SAMPLING BITUMINOUS MATERIALS (See Addendum for DOT&PF Guidelines)
WAQTC FOP FOR AASHTO T 40

Scope

The procedure covers obtaining samples of liquid bituminous materials in accordance with AASHTO T 40. Sampling of solid and semi-solid bituminous materials – included in AASHTO T 40 – is not covered here.

Agencies may be more specific on exactly who samples, where to sample, and what type of sampling device to use.

Warning: Always use appropriate safety equipment and precautions for hot liquids.

Procedure

1. Coordinate sampling with contractor or supplier.
2. Allow a minimum of 4 L (1 gal) to flow before obtaining a sample(s).
3. Obtain samples of:
   - Asphalt binder from hot mix asphalt (HMA) plant from the line between the storage tank and the mixing plant while the plant is in operation, or from the delivery truck.
   - Cutback and emulsified asphalt from distributor spray bar or application device; or from the delivery truck before it is pumped into the distributor. Sample emulsified asphalt at delivery or prior to dilution.

Containers

Sample containers must be new, and the inside may not be washed or rinsed. The outside may be wiped with a clean, dry cloth.

All samples shall be put in 1 L (1 qt) containers and properly identified on the outside of the container with contract number, date sampled, data sheet number, brand and grade of material, and sample number. Include lot and sublot numbers when appropriate.

- Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion. The sample container should be completely filled to minimize a skin formation on the sample.
- Asphalt binder and cutbacks: Use metal cans.

Note: The sample container shall not be submerged in solvent, nor shall it be wiped with a solvent saturated cloth. If cleaning is necessary, use a clean dry cloth.
Addendum WAQTC FOP for AASHTO T 40

The following guidelines for the use of WAQTC FOP for AASHTO T 40 by the State of Alaska DOT&PF.

1. When obtaining samples from HMA plants, sample only from the line between the storage tank and the mixing plant while the plant is in operation.

2. Sample containers for elastomer modified asphaltic cements shall conform to requirements under containers/asphalt binders.

3. When sampling emulsified asphalt, use 1 gallon wide mouth plastic containers.

4. When material is sampled by other than DOT&PF personnel or their agent(s), the sampling must be witnessed and possession of the sample transferred immediately to DOT&PF personnel or their agent(s).
SAMPLING OF BITUMINOUS PAVING MIXTURES
FOP FOR AASHTO T 168 (See Addendum for DOT&PF Guidelines)

Scope

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

Apparatus

- Shovel
- Sample containers: such as cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers
- Scoops, trowels, or other equipment to obtain mix
- Sampling plate: heavy gauge metal plate 380 mm x 380 mm (15 in x 15 in) minimum 8 gauge thick, with a wire attached to one corner long enough to reach from the center of the paver to the outside of the farthest auger extension. Holes ¼” in diameter should be provided in each corner.
- Cookie cutter sampling device: A 330 mm (13 in.) square sampling template, constructed from 75 mm x 50 mm x 3 mm (3 in. x 2 in. x 1/8 in.) formed steel angle with two 100mm x 150 mm x 9 mm (4 in. x 6 in. x 3/8 in.) handles. See diagram.

  Note 1: Sampling Plate and Cookie cutter may be sized appropriately to accommodate sample size requirements.

- Mechanical sampling device

Sample Size

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

Sampling

General

1. The material shall be tested to determine variations. The supplier/contractor shall provide equipment for safe and appropriate sampling, including sampling devices on plants when required.

2. Place dense graded mixture samples in cardboard boxes, stainless steel bowls or other agency-approved containers. Place open graded mixture samples in stainless steel bowls. Do not put open graded mixture samples in boxes until they have cooled to the point that bituminous material will not migrate from the aggregate.
Attached Sampling Devices

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

1. Lightly coat the container attached to the sampling device with an agency-approved release agent and/or preheat it to approximately the same discharge temperature of the mix.

2. Pass the container twice through the material perpendicularly without overfilling the container.

3. Repeat until proper sample size has been obtained.

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

Sampling from Haul Units

1. Visually divide the haul unit into approximately four equal quadrants.

2. Identify one sampling location in each quadrant.

3. Dig down and remove approximately 0.3 m (1 ft) of material to avoid surface segregation. Obtain each increment from below this level.

