 7.4.

NOTE 2—Specimens made from plant-produced mixtures in accordance with Section 7 may yield different results from specimens made from laboratory-produced mixtures of the same job mix made in accordance with Section 6.

8. Procedure

NOTE 3—A data sheet that is convenient for use with this procedure appears in Appendix X1.

8.1 Determine the theoretical maximum specific gravity in accordance with Test Method D2041.

8.2 Determine the specimen height in accordance with Test Method D3549.

8.3 Determine the bulk specific gravity in accordance with Test Method D2726, and express the volume of the specimen in cubic centimeters. The term (*B-C*) in Test Method D2726 is the volume of the specimen in cubic centimeters.

8.4 Calculate the percent air voids in accordance with Test Method D3203, and express the volume of air in cubic centimeters. The volume of air is the volume of the specimen in 8.3 multiplied by the percent air voids.

8.5 Sort the specimens into two subsets so that the average air voids of the two subsets are approximately equal. Store the subset to be tested dry at room temperature.

8.6 Partially saturate the subset to be moisture conditioned with distilled water at room temperature using a vacuum chamber. If it is difficult to reach the minimum degree of saturation required in 8.6.3, the water used to saturate may be heated up to 60°C (140°F).

8.6.1 Partially saturate, to the degree specified in 8.6.3, by applying a partial vacuum such as 70 kPa or 525 mm Hg (20 in. Hg) for a short time such as five min.

NOTE 4—Experiments with partial vacuum at room temperature indicate that the degree of saturation is very sensitive to the magnitude of the vacuum and practically independent of the duration. The level of vacuum needed appears to be different for different mixtures.

8.6.2 Determine the volume of the partially saturated specimen in accordance with Test Method D2726. Determine the volume of the absorbed water by subtracting the air-dry mass of the specimen in 8.3 from the saturated surface-dry mass of the partially saturated specimen.

8.6.3 Determine the degree of saturation by dividing the volume of the absorbed water in 8.6.2 by the volume of air voids in 8.4 and express the result as a percentage. If the volume of water is between 55 and 80 % of the volume of air, proceed to 8.7. If the volume of water is less than 55 %, repeat the procedure beginning with 8.6.1 using a slightly higher partial vacuum. If the volume of water is more than 80 %, the specimen has been damaged and is discarded.

NOTE 5—If the average air voids of the saturated subset is less than 6.5 %, a degree of saturation of at least 70 % is recommended.

8.7 Moisture condition the partially saturated specimens by soaking in distilled water at 60 ± 1.0°C (140 ± 1.8°F) for 24 h.

NOTE 6—If a freeze-thaw conditioning cycle is desired, the following procedure is suggested instead of the procedure in 8.7. Wrap each of the partially saturated specimens tightly with two layers of plastic film using masking tape to hold the wrapping if necessary. Place each wrapped specimen into a leak-proof plastic bag containing approximately 3 mL of distilled water, and seal the bag with a tie or tape. Place the wrapped and bagged specimens into an air bath freezer at −18 ± 2.0°C (−0.4 ± 3.6°F). After at least 15 h in the freezer, remove the specimens and immerse them in a water bath at 60 ± 1.0°C (140 ± 1.8°F) for 24 h. After 3 min of immersion, after specimen surface thaw occurs, remove the bag and wrapping from the specimens.

8.8 Adjust the temperature of the moisture-conditioned subset by soaking in a water bath for 1 h at 25 ± 1°C (77 ± 1.8°F).

8.9 Measure the height of the moisture-conditioned subset by Test Method D3549, and determine volume by Test Method D2726.

8.9.1 Determine the water absorption and the degree of saturation in accordance with 8.6.2 and 8.6.3. A degree of saturation exceeding 80 % is acceptable.

8.9.2 Determine the swell of the partially saturated specimens by dividing the change in specimen volumes in 8.6.2 and 8.3 by the specimen volume in 8.3. Determine the swell of moisture-conditioned specimens by dividing the change in the specimen volume in 8.9 and 8.3 by the specimen volume in 8.3.

8.10 Adjust the temperature of the dry subset by soaking in a water bath for 20 min at 25 ± 1.0°C (77 ± 1.8°F).

8.11 Determine the tensile strength at 25 ± 1.0°C (77 ± 1.8°F) of both subsets.

8.11.1 Place a specimen into the loading apparatus and position the loading strips so that they are parallel and centered on the vertical diametral plane. Apply a diametral load at 50 mm/min (2 in./min) until the maximum load is reached, and record the maximum load.

8.11.2 Continue loading until the specimen fractures. Break the specimen open and visually estimate and record the approximate degree of moisture damage, if any.

8.11.3 Inspect all surfaces, including the failed faces, for evidence of cracked or broken aggregate, that may influence test results, and record observations.

9. Calculation

9.1 Calculate the tensile strength as follows:

$$S_t = 2000\,P\,\pi tD\,(\mathrm{kPa}) \quad (1)$$

or

$$S_t = 2P/\pi tD\,(\mathrm{psi})$$

where:

S_t = tensile strength, kPa (psi)
P = maximum load, N (lbf)
t = specimen height immediately before tensile test, mm (in.), and
D = specimen diameter, mm (in.).

9.2 Calculate the tensile strength ratio as follows:

$$TSR = (S_{tm}/S_{td})100 \quad (2)$$

where:

TSR = tensile strength ratio, %
S_{tm} = average tensile strength of the moisture-conditioned subset, kPa (psi), and
S_{td} = average tensile strength of the dry subset, kPa (psi).

10. Report

10.1 Report the following information:
10.1.1 Number of specimens in each subset,
10.1.2 Average air voids of each subset,
10.1.3 Average degree of saturation after partial saturation and after moisture conditioning,
10.1.4 Average swell after partial saturation and after moisture conditioning,
10.1.5 Tensile strength of each specimen in each subset,
10.1.6 Tensile strength ratio,
10.1.7 Results of visually-estimated moisture damage observed when the specimen fractures, and
10.1.8 Results of observations of fractured or crushed aggregate.

NOTE 7—If the conditioning procedure described in Note 6 is used, that fact should be included in the report.

11. Precision and Bias

11.1 *Precision*—The standard deviations for use with this test method have been determined using laboratory-mixed specimens conditioned in accordance with 8.7. Neither plant-mixed material nor the conditioning in Note 6 has been studied. Nineteen laboratories participated in the precision study by testing five asphalt concrete mixtures, two of which contained a liquid antistripping additive.

11.1.1 *Within-Laboratory Precision*—The single-operator standard deviation of tensile strength for either dry or moisture-conditioned specimens has been found to be 55 kPa (8 psi). The d2s limit for the maximum allowable difference in tensile strength between duplicate specimens of the same mixture tested by the same operator is 159 kPa (23 psi).

11.1.2 *Between-Laboratory Precision*—The multilaboratory standard deviation of the tensile-strength ratio has been found to be 8 %. The d2s limit for the maximum allowable difference in tensile-strength ratio between results of tests performed on samples of the same mixture by two different laboratories is 23 %.

11.2 *Bias*—This test method has an undetermined bias because the value of a tensile-strength ratio can be defined only in terms of the test method.