4. Combine the increments to form a sample of the required size.

Sampling from Roadway Prior to Compaction (Plate Method)

Plate method using the “cookie cutter” sampling device.

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

1. Laying HMA on grade or untreated base material requires Method 1.

2. Laying HMA on existing asphalt or laying a second lift of HMA requires Method 2.

SAFETY:

Sampling is performed behind the paving machine and in front of the breakdown roller. For safety, the roller must remain at least 3 m (10 ft) behind the sampling operation until the sample has been taken and the hole filled with loose HMA.

Method 1 requires a plate to be placed in the roadway in front of the paving operation and therefore there is always concern with moving, operating equipment. It is safest to stop the paving train while a plate is installed in front of the paver. When this is not possible the following safety rules must be followed.
1. The plate placing operation must be at least 3 m (10 ft) in front of the paver or pickup device. The technician placing the plate must have eye contact and communication with the paving machine operator. If eye contact cannot be maintained at all time, a third person must be present to provide communication between the operator and the technician.

2. No technician is to be between the asphalt supply trucks and the paving machine. The exception to this rule is if the supply truck is moving forward creating a windrow, in which case the technician must be at least 3 m (10 ft) behind the truck.

If at any time the Engineer feels that the sampling technique is creating an unsafe condition, the operation is to be halted until it is made safe or the paving operation will be stopped while the plate is being placed.

**Method 1 - Obtaining a Sample on Untreated Base:**

1. Following the safety rules detailed above, the technician is to:
   
   a. Smooth out a location in front of the paver at least 0.5 m (2 ft) inside the edge of the mat.
   
   b. Lay the plate down diagonally with the direction of travel, keeping it flat and tight to the base with the lead corner facing the paving machine.

2. Secure the plate in place by driving a nail through the hole in the lead corner of the plate.

3. Pull the wire, attached to the outside corner of the plate, taut past the edge of the HMA mat and secure with a nail.

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

5. Using the exposed end of the wire, pull the wire up through the fresh HMA to locate the corner of the plate. Place the “cookie cutter” sample device, just inside the end of the wire; align the cutter over the plate. Press “cookie cutter” device down through the HMA to the plate.

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

7. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose HMA.
Method 2 - Obtaining a Sample on Asphalt Surface:

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

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

Identification and Shipping

1. Identify sample containers as required by the agency.

2. Ship samples in containers that will prevent loss, contamination, or damage.
Addendum WAQTC FOP for AASHTO T 168

Following are guidelines for the use of WAQTC FOP for AASHTO T 168 by the State of Alaska DOT&PF.

1. ATM 403 contains additional sampling methods.

2. When sampling asphalt mixture from a mat after compaction, sample in accordance with Section 413, WAQTC TM 11, “Sampling Bituminous Material after Compaction (Obtaining Cores).”
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Sampling Hot Mix Asphalt   ATM 403

1. **Scope**

This method describes the procedures used for sampling Hot Mix Asphalt (HMA).

2. **Significance and Use**

This method provides procedures for sampling HMA in the field.

2.1. Sampling is equally as important as the testing, and the sampler shall use every precaution to obtain samples that will yield an acceptable estimate of the nature and conditions of the materials for which they represent.

2.2. Care shall be taken in sampling to avoid segregation of the material being sampled, and to prevent contamination by dust or other foreign matter.

2.3. If material is sampled by other than DOT&PF personnel or their agent(s), the sampling must be witnessed and possession of the sample transferred immediately to DOT&PF personnel or their agent(s).

3. **Equipment**

3.1. Flat scoop with vertical sides or a square point shovel

3.2. Plate with small lip (approximately ½”) and of sufficient size and rigidity to accommodate required sample. Plate to have wire(s) attached to allow the plate to be located and removed from the mat after paver travels past it.

3.3. Approved sample containers including new cardboard boxes, clean metal buckets, cans or bowls.

3.4. Miscellaneous tools, scraper, scoop, gloves, etc.

4. **Sampling from the Auger**

4.1. Obtain samples from the accessible portion of the auger, using a square point shovel.

4.2. Place the shovel in front of the auger, with the blade flat upon the surface to be paved.

4.3. Allow the front face of the HMA coming off the auger to cover the shovel. Remove the shovel before the auger reaches the shovel by lifting it upward as vertically as possible being careful not to lose material.

4.4. Repeat the procedure at least three times, but as many times as necessary to obtain a sample of the required size.

4.5. Place the sample in an approved container for transport to Lab.

5. **Lipped Plate Sampling**

5.1. When using a pickup machine:

5.1.1. Stop the paver and pickup machine.

5.1.2. Place plate(s) underneath the pickup machine, midway between and just behind the rear tires and right in front of the paver.

5.2. When using dump trucks:

5.2.1. Stop the paver after the truck is attached to the paver.

5.2.2. Place plate(s) at the midpoint of the axis of the paver and behind the truck tires.

Note: when placing plate(s), avoid influence from truck tires, pickup machine tires, and paver tracks or tires.
5.3. Run an attached wire perpendicular to the direction of the paver, beyond the farthest auger extension and/or the ski.

5.4. Hold the wire to the ground with your foot.

5.5. Allow the paving operation to resume.

5.6. When the paver has passed over the plate position, pull up on the wire to locate the plate. Remove the plate(s) laden with mix from the HMA mat by lifting vertically being careful not to disturb the mix at the edge of the plate.

5.7. Place the entire sample in an approved container(s) for transport to the Lab.

Note: make sure to hold the wire down on the ground so the ski will not snag it.

6. **Windrow Sampling**

6.1 Sample from the windrow created by a single truck. Divide the windrow length into three sections. Sample from three locations along the top of the middle section.

6.2 At each of the three locations in the middle section, remove and discard the top 12 inches. Remove a sample increment by digging vertically down with a square point shovel. Repeat for each increment.

6.3 Combine the three increments to form the composite sample.

6.4 Place the sample in an approved container for transport to the Lab.
REDUCING SAMPLES OF HOT MIX ASPHALT (HMA) TO TESTING SIZE
FOP FOR AASHTO R 47 (See Addendum for DOT&PF Guidelines)

Significance

Samples of bituminous paving mixes taken in accordance with the FOP for AASHTO T 168 are composites and typically large in size. Materials sampled in the field need to be reduced to appropriate sizes for testing. As a general rule, field samples should be of a size that splitting once will result in the required test sample size. It is extremely important that the procedure used to reduce the field sample not modify the material properties.

Scope

This procedure covers sample reduction of Hot Mix Asphalt (HMA) to testing size. The reduced portion is to be representative of the original sample.

Apparatus

- Thermostatically controlled oven capable of maintaining a temperature of at least 110°C (230°F) or high enough to heat the material to a pliable condition for splitting.
- Non-contact temperature measuring device.
- Metal spatulas, trowels, metal straightedges, and/or drywall taping knives; for removing HMA samples from the quartering device, cleaning surfaces used for splitting, etc.
- Square-tipped, flat-bottom scoop, shovel or trowel for mixing HMA prior to quartering.
- Miscellaneous equipment including hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, and cans.
- Sheeting: Non-stick heavy paper, heat-resistant plastic, or other material as approved by the agency.
- Agency-approved release agent, free of solvent or petroleum-based products that could affect asphalt binder properties.
- Mechanical Splitter Type A (Quartermaster): having four equal-width chutes discharging into four appropriately sized sample receptacles. Splitter is to be equipped with a receiving hopper that will hold the sample until the release lever is activated with four sample receptacles of sufficient capacity to accommodate the reduced portion of the HMA sample from the mechanical splitter. Refer to AASHTO R 47, Figures 1 through 3, for configuration and required dimensions of the mechanical splitter.
- Mechanical Splitter Type B (Riffle): having a minimum of eight equal-width chutes discharging alternately to each side with a minimum chute width of at least 50% larger than the largest particle size. A hopper or straight-edged pan with a width equal to or slightly smaller than the assembly of chutes in the riffle splitter to permit uniform discharge of the HMA through the chutes without segregation or loss of material. Sample receptacles of sufficient width and capacity to receive the reduced portions of HMA from the riffle splitter without loss of material.
• Quartering Template: formed in the shape of a cross with equal length sides at right angles to each other. Template shall be manufactured of metal that will withstand heat and use without deforming. The sides of the quartering template should be sized so that the length exceeds the diameter of the flattened cone of HMA by an amount allowing complete separation of the quartered sample. Height of the sides must exceed the thickness of the flattened cone of HMA.