12. Keywords

12.1 antistripping additives; asphalt concrete paving mixtures; moisture; tensile strength; water

APPENDIX

(Nonmandatory Information)

X1. MOISTURE DAMAGE LABORATORY DATA SHEET

Project									
Additive					Dosage				
Compaction Method					Effort				
	Date Tested					By			
Sample I.D.									
Diameter, mm (in.)	*D*								
Thickness, mm (in.)	*t*								
Dry mass in air	*A*								
SSD mass	*B*								
Mass in water	*C*								
Volume (*B*-*C*)	*E*								
Bulk Sp. Gr. (*A*/*E*)	*F*								
Max Sp. Gr.	*G*								
% AirVoid (100(G-F)/G)	*H*								
Volume AirVoid, HE/100	*I*								
Load, N (lbf)	*P*								
Saturated min. @		kPa or mm Hg (in. Hg)							
SSD Mass	*B*'								
Mass in water	*C*'								
Volume (*B*'-*C*')	*E*'								
Vol Abs. water (*B*'-*A*)	*J*'								
% Saturation (100*J*'/*I*)									
% Swell (100(*E*'-*E*)/*E*)									
Conditioned 24 h in 140°F water									
Thickness, mm (in.)	*t*″								
SSD Mass	*B*″								
Mass in water	*C*″								
Volume (*B*″-*C*″)	*E*″								
Vol Abs. Water (*B*″-*A*)	*J*″								
% Saturation, (100*J*″/*I*)									
% Swell, 100(*E*″-*E*)/*E*									
Load, N (lbf)	*P*″								
Dry Strength, 2000 *P*/π*tD* (2*P*/π *tD*)	S_{td}								
Wet Strength, 2000 *P*″/π*t*″*D* (2*P*″/π *t*″*D*)	S_{tm}								
TSR, 100S_{tm} /S_{td}									
Visual Moisture Damage									
Crack/Break Aggregate									

Standard Practice for

Preparation of Asphalt Mixtures by Means of the Marshall Apparatus

AASHTO Designation: R 68-15[1]

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

AASHTO

American Association of State Highway and Transportation Officials
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Washington, D.C. 20001

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AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

1. SCOPE

1.1. This standard practice describes procedures for the compaction of cylindrical specimens of asphalt mixtures using the Marshall compaction hammer. This practice is for use with mixtures containing asphalt binder or asphalt cutback and aggregate up to 25.4-mm (1-in.) maximum size.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 275, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

3. APPARATUS

3.1. *Specimen Mold Assembly*—Mold cylinders 101.6 mm (4 in.) in diameter by 76.2 mm (3 in.) in height, base plates, and extension collars shall conform to the details shown in Figure 1. Three mold cylinders are recommended.

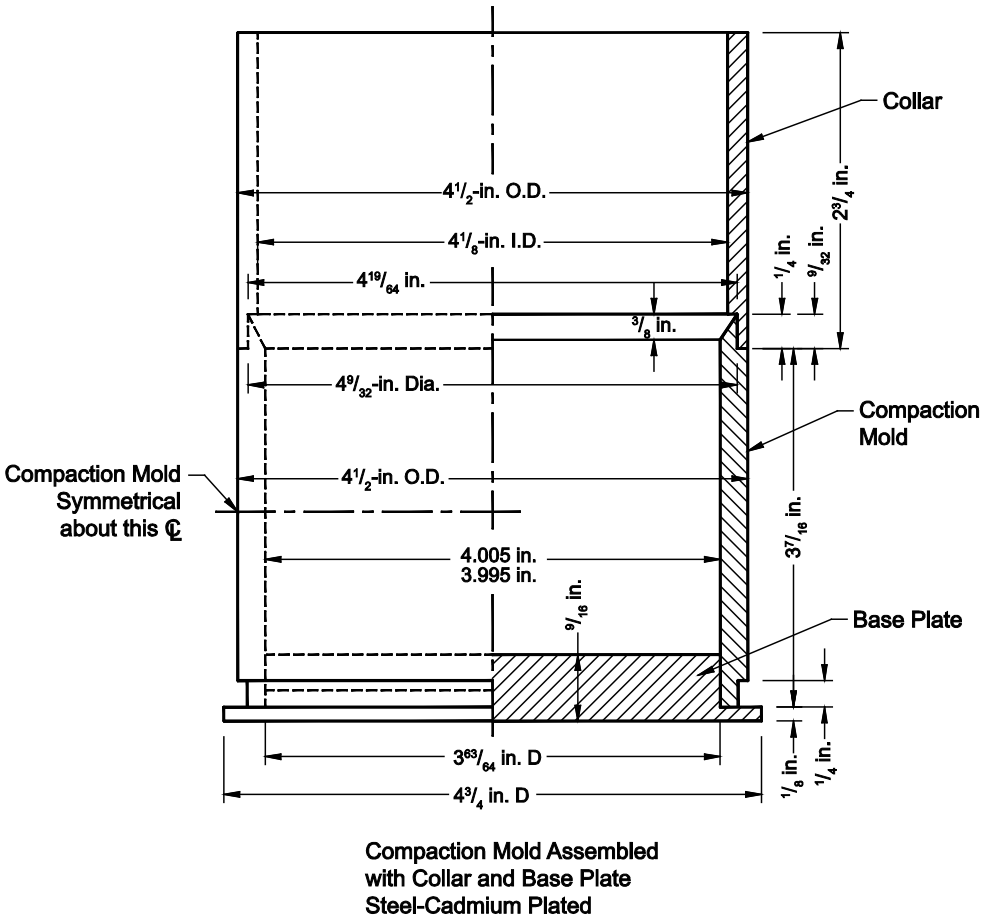


Figure 1—Specimen Mold Assembly

Table 1—Table of Equivalents for Figures 1 and 3

Metric Equivalents, mm	U.S. Customary Units, in.	Metric Equivalents, mm	U.S. Customary Units, in.	Metric Equivalents, mm	U.S. Customary Units, in.	Metric Equivalents, mm	U.S. Customary Units, in.
0.11	0.005	17.5	11/16	58.7	2 5/16	104.8	4 1/8
0.8	1/32	19.0	3/4	63.5	2 1/2	108.7	4 9/32
1.6	1/16	22.2	7/8	69.8	2 3/4	109.1	4 19/64
3.2	1/8	23.8	15/16	73.0	2 7/8	114.3	4 1/2
4.8	3/16	25.4	1	76.2	3	117.5	4 5/8
6.4	1/4	28.6	1 1/8	82.6	3 1/4	120.6	4 3/4
7.1	9/32	31.8	1 1/4	87.3	3 7/16	128.6	5 1/16
9.5	3/8	34.9	1 3/8	98.4	3 7/8	130.2	5 1/8
12.6	0.496	38.1	1 1/2	101.2	3 63/64	146.0	5 3/4
12.67	0.499	41.3	1 5/8	101.35	3.990	152.4	6
12.7	1/2	44.4	1 3/4	101.47	3.995	158.8	6 1/4
14.3	9/16	50.8	2	101.6	4	193.7	7 5/8
15.9	5/8	57.2	2 1/4	101.73	4.005	685.8	27

3.2. *Specimen Extractor*—Steel, in the form of a disk with a diameter not less than 100 mm (3.95 in.) and 12.7 mm (1/2 in.) thick for extracting the compacted specimen from the specimen mold with

the use of the mold collar. A suitable bar is required to transfer the load from the ring dynamometer adapter to the extension collar while extracting the specimen. A hydraulic jack or similar device may also be used provided specimens are not damaged during extraction.

3.3. *Compaction Hammer*:

3.3.1. *Manual Hammer*—The compaction hammer (Figure 2) shall have a flat, 98.4 ± 3.2 mm ($3^{7}/_{8} \pm {}^{1}/_{8}$ in.) circular tamping face and a 4536 ± 9 g (10 ± 0.02 lb) sliding weight (including a safety finger guard if so equipped) with a free fall of 457.2 ± 1.524 mm (18 ± 0.06 in.).

3.3.2. *Automatic Hammer*—An automatic hammer shall meet the requirements listed for manual hammers in Section 3.3.1. The automatic hammer consists of the mechanical compactor, an automatic counter, and a tapered-foot hammer assembly for rotating-mold models or a flat-foot hammer assembly for stationary mold models. To calibrate the automatic hammer to the manual hammer, compact six specimens: three specimens using the manual hammer and three specimens using the automatic hammer. Use the same number of blows for each specimen. After the specimens have cooled to room temperature, use T 166, T 275, or T 331 to determine the average bulk densities of the two sets of specimens. If the bulk densities of the two sets of specimens are within 2.0 percent of each other, then the results are comparable. If the results are not within 2.0 percent of each other, then the tests need to be repeated using more or fewer blows on the automatic hammer to achieve a comparable density.

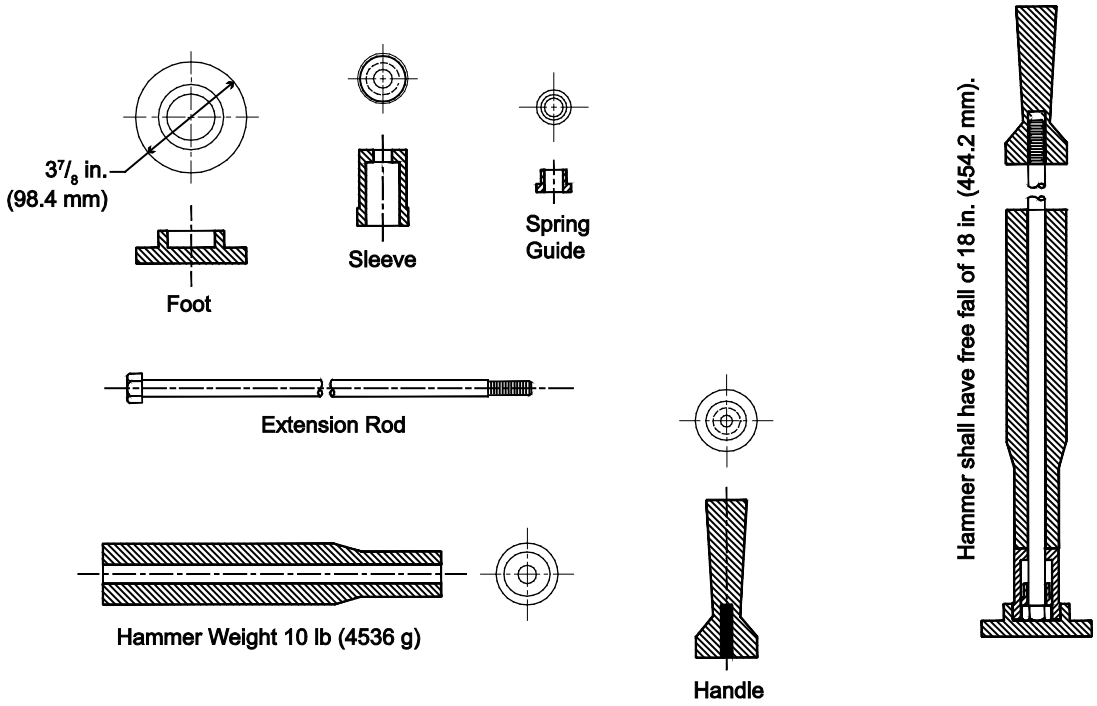


Figure 2—Compaction Hammer (Manual)

3.4. *Compaction Pedestal*—The compaction pedestal shall consist of a 203.2-by-203.2-by-457.2-mm (8-by-8-by-18-in.) wooden post capped with a steel plate with minimum dimensions of 304.8-by-304.8-by-25.4-mm (12-by-12-by-1-in.). The wooden post shall have an average dry weight of 0.67 to 0.77 g/cm^3 (42 to 48 lb/ft^3). The wooden post shall be secured by four angle brackets to a solid concrete slab. The steel cap shall be firmly fastened to the post. The pedestal assembly shall be installed so that the post is plumb and the cap is level.

3.5. *Specimen Mold Holder*—Mounted on the compaction pedestal so as to center the compaction mold over the center of the post. It shall hold the compaction mold, collar, and base plate securely in position during compaction of the specimen.

3.6. *Ovens or Hot Plates*—Ovens or hot plates shall be provided for heating aggregates, asphalt material, specimen molds, compaction hammers, and other equipment to the required mixing and molding temperatures. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 2.8°C (5°F). Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

3.7. *Heating Device*—A small hot plate with continuously variable heating rate, a sand bath, infrared lamp, or other suitable device shall be available for supplying sufficient heat under the mixing bowl to maintain the aggregate and asphalt material at the desired temperature during mixing. If a hot plate is used, a wire mesh or similar material shall be placed on the hot plate to prevent direct contact between the hot plate and mixing bowl.

3.8. *Mixing Apparatus*—Mechanical mixing is recommended. Any type of mechanical mixer may be used provided it can be maintained at the required mixing temperature and will produce a well-coated, homogeneous mixture of the required amount in the allowable time, and further provided that essentially all of the batch can be recovered. A metal pan or bowl of sufficient capacity and hand mixing may also be used.

3.9. *Air Bath*—The air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1°C (77° ± 2°F).

3.10. *Thermometers*—For determining temperatures of aggregates, asphalt binder, and asphalt mixtures. Armored-glass, dial type, or digital thermometers with metal stems are recommended. A range from 9.9 to 204°C (50 to 400°F) with sensitivity of 2.8°C (5°F) is required.

3.11. *Balance*—A balance meeting the requirements of M 231, Class G 2, for determining the mass of aggregates, binder and asphalt mixture.

3.12. *Miscellaneous Equipment*—Flat-bottom metal pans or other suitable containers for heating aggregates, containers (gill-type, beakers, pouring pots, or saucepan) for heating asphalt, flat bottom scoop for batching aggregates, steel trowel (garden type) or spatula for spading and hand mixing, gloves for handling hot equipment, paper disks, marking crayons for identifying specimens, and a large spoon for placing mixture in specimen molds.

4. PROCEDURE

4.1. *Number of Specimens*—Prepare at least three specimens for each combination of aggregates and bitumen content.

4.2. *Preparation of Aggregates*—Dry aggregates to constant mass at 105 to 110°C (221 to 230°F) and separate the aggregates by dry-sieving into the desired size fractions. The following size fractions are recommended:

- 25.0 to 19.0 mm (1 to $^3/_4$ in.)
- 19.0 to 9.5 mm ($^3/_4$ to $^3/_8$ in.)
- 9.5 mm to 4.75 mm ($^3/_8$ in. to No. 4)
- 4.75 mm to 2.36 mm (No. 4 to No. 8)
- Passing 2.36 mm (No. 8)

4.3. *Determination of Mixing and Compacting Temperatures*:

4.3.1. The temperatures to which the asphalt binder and asphalt cutback must be heated to produce a viscosity of 170 ± 20 cSt shall be the mixing temperature.

4.3.2. The temperature to which asphalt binder must be heated to produce a viscosity of 280 ± 30 cSt shall be the compacting temperature.

4.3.3. From a composition chart for the asphalt cutback used, determine from its viscosity at 60°C (140°F) the percentage of solvent by mass. Also determine from the chart the viscosity at 60°C (140°F) of the asphalt cutback after it has lost 50 percent of its solvent. The temperature determined from the viscosity temperature chart to which the asphalt cutback must be heated to produce a viscosity of 280 ± 30 cSt after a loss of 50 percent of the original solvent content shall be the compaction temperature.

4.4. *Preparation of Mixtures (Laboratory Prepared)*:

4.4.1. An initial batch shall be mixed for the purpose of "buttering" the mixture bowl and stirrers. This batch shall be emptied after mixing and the sides of the bowl and stirrers shall be cleaned of mixture residue by scraping with a small limber spatula but shall not be wiped with cloth or washed clean with solvent, except when a change is to be made in the binder or at the end of a run.

4.4.2. Weigh into separate pans for each test specimen the amount of each size fraction required to produce a batch that will result in a compacted specimen 63.5 ± 1.27 mm (2.5 ± 0.05 in.) in height (about 1200 g).

4.4.3. Mix the aggregate in each pan and place the pans on a hot plate or in the oven and heat to a temperature not exceeding the mixing temperature established in Section 4.3 by more than approximately 28°C (50°F) for asphalt mixtures and 14°C (25°F) for cutback asphalt mixes.

4.4.4. Heat, to the established mixing temperature, just sufficient asphalt material for the batch in a separate container.

4.4.5. Charge the mixing bowl with the heated aggregate. Form a crater in the dry-blended aggregate and weigh the preheated required amount of asphalt material into the mixture. For mixes prepared with cutback asphalt, introduce the mixing blade in the mixing bowl and determine the total mass of the mix components plus bowl and blade before proceeding with mixing. Care must be exercised to prevent loss of the mix during mixing and subsequent handling. At this point, the temperature of the aggregate and asphalt material shall be within the limits of the mixing temperature established in Section 4.3.

4.4.6. Mix the aggregate and asphalt material rapidly until thoroughly coated. To maintain proper mixing temperature, one of the methods described in Section 3.8 may be used.