• Non-stick mixing surface that is hard, heat-resistant, clean, level, and large enough to permit HMA samples to be mixed without contamination or loss of material.

**Sampling**

Obtain samples according to the FOP for AASHTO T 168.

**Sample Preparation**

The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily. Do not exceed either the temperature or time limits specified in the test method(s) to be performed.

**Selection of Procedure (Method)**

Refer to agency requirements when determining the appropriate method(s) of sample reduction. In general, the selection of a particular method to reduce a sample depends on the initial size of the sample vs. the size of the sample needed for the specific test to be performed.

It is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. This decreases the time needed for reduction and minimizes temperature loss. Further reduction of the remaining HMA may be performed by a combination of the following methods, as approved by the agency. The methods for reduction are:

• Mechanical Splitter Method
  – Type A (Quartermaster)
  – Type B (Riffle Splitter)

• Quartering Method
  – Full Quartering
  – By Apex

• Incremental (Loaf) Method
Procedure

Mechanical Splitter Type A (Quartermaster)

Figure 1

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will contact HMA.
2. Close and secure hopper gates.
3. Place the four sample receptacles in the splitter so that there is no loss of material.
4. Remove the sample from the agency-approved container(s) and place the heated sample in the mechanical splitter hopper. Avoid segregation, loss of HMA or the accidental addition of foreign material.
5. Release the handle, allowing the HMA to drop through the divider chutes and discharge into the four receptacles.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
7. Close and secure the hopper gates.
8. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.
9. Combine the material contained in the receptacles from opposite corners and repeat the splitting process until an appropriate sample size is obtained.
10. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.
Reducing Samples of Hot Mix Asphalt to Testing Size 10/08
Effective 6/15/10

Mechanical Splitter Type B (Riffle)

Figure 2

1. If heating of the testing equipment is desired, it shall be heated to a temperature not to exceed 110 ºC (230ºF).
2. Clean the splitter and apply a light coating of approved release agent to the surfaces that will come in contact with HMA (hopper or straight-edged pan, chutes, receptacles).
3. Place two empty receptacles under the splitter.
4. Carefully empty the heated HMA from the agency-approved container(s) into the hopper or straight-edged pan without loss of material. Uniformly distribute from side to side of the hopper or pan.
5. Discharge the HMA at a uniform rate, allowing it to flow freely through the chutes.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
7. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.
8. Using one of the two receptacles containing HMA, repeat the reduction process until the HMA contained in one of the two receptacles is the appropriate size for the required test.
9. After each split, remember to clean the splitter hopper and chute surfaces if needed.
10. Retain and properly identify the remaining unused HMA sample for further testing if required by the agency.

Quartering Method

1. Heat all of the testing equipment (quartering template, scoop or trowel) to a temperature not to exceed 110 ºC (230ºF).
2. If needed, apply a light coating of release agent to quartering template.
3. Dump the heated sample from the agency approved container(s) into a conical pile on a hard, “non-stick”, clean, level surface where there will be neither a loss of material nor the accidental addition of foreign material. The surface can be made non-stick by the application of an approved asphalt release agent, or sheeting.
4. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.

5. Flatten the conical pile to a uniform diameter and thickness where the diameter is four to eight times the thickness. Make a visual observation to ensure that the material is homogeneous.

6. Divide the flattened cone into four equal quarters using the quartering template. Press the template down until it is in complete contact with the surface on which the sample has been placed, assuring complete separation.

Note 1: Straightedges may be used in lieu of the quartering device to completely separate the material in approximately equal quarters.