4.4.7. Cure mixtures containing asphalt binder in accordance with R 30.

4.4.8. Cure asphalt cutback mixtures in a ventilated oven maintained at approximately 11.1°C (20°F) above the compaction temperature. Curing is to be continued in the mixing bowl until the precalculated weight of 50 percent solvent loss or more has been obtained. The mix may be stirred in a mixing bowl during curing to accelerate the solvent loss. However, care should be exercised to prevent loss of the mix. Weigh the mix during curing in successive intervals of 15 min initially and less than 10-min intervals as the weight of the mix at 50 percent solvent loss is approached.

4.5. *Preparation of Mixture (Plant Produced)*:

4.5.1. Obtain the sample in accordance with T 168.

4.5.2. Reduce the sample in accordance with R 47 to a sample size that will result in compacted specimens 63.5 ± 1.27 mm (2.5 ± 0.05 in.) in height as described in Section 4.4.2.

4.5.3. Place the sample into a pan to a uniform thickness.

4.5.4. Bring the asphalt mixture to the compaction temperature range by careful, uniform heating in an oven immediately prior to compaction.

4.6. *Compaction of Specimens*:

4.6.1. Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water, on the hot plate, or in an oven, to a temperature between 93.3 and 148.9°C (200 and 300°F).

4.6.2. Place a piece of filter paper or paper towel, cut to size, in the bottom of the mold before the mixture is introduced.

4.6.3. Place the entire batch in the mold, and spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Smooth the surface of the mix with a trowel to a slightly rounded shape. Remove the collar if necessary. Temperatures of the mixtures immediately prior to compaction shall be within the limits of the compaction temperature established in Section 4.3. If the temperature of the specimen is too high, allow the specimen to cool within the range of compaction temperatures; however, if the mixture is below compaction temperature, remove the mixture from the mold and replace it in the oven until the desired temperature is reached. Next, repeat the steps in this section. This process should not be repeated more than once. The material should be heated for the minimum time required to achieve the compaction temperature.

Note 1—Excessive heating times may cause oxidation and loss of volatiles and should be avoided.

4.6.4. Replace the collar, then place a piece of filter paper or paper toweling cut to size on top of the mixture and place the mold assembly on the compaction pedestal in the mold holder, and unless otherwise specified, apply 50 or 75 blows with the compaction hammer with a free fall in 457.2 mm (18 in.). Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction. Remove the base plate and collar, and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen.

4.6.5. After compaction, remove the base plate, carefully extract the specimen from the mold and transfer to a smooth, flat surface.

4.6.6. Allow the specimen to stand overnight at room temperature.

Note 2—In general, specimens shall be cooled as specified in Section 4.6.6. When more rapid cooling is desired, table fans may be used. Mixtures that lack sufficient cohesion to result in the required cylindrical shape on removal from the mold immediately after compaction may be cooled in the mold in air until sufficient cohesion has developed to result in the proper cylindrical shape.

5. KEYWORDS

5.1. Aggregate; asphalt binder; asphalt cutback; Marshall compaction hammer.

[1] Formerly part of T 245. First published as a practice in 2015.

4

Miscellaneous

DEFINITIONS

TABLE OF CONTENTS

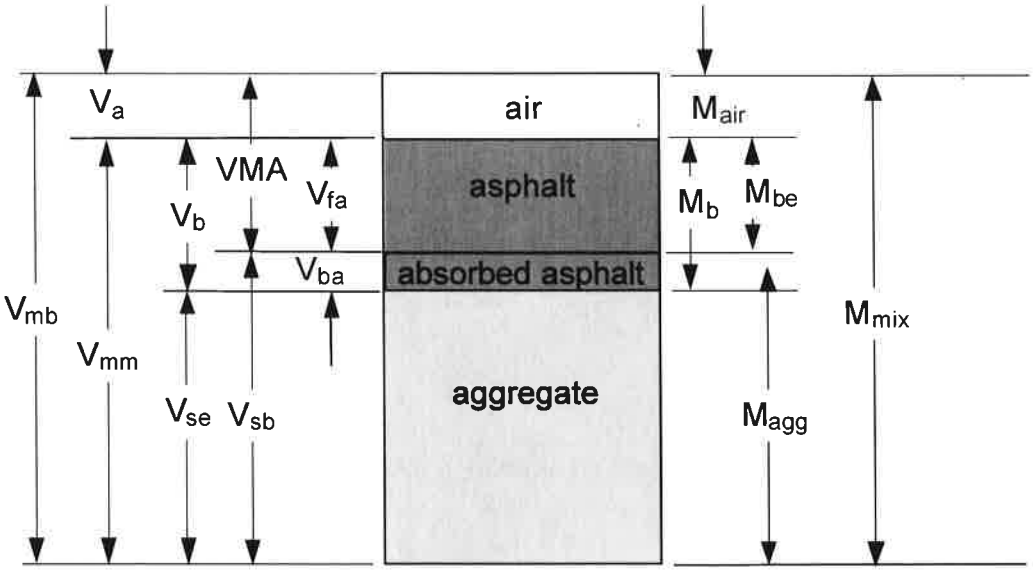
VOLUMETRIC DEFINITIONS AND FORMULAS

A factor that must be taken into account when considering asphalt mixture behavior is the *volumetric proportions* of asphalt binder and aggregate components, or more simply, *asphalt mixture volumetrics*. The volumetric properties of a compacted paving mixture [air voids (V_a), voids in the mineral aggregate (VMA), voids filled with asphalt (VFA), and effective asphalt content (P_{be})] provide some indication of the mixture's probable pavement service performance. It is necessary to understand the definitions and analytical procedures described in this chapter to be able to make informed decisions concerning the selection of the design asphalt mixture.

This chapter describes volumetric analysis of HMA, which plays a significant role in most mixture design procedures, including the Superpave system. This chapter reviews the component relationships (mass and volume, aggregate and asphalt), and presents the calculations for conducting a volumetric analysis. The information here applies to both paving mixtures that have been compacted in the laboratory, and to undisturbed samples that have been cut from a pavement in the field.

COMPONENT DIAGRAM

A tool that can assist in analyzing the properties of HMA is the component diagram -- a diagram that illustrates the individual components that make up the HMA: asphalt, aggregate and air. The simplified layout of the component diagram helps visualize the volumetric and mass



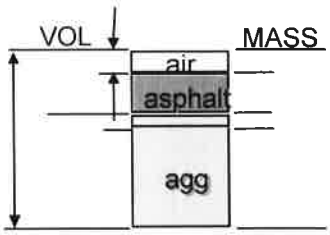
VMA = Volume of voids in mineral aggregate
V_{mb} = Bulk volume of compacted mix
V_{mm} = Voidless volume of paving mix
V_{fa} = Volume of voids filled with asphalt
V_a = Volume of air voids
V_b = Volume of asphalt binder
V_{ba} = Volume of absorbed asphalt binder
V_{sb} = Volume of mineral aggregate (by bulk specific gravity)
V_{se} = Volume of mineral aggregate (by effective specific gravity)

M = Total mass of asphalt mixture
M_b = Mass of asphalt binder
M_{be} = Mass of effective asphalt binder
M_{agg} = Mass of aggregate
M_{air} = Mass of air = 0

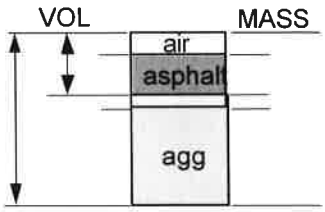
relationships that are used in the analysis of HMA.

Volumetric Properties of Asphalt Mixtures

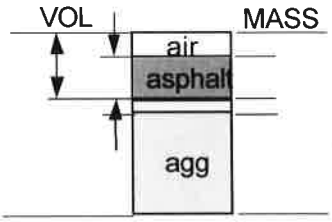
Air Voids, V_a - the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the total volume of the compacted paving mixture.



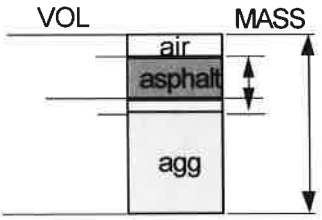
Voids in the Mineral Aggregate, VMA - the volume of intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume of the compacted paving mixture.



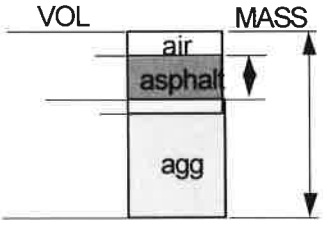
Voids Filled with Asphalt, VFA - the percentage portion of the volume of intergranular void space between the aggregate particles that is occupied by the effective asphalt. It is expressed as the ratio of (VMA - V_a) to VMA.



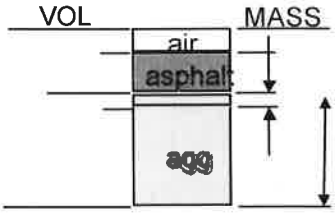
Asphalt Content, P_b - the total asphalt content of a paving mixture



Effective Asphalt Content, P_{be} - the total asphalt content of a paving mixture minus the portion of asphalt absorbed into the aggregate particles.



Absorbed Asphalt Content, P_{ba} - the portion of asphalt absorbed into the aggregate particles.



Specific Gravity

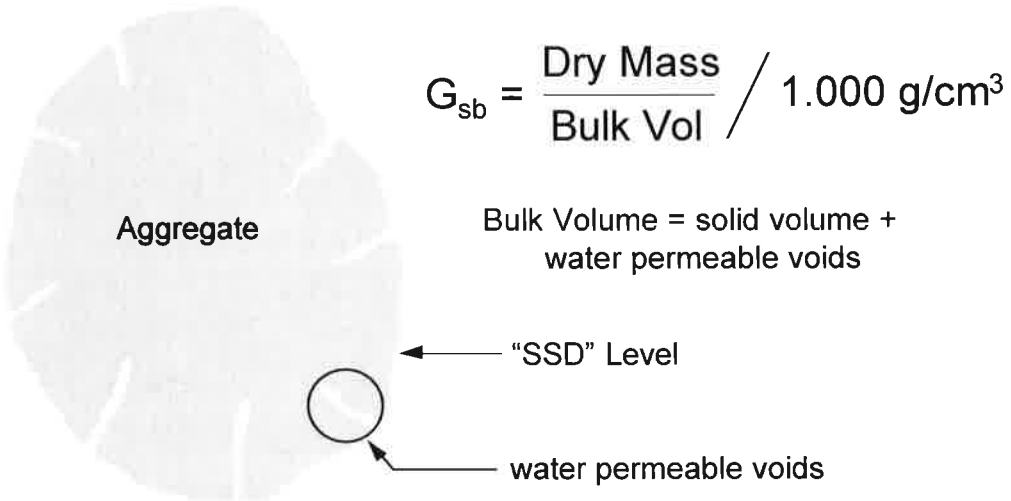
Specific gravity is "the ratio of the mass of a unit volume of a material to the mass of the same volume of water at stated temperatures." The mass of an object divided by its volume is its density, so another way to describe specific gravity is the density of an object divided by the density of water. Conveniently, at 25°C the density of water is 1.000 g/cm^3. Since the density of water is 1.000 at 25°C, the specific gravity of any object at 25°C is its weight divided by its volume. By knowing the specific gravity of an object, the volume can be calculated after measuring its mass, or the mass can be calculated after measuring its volume. Although the units for specific gravity and density are not the same, the terms are often used interchangeably. In fact, when using the metric units of g/cm^3, the values of density and specific gravity are numerically identical.

In the analysis of HMA, the specific gravities of the specific components of the HMA, as well as the specific gravities of the mixture, are used as "bridges" to go between the mass side of the component diagram and the volume side of the component diagram. Specific gravity is abbreviated using the letter G.

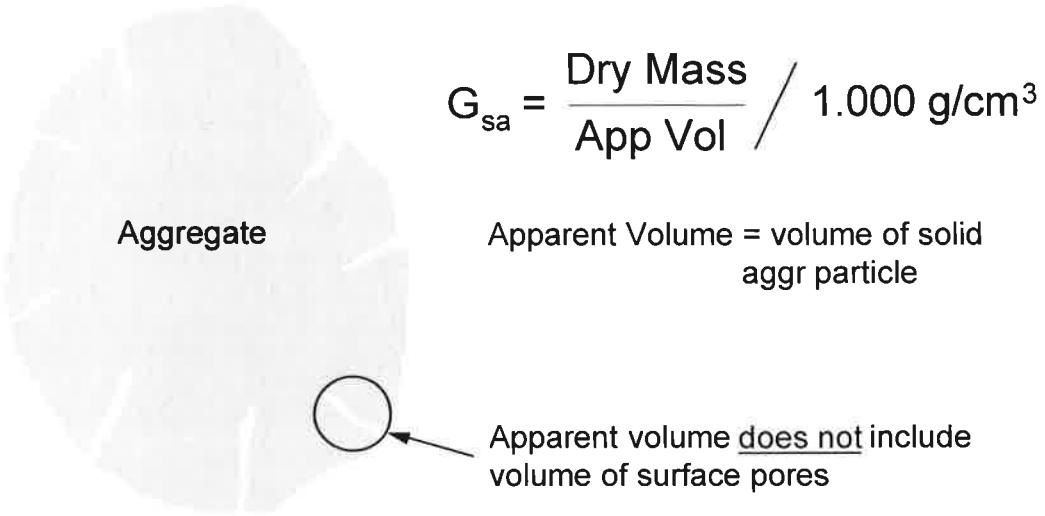
AGGREGATE SPECIFIC GRAVITIES

Mineral aggregate is porous and can absorb water and asphalt to a variable degree. Furthermore, the ratio of water to asphalt absorption varies with each aggregate. The three methods of measuring aggregate specific gravity take these variations into consideration. These methods are bulk, apparent, and effective specific gravities:

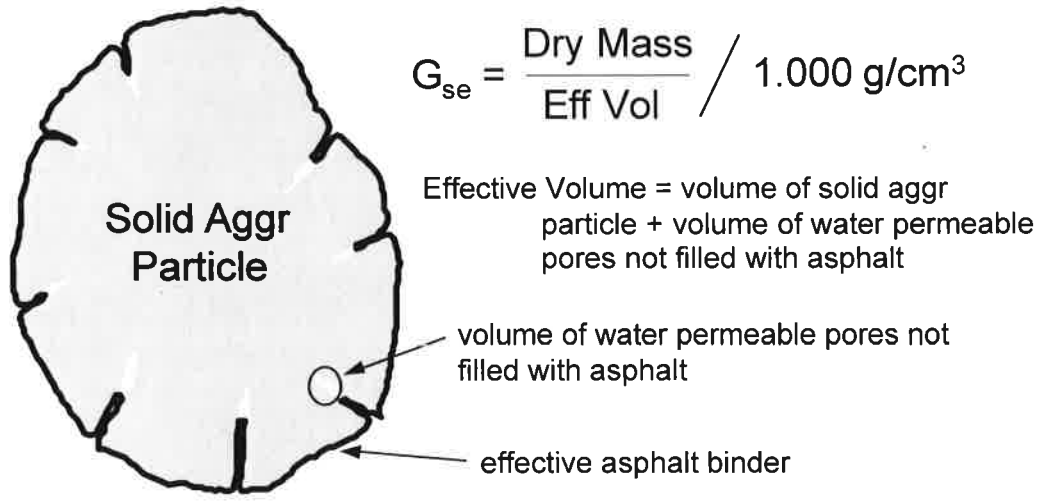
Bulk Specific Gravity, G_{sb} - the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. In other words, the aggregate bulk specific gravity includes the volume of the water permeable voids in the aggregate (often termed the ""saturated surface dry" or SSD volume of the aggregate.



Apparent Specific Gravity, G_{sa} - the ratio of the mass in air of a unit volume of an impermeable material at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. In other words, the aggregate apparent specific gravity does not include the volume of the water permeable voids in the aggregate



Effective Specific Gravity, G_{se} - the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. In other words, the effective specific gravity includes the volume of the water permeable voids in the aggregate that cannot be reached by the asphalt.

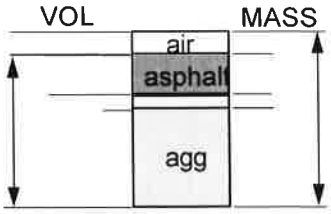


When comparing specific gravities, the mass of the aggregate does not change; the volume does change. The bulk volume is greater than the effective volume, which is greater than the apparent volume. Since mass is divided by volume in calculating the specific gravity, G_{sa} will be larger than G_{se}, which will be larger than G_{sb}. Written symbolically, $V_{sb} > V_{se} > V_{sa}$, and $G_{sa} > G_{se} > G_{sb}$.