7. Reduce the sample by quartering the sample completely or by removing the sample from the apex.

8. Full Quartering
   8a. Remove two diagonally opposite quarters, including all of the fine material.
   8b. Remove the quartering template and combine the remaining quarters, again forming a conical pile.
   8c. Repeat steps 4, 5, 6, 8a, & 8b until a sample of the required size has been obtained. The final sample must consist of the two remaining diagonally opposite quarters.
   8d. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

9. By Apex
   9a. Using a straightedge, slice through a quarter of the HMA from the center point to the outer edge of the quarter.
   9b. Pull or drag the material from the quarter, holding one edge of the straightedge in contact with quartering device.
   9c. Remove an equal portion form the opposite quarter and combine these increments to create the required sample size.

Note 2: Two straightedges may be used in lieu of the quartering device.

9d. Continue using the apex method with the unused portion of the HMA until samples have been obtained for all required tests.

9e. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Incremental Method (Loaf)

1. Cover a hard, clean, level surface with sheeting. This surface shall be large enough that there will be neither a loss of material nor the accidental addition of foreign material.

2. Place the sample from the agency approved container(s) into a conical pile on that surface.
3. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.

4. Grasp the sheeting and roll the conical pile into a cylinder (loaf), then flatten the top. Make a visual observation to determine that the material is homogenous.

5. Pull the sheeting so at least ¼ of the length of the loaf is off the edge of the counter. Allow this material to drop into a container to be saved. As an alternate, using a straightedge, slice off approximately ¼ of the length of the loaf and place in a container to be saved.

6. Pull material (loaf) off the edge of the counter and drop into an appropriate size sample pan or container for the test to be performed. Continue removing material from the loaf until the proper size sample has been acquired. As an alternate, using a straightedge, slice off an appropriate size sample from the length of the loaf and place in a sample pan or container.

7. Repeat step 6 until all the samples for testing have been obtained.

Note 3: When reducing the sample to test size it is advisable to take several small increments, determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size, use the sample as reduced for the test.

Sample Identification

1. Identify the sample as required by the agency.

2. Samples shall be submitted in agency approved containers and secured to prevent contamination and spillage.
Addendum FOP for AASHTO R 47

Following are guidelines for the use of FOP for AASHTO R 47 by the State of Alaska DOT&PF.

1. The incremental method may be done without sheeting.
2. Unless specifically allowed by project specifications, the mechanical splitter method(s) are not allowed.
Asphalt Cement Content of Hot Mix Asphalt by the Nuclear Method
ATM 405

1. Scope
This method covers the quantitative determination of the asphalt cement content of Hot Mix Asphalt by testing a sample with a device that utilizes neutron thermalization techniques. This is an adaptation of AASHTO T 287. Job mix design (JMD) calibration, cross calibration of master and field gauges and calibration transfer are included.

2. Referenced Documents
   - WAQTC Standards:
     - FOP for AASHTO T 2, Sampling of Aggregates
     - FOP for AASHTO T 168, Sampling Bituminous Paving Mixtures
     - FOP for AASHTO R47, Reducing Samples of Hot Mix Asphalt to Testing Size
     - FOP for AASHTO T 329, Moisture Content of Bituminous Mixes by Oven
   - Other Documents:
     - Manufacturer’s instruction manual.

3. Significance and Use
This method can be used for rapidly determining the asphalt content of HMA. Testing can be completed in a matter of minutes so that adjustments, if necessary, can be made in the asphalt metering system with a limited amount of mix production. The procedure is useful in the determination of asphalt content only, as it does not provide extracted aggregate for the gradation analysis.