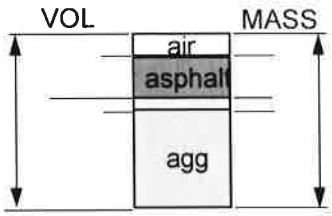
MIXTURE SPECIFIC GRAVITIES

Two measurements of the specific gravity of the HMA mixture are important in determining the volumetric properties of the HMA: the maximum theoretical specific gravity, G_{mm}, and bulk specific gravity, G_{mb}.

Maximum Theoretical Specific Gravity, G_{mm} - the ratio of the mass in air of a unit volume of the asphalt and aggregate in the mixture at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. In other words, the maximum theoretical specific gravity, G_{mm}, is the mass of the asphalt and aggregate mixture divided by the volume, not including the air voids.



Bulk Specific Gravity, G_{mb} - the ratio of the mass in air of a unit volume of the compacted asphalt and aggregate mixture at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. In other words, the bulk specific gravity, G_{mb}, is the mass of the asphalt and aggregate mixture divided by the volume, including the air voids.



Superpave mix design calculates VMA values for compacted paving mixtures in terms of aggregate bulk specific gravity, G_{sb}. Use of other aggregate specific gravities to compute VMA means that the VMA criteria no longer apply and the mixture may not meet the requirements of Superpave. The aggregate effective specific gravity, G_{se}, should be the basis for calculating the air voids in a compacted asphalt paving mixture. **Tennessee DOT has chosen to use effective specific gravity to calculate VMA, and has changed the requirements to reflect this change.**

Voids in the mineral aggregate (VMA) and air voids (V_a) are expressed as percent by volume of the paving mixture. Voids filled with asphalt (VFA) is the percentage of VMA filled by the effective asphalt. In Superpave, the total asphalt content and the effective asphalt content are expressed as a percentage of the total mass of the paving mixture.

Because air voids, VMA and VFA are volume quantities and therefore cannot be easily measured, a paving mixture must first be designed or analyzed in terms of volumes calculated from mass measurements. For mix production purposes, these volume quantities are later changed over to mass quantities to provide a job-mix formula that can be controlled at the plant.

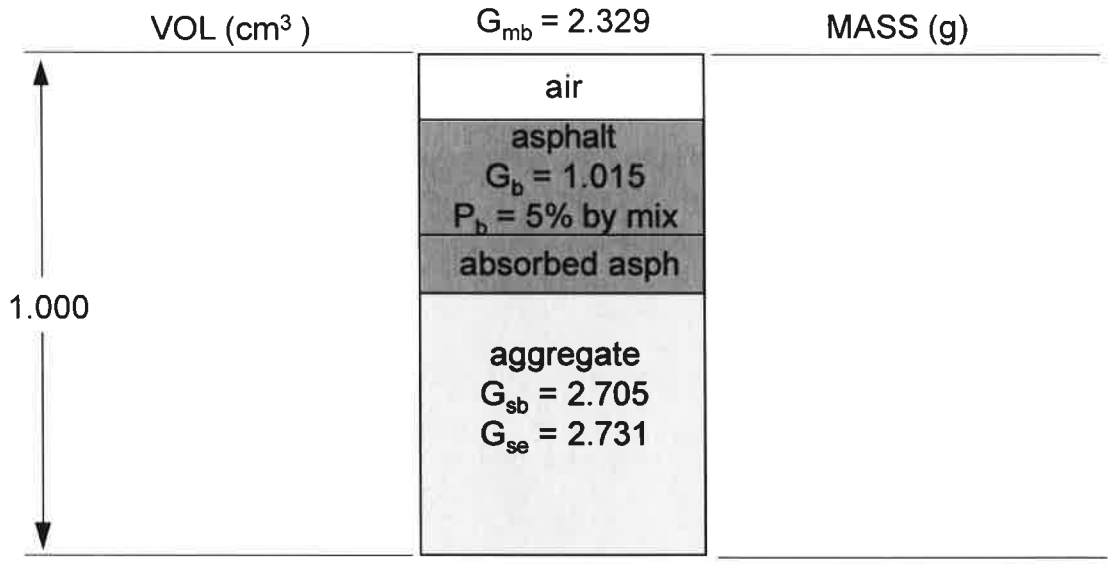
ANALYZING A COMPACTED PAVING MIXTURE

Two methods can be used to analyze the volumetric properties of compacted asphalt mixture. The first involves using the component diagram and various specific gravity measurements to calculate the relative masses and volumes of the mixture components, and then in turn calculating the volumetric properties. The second method uses the same specific gravity measurements with mathematical formulas to directly determine the mixture properties.

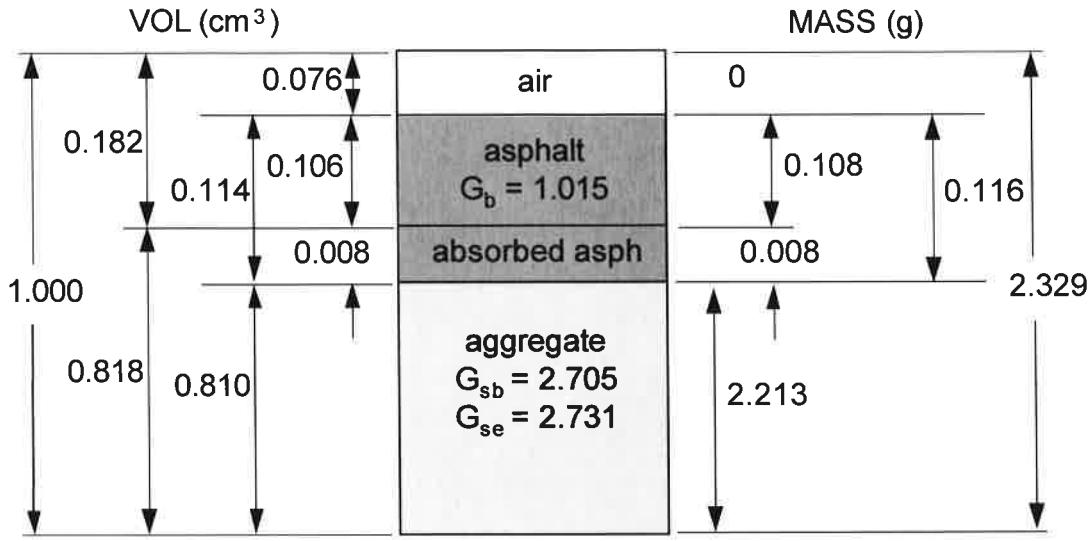
The first method is often used to illustrate the concepts behind the volumetric analysis of asphalt mixtures, and is therefore included in the presentation materials in this course. The second method, because the mathematical formulas can easily be placed into spreadsheet calculations, is more often used in laboratory mix design and analysis. These formulas are included in the text for information purposes, but are not detailed in the course presentation.

Component Diagram Method

This component diagram shows five properties (four specific gravities and the asphalt content) of a compacted specimen of HMA that have been measured at 25°C. Using only these few values, all of the volumetric properties and mass quantities of the HMA can be determined, as demonstrated in the course presentation.



These are the volumetric properties and mass quantities of this compacted specimen of HMA:



Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

Effective Asphalt Content = 4.6%
Absorbed Asphalt Content = 0.4%
Max Theo Sp Grav = 2.521

Mathematical Equations Method

The measurements and calculations needed for a voids analysis are:

(a) Measure the bulk specific gravities of the coarse aggregate (AASHTO T 85 or ASTM C 127) and of the fine aggregate (AASHTO T 84 or ASTM C 128).
(b) Measure the specific gravity of the asphalt cement (AASHTO T 228 or ASTM D 70) and of the mineral filler (AASHTO T 100 or ASTM D 854).
(c) Calculate the bulk specific gravity of the aggregate combination in the paving mixture.
(d) Measure the maximum specific gravity of the loose paving mixture (ASTM D 2041 or AASHTO T209).
(e) Measure the bulk specific gravity of the compacted paving mixture (ASTM D 1188/D 2726 or AASHTO T166).
(f) Calculate the effective specific gravity of the aggregate.
(g) Calculate the maximum specific gravity at other asphalt contents.
(h) Calculate the asphalt absorption of the aggregate.
(i) Calculate the effective asphalt content of the paving mixture.
(j) Calculate the percent voids in the mineral aggregate in the compacted paving mixture.
(k) Calculate the percent air voids in the compacted paving mixture.
(l) Calculate the percent voids filled with asphalt in the compacted paving mixture

Equations for these calculations are found below.

This table provides the basic data for a sample of paving mixture. These design data are used in the sample calculations used in the remainder of this chapter.

Basic Data for Sample of Paving Mixture

Mixture Components

Material	Specific Gravity		Mix Composition	
		Bulk	Percent by Mass of Total Mix	Percent By Mass of Total Aggregate
Asphalt Cement	1.030(G_b)		5.3 (P_b)	5.6 (P_b)
Coarse Aggregate		2.716(G_1)	47.4(P_1)	50.0(P_1)
Fine Aggregate		2.689(G_2)	47.3(P_2)	50.0(P_2)
Mineral Filler	---		---	---

Paving Mixture

Bulk specific gravity of compacted paving mixture sample, G_{mb} = 2.442
Maximum specific gravity of paving mixture sample, G_{mm} = 2.535

Bulk Specific Gravity of Aggregate

When the total aggregate consists of separate fractions of coarse aggregate, fine aggregate, and mineral filler, all having different specific gravities, the bulk specific gravity for the total aggregate is calculated using:

$$G_{sb} = \frac{P_1 + P_2 + \ldots + P_N}{\frac{P_1}{G_1} + \frac{P_1}{G_2} + \ldots + \frac{P_N}{G_N}}$$

where G_{sb} = bulk specific gravity for the total aggregate
P_1, P_2, P_N = individual percentages by mass of aggregate
G_1, G_2, G_N = individual bulk specific gravities of aggregate

The bulk specific gravity of mineral filler is difficult to determine accurately. However, if the apparent specific gravity of the filler is substituted, the error is usually negligible.

Using the sample paving mixture data:

$$G_{sb} = \frac{50.0 + 50.0}{\frac{50.0}{2.716} + \frac{50.0}{2.689}} = \frac{100}{18.41 + 18.59} = 2.703$$

Effective Specific Gravity of Aggregate

When based on the maximum specific gravity of a paving mixture, G_{mm}, the effective specific gravity of the aggregate, G_{se}, includes all void spaces in the aggregate particles except those that absorb asphalt. G_{se} is determined using:

$$G_{se} = \frac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}}$$

where G_{se} = effective specific gravity of aggregate
G_{mm} = maximum specific gravity (ASTM D 2041/AASHTO T 209) of paving mixture (no air voids)
P_{mm} = percent by mass of total loose mixture = 100
P_b = asphalt content at which ASTM D 2041/AASHTO T 209 test was performed, percent by total mass of mixture
G_b = specific gravity of asphalt

Using the sample paving mixture data:

$$G_{se} = \frac{100 - 5.3}{\frac{100}{2.535} - \frac{5.3}{1.030}} = \frac{94.7}{39.45 - 5.15} = 2.761$$

NOTE: The volume of asphalt binder absorbed by an aggregate is almost invariably less than the volume of water absorbed. Consequently, the value for the effective specific gravity of an aggregate should be between its bulk and apparent specific gravities. When the effective specific gravity falls outside these limits, its value must be assumed to be incorrect. The calculations, the maximum specific gravity of the total mix by ASTM D 2041/AASHTO T 209, and the composition of the mix in terms of aggregate and total asphalt content should then be rechecked to find the source of the error.

Maximum Specific Gravity of Mixtures with Different Asphalt Contents

In designing a paving mixture with a given aggregate, the maximum specific gravity, G_{mm}, at each asphalt content is needed to calculate the percentage of air voids for each asphalt content. While the maximum specific gravity can be determined for each asphalt content by ASTM D 2041/AASHTO T 209, the precision of the test is best when the mixture is close to the design asphalt content. Also, it is preferable to measure the maximum specific gravity in duplicate or triplicate.

After calculating the effective specific gravity of the aggregate from each measured maximum specific gravity and averaging the G_{se} results, the maximum specific gravity for any other asphalt content can be obtained using the equation shown below. The equation assumes the effective specific gravity of the aggregate is constant, and this is valid since asphalt absorption does not vary appreciably with changes in asphalt content.

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

where G_{mm} = maximum specific gravity of paving mixture (no air voids)
P_{mm} = percent by mass of total loose mixture = 100
P_s = aggregate content, percent by total mass of mixture
P_b = asphalt content, percent by total mass of mixture
G_{se} = effective specific gravity of aggregate
G_b = specific gravity of asphalt

Using the specific gravity data from the sample paving mixture data, the effective specific gravity, G_{se}, and an asphalt content, P_b, of 4.0 percent:

$$G_{mm} = \frac{100}{\frac{96.0}{2.761} + \frac{4.0}{1.030}} = \frac{100}{34.77 + 3.88} = 2.587$$

Asphalt Absorption

Absorption is expressed as a percentage by mass of aggregate rather than as a percentage by total mass of mixture. Asphalt absorption, P_{ba}, is determined using:

$$P_{ba} = 100 \times \frac{G_{se} - G_{sb}}{G_{sb} G_{se}} \times G_b$$

where P_{ba} = absorbed asphalt, percent by mass of aggregate
G_{se} = effective specific gravity of aggregate
G_{sb} = bulk specific gravity of aggregate
G_b = specific gravity of asphalt

Using the bulk and effective aggregate specific gravities determined earlier and the asphalt specific gravity from the sample paving mixture data:

$$P_{ba} = 100 \times \frac{2.761 - 2.703}{2.703 \times 2.761} \times 1.030 = 100 \times \frac{0.058}{7.463} \times 1.030 = 0.8$$

Effective Asphalt Content of a Paving Mixture

The effective asphalt content, P_{be}, of a paving mixture is the total asphalt content minus the quantity of asphalt lost by absorption into the aggregate particles. It is the portion of the total asphalt content that remains as a coating on the outside of the aggregate particles and it is the asphalt content which governs the performance of an asphalt paving mixture. The formula is:

$$P_{be} = P_b - \frac{P_{ba}}{100} \times P_s$$

where P_{be} = effective asphalt content, percent by total mass of mixture
P_b = asphalt content, percent by total mass of mixture
P_{ba} = absorbed asphalt, percent by mass of aggregate
P_s = aggregate content, percent by total mass of mixture

Using the sample paving mixture data:

$$P_{be} = 5.3 - \frac{0.8}{100} \times 94.7 = 4.5$$

Percent VMA in Compacted Paving Mixture

The voids in the mineral aggregate, VMA, are defined as the intergranular void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume. The VMA is calculated on the basis of the bulk specific gravity of the aggregate and is expressed as a percentage of the bulk volume of the compacted paving mixture. Therefore, the VMA can be calculated by subtracting the volume of the aggregate determined by its bulk specific gravity from the bulk volume of the compacted paving mixture. The calculation is illustrated for each type of mixture percentage content.