4. Apparatus
   - Nuclear asphalt content gauge system consisting of:
     - Neutron source: an encapsulated and sealed radioactive source
     - Thermal neutron detectors
     - Read-out instrument displaying, at a minimum, percent asphalt cement
     - Two or more stainless steel sample pans conforming to gauge requirements
   - Sample containers with lids or other methods of closing to prevent contamination and of sufficient size to hold the entire sample. The containers should be able to withstand the reheating of the mix to mixing temperature.
   - Sample quartering apparatus conforming to requirements of the WAQTC FOP for AASHTO R 47.
   - Balance or scale: capable of determining mass to 15 kg, readable to 1 g and conforming to AASHTO M 231.
   - Drying oven, of either of the following types, capable of handling the volume and sample size expected for the project:
     - Forced air, ventilated or convection oven capable of maintaining a temperature of 177 ±3°C (350 ±5°F)
     - Leveling plate: Flat, rigid plate of metal with a minimum thickness of 10 mm (⅜ in) and slightly larger than the sample pans
   - Thermometer with a temperature range of 10-300°C (50-500°F)
   - Assorted pans, spoons, spatulas, and mixing bowls
• Radioactive materials information and calibration packet containing:
  • Daily Background Count Log
  • Leak Test Certificate
  • Shippers Declaration for Dangerous Goods
  • Procedure Memo for Storing, Transporting and Handling Nuclear Testing Equipment
  • Other radioactive materials documentation as required by local regulatory requirements

5. **Precautions**

1. The equipment shall be so constructed as to be licensable in accordance with applicable health and safety regulations.

2. Equipment operators shall wear an approved form of radiation dosimetry (i.e., film badges, thermoluminescent dosimeter, etc) capable of monitoring the occupational radiation exposure.

3. Since nuclear equipment measures the total amount of hydrogen in the sample, this procedure is sensitive to changes in moisture content. It must be remembered that both asphalt cement and water contain hydrogen.

4. Keep any other source of neutron radiation at least 10 m (30 ft) from the equipment. Do not place the equipment where large amounts of hydrogenous material may be moved during the calibration or testing procedures (for example, water or plastic materials).

5. All personnel shall be kept at least 1 m (3 ft) away from the gauge during testing.

6. **Standardization**

1. Obtain and record a 16 minute background count, in accordance with manufacturer’s procedure, each day prior to taking test measurements or whenever the gauge has been moved or the conditions within 1 m (3 ft) of the gauge have changed. The measurement time for the background count is the same as that used for test measurements.

2. If the background count has not changed by more than 2 percent from the previous background count, then the apparatus shall be considered stable and acceptable for use. If the gauge has been moved or if the surrounding conditions have changed, additional background counts must be obtained until the 2 percent standard is met.

7. **Calibration**

1. This method is sensitive to the type of aggregate, percentage and source of asphalt cement, and to the aggregate gradation. Accordingly, a calibration curve must be developed for each mix type. When changes occur, a new calibration should be run. The curve shall be established with 3 points. (See Appendix A)

2. Prior to the start of each test, verify that the activated calibration is correct.

8. **Procedure**

1. Determine the mass of a clean gauge sample pan, and use this to determine the sample mass in the pan, or tare the pan on the scale.

2. Using a hot asphalt concrete mixture sample having a temperature of 121° to 149°C (250° to 300°F) obtained in accordance with WAQTC FOP for AASHTO T 168, and reduced in accordance with WAQTC FOP for AASHTO R 47, fill the sample pan one-half full, evenly distributing the sample in the pan. Level the asphalt concrete mixture with a preheated trowel or spatula, spading as necessary to compact (usually 10 to 15 spades are sufficient), being careful to avoid segregating the mix or driving the fines into the bottom.
3. Fill the remainder of the pan until the mass of the asphalt concrete mixture in the pan is approximately equal to or up to 5 grams above the mass of mix used for the calibration samples. Level the top of the asphalt concrete mixture using a spatula or trowel and spade as necessary to compact (usually 10 to 15 spades are sufficient), avoiding segregation of the mix. Compact the sample into the pan, until it is level with the top of the pan, by standing on the metal plate and rocking/twisting back-and-forth.

4. Verify that the mass of mix is ± 5 g of the calibration mass. Record the mass of the asphalt concrete mixture in the pan.

5. If the gauge does not have temperature compensation capability, measure and record the temperature of the compacted specimen. This temperature must be within ± 5°C (± 9°F) of the calibration test specimen temperature.

6. Place the pan into the gauge. Perform a 16 minute count.

7. Determine and record the uncorrected asphalt cement content to the nearest 0.01 percent by direct readout from the gauge, from the calibration graph, or by the formula supplied by the manufacturer.

8. Using a representative portion of the original sample or a portion of the material removed from the gauge pan, determine the moisture in the mixture in accordance with the WAQTC FOP for AASHTO T 329 and record to the nearest 0.01 percent.

Note 1: When taking the moisture from the gauge pan sample, remove it immediately after completing the oil content test.

9. **Calculation**

   1. Subtract the moisture content from the uncorrected asphalt cement content. Record this as the corrected asphalt cement content.

10. **Report**

    Results shall be reported on standard forms approved by the agency. Report the following information.

    - Make, model, and serial number of the nuclear asphalt content gauge.
    - Date and source of calibration.
    - Date of test.
    - Name and signature of operator.
    - Background count for the day of the test.
    - Mix identification.
    - Aggregate type and source(s); Asphalt cement source, type and grade.
    - Calibration sample mass and temperature.
    - Test sample mass and temperature, if gauge does not have temperature compensation capability.
    - Gauge reading, including print-out from gauge.
    - Asphalt cement content value to the nearest 0.1 %.
    - Attach the Nuclear Gauge print out to the report.
Appendix A ATM 405

1. Gauge Calibration

1. Obtain samples of aggregate in accordance with WAQTC FOP for AASHTO T 2. Approximately 50 kg (110 lb) total will be required for calibration specimens. Dry the aggregates in accordance with WAQTC FOP for AASHTO T 255/T 265, separate into sieve sizes determined by the JMD.

2. Blend the aggregate together at the proper proportion to match the job mix formula following steps 3 and 4.

3. Calculate the required cumulative mass for each specified sieve using the following formula:

\[ X = \frac{(100 - P)}{100} \times T \]

where:
- \( X \) = Required cumulative batch mass for each specified sieve
- \( P \) = Percent passing for each specified sieve according to the job mix formula
- \( T \) = Initial total aggregate mass

4. Correct for aggregate dust as follows.
   a. Prepare a wash gradation sample from the mass calculated in Step 4.
   b. Perform a washed gradation following WAQTC FOP for AASHTO T 27/T 11.
   c. Compute the corrected batch mass for each specified sieve for the calibration points using the following formula:

\[ Z_n = \frac{X^2}{Y} \]

where:
- \( Z_n \) = Adjusted cumulative batch mass for sieve size n.
- \( X \) = Pre-wash cumulative batch mass for each specified sieve.
- \( Y \) = Post-wash cumulative batch mass for each specified sieve.

5. Obtain samples of bituminous materials in accordance with WAQTC FOP for AASHTO T 40. Approximately 4 L (1 gal) will be required.

6. Calculate the mass of asphalt cement for each calibration point as follows:

\[ B = E \times P_{bm} \]

where:
- \( B \) = mass of asphalt cement to the nearest 0.1 g
- \( E \) = mass of mix
- \( P_{bm} \) = percent asphalt cement content by total mass of mixture, expressed as a decimal.

7. Use the three following asphalt cement contents:
   - Specified minus 1.0 percent
   - Specified (mix design value)
   - Specified plus 1.0 percent
8. Calculate the mass of aggregate required for each calibration point as follows:

\[ A = E - B \]

where:

\[ A = \text{mass of aggregate to the nearest } 0.1 \text{ g} \]
\[ B = \text{mass of asphalt cement to the nearest } 0.1 \text{ g} \]
\[ E = \text{mass of mix} \]

2. Preparation of Calibration Specimens

1. Heat the prepared aggregate specimens to the mixing temperature range midpoint for the asphalt cement ± 5°C (± 9°F) and hold at that temperature for three hours or to constant mass.

2. Heat the asphalt cement to the mid-point of the mixing temperature range ± 5°C (± 9°F) in a covered container(s). It is best to use the asphalt cement as soon as it reaches mixing temperature. If this is not possible, maintain the asphalt cement at this temperature, rather than cool and reheat it, but do not hold the sample at this temperature for more than 4 hours.

3. All bowls, sample pans