If the mix composition is determined as percent by mass of total mixture:

$$VMA_{bulk} = 100 - \frac{G_{mb} \times P_s}{G_{sb}} \qquad VMA_{eff} = 100 - \frac{G_{mb} \times P_s}{G_{se}}$$

Superave Definition TDOT Definition

where VMA = voids in mineral aggregate (percent of bulk volume)
G_{sb} = bulk specific gravity of total aggregate
G_{se} = effective specific gravity of aggregate from AASHTO T 209
G_{mb} = bulk specific gravity of compacted mixture (ASTM D 1188 or D 2726/AASHTO T 166)
P_s = aggregate content, percent by total mass of mixture

Using the sample paving mixture data:

$$VMA_{bulk} = 100 - \frac{2.442 \times 94.7}{2.703} = 100 - 85.6 = 14.4$$

$$VMA_{eff} = 100 - \frac{2.442 \times 94.7}{2.761} = 100 - 83.8 = 16.2$$

Percent Air Voids in Compacted Mixture

The air voids, V_a, in the total compacted paving mixture consist of the small air spaces between the coated aggregate particles. The volume percentage of air voids in a compacted mixture can be determined using:

$$V_a = 100 \times \frac{G_{mm} - G_{mb}}{G_{mm}}$$

where V_a = air voids in compacted mixture, percent of total volume
G_{mm} = maximum specific gravity of paving mixture (as calculated earlier or as determined directly for a paving mixture by ASTM D 2041/AASHTO T 209)
G_{mb} = bulk specific gravity of compacted mixture

Using the sample paving mixture data:

$$V_a = 100 \times \frac{2.535 - 2.442}{2.535} = 3.7$$

Percent VFA in Compacted Mixture

The percentage of the voids in the mineral aggregate that are filled with asphalt, VFA, not including the absorbed asphalt, is determined using:

$$VFA_{bulk} = 100 \times \frac{VMA_{bulk} - V_a}{VMA_{bulk}} \qquad VFA_{eff} = 100 \times \frac{VMA_{eff} - V_a}{VMA_{eff}}$$

Superpave Definition TDOT Definition

Where, VFA = voids filled with asphalt, percent of VMA
VMA = voids in mineral aggregate, percent of bulk volume
V_a = air voids in compacted mixture, percent of total volume

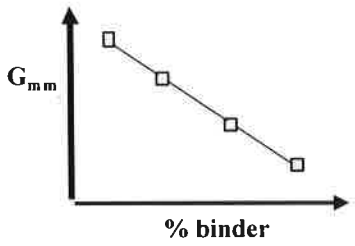
Using the sample paving mixture data:

$$VFA_{bulk} = 100 \times \frac{14.4 - 3.7}{14.4} = 74.3 \qquad VFA_{eff} = 100 \times \frac{16.2 - 3.7}{16.2} = 77.2$$

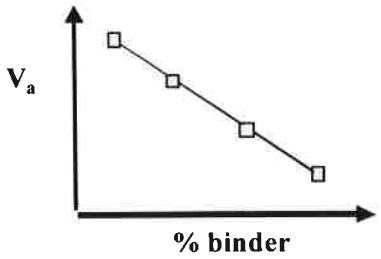
Remember, since there are two different VMA values, there are also two different VFA values

EFFECT OF CHANGING ASPHALT CONTENT ON VOLUMETRIC PROPERTIES

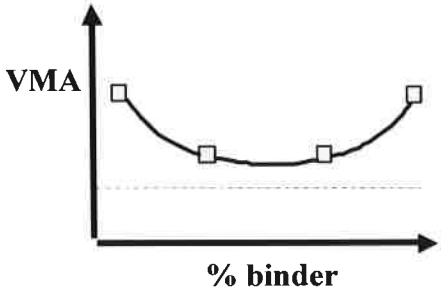
Maximum Theoretical Specific Gravity at Other Asphalt Contents



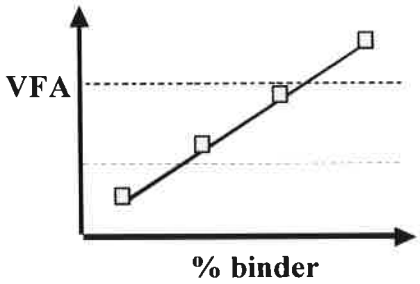
Air Void Content



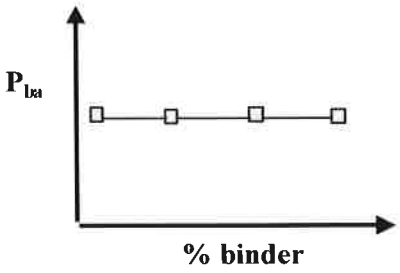
Voids in the Mineral Aggregate



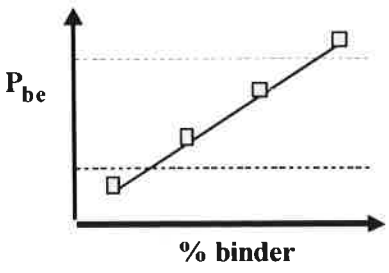
Voids Filled With Asphalt



Absorbed Asphalt Content



Effective Asphalt Content



Building Pans (Aggregate Only)

$$M_{xy} = P_x \times P_{IRy} \times M_{Tot}$$

Where M_{xy} = Mass of a given aggregate size fraction to the blended pan
P_x = Decimal Percent of that aggregate stockpile contributing to the blend.
P_{Iry} = Decimal Percent individually retained on a given sieve y.
M_{Tot}= Total blended mass of aggregate.

Building Pans (Rap)
Rap material to add to the blend.

$$M_{Rap} = \frac{P_{RAP} \times M_{Tot}}{\frac{100 - P_{bRAP}}{100}}$$

Where P_{RAP} = Decimal Percent of RAP aggregates contributing to the blend.
P_{bRAP} = Percent binder of the RAP

Asphalt to add to aggregate and RAP blends to make a HMA sample of known AC content.

$$M_{AC\,Pb} = \frac{M_{Tot}}{\frac{100 - P_b}{100}} - \frac{M_{RAP} \times P_{bRAP}}{100} - M_{Tot}$$

Where M_{ACPb}= Mass of asphalt at a known AC content (P_b)
M_{Tot} = Total mass of aggregate blend
M_{RAP} = Mass of RAP material added in the blend
P_{bRAP} = Percent binder in the RAP

ABBREVIATIONS	
G_b	Specific **G**ravity of an Asphalt **B**inder
G_{mb}	**B**ulk Specific **G**ravity of an Asphalt **M**ixture
G_{mm}	**M**aximum Theoretical Specific **G**ravity of an Asphalt **M**ixture (Rice Gravity)
G_{sa}	**A**pparent Specific **G**ravity of an Aggregate (**S**tone)
G_{sb}	**B**ulk Specific **G**ravity of an Aggregate (**S**tone)
G_{se}	**E**ffective Specific **G**ravity of an Aggregate (**S**tone)
M	Total **M**ass of an Asphalt Mixture
M_{ACPb}	**M**ass of an Binder at a known **A**sphalt **C**ontent (P_b)
M_{agg}	**M**ass of **Agg**regate
M_{air}	**M**ass of **Air** (Equivalent to zero grams)
M_b	**M**ass of Asphalt **B**inder
M_{be}	**M**ass of **E**ffective Asphalt **B**inder
M_{RAP}	**M**ass of **RAP** material added in the blend.
M_{tot}	**Tot**al **M**ass of Aggregate Blend
M_{xy}	**M**ass of a given aggregate size fraction to the blended pan
P_b	**B**inder Content (**P**ercent by total mass of mixture)
P_{bRAP}	**P**ercent **B**inder of the **RAP**
P_{ba}	**A**bsorbed **B**inder Content (**P**ercent by mass of aggregate)
P_{be}	**E**ffective **B**inder Content (**P**ercent by total mass of mixture)
P_{iry}	**P**ercent **I**ndividually **R**etained on a given sieve "**y**"
P_{mm}	**P**ercent by **M**ass of Total Loose **M**ixture (Equivalent to 100%)
P_{RAP}	**P**ercent of **RAP** Aggregates contributing to the blend.
P_s	Aggregate (**S**tone) Content (**P**ercent by total mass of mixture)
P_x	**P**ercent of Aggregate Stockpile contributing to the blend.
SSD	**S**aturated **S**urface **D**ry
V_a	**V**olume of **A**ir Voids (Percent of total volume)
V_b	**V**olume of Asphalt **B**inder
V_{ba}	**V**olume of **A**bsorbed Asphalt **B**inder
V_{fa}	**V**olume of Voids **F**illed with **A**sphalt
V_{ma}	**V**olume of Voids in **M**ineral **A**ggregate
V_{mb}	**B**ulk **V**olume of Compacted **M**ixture
V_{mm}	Voidless **V**olume of Asphalt **M**ixture (at Theoretical **M**aximum Gravity)
V_{sb}	**V**olume of Mineral Aggregate (by **B**ulk **S**pecific Gravity)
V_{se}	**V**olume of Mineral Aggreagte (by **E**ffective **S**pecific Gravity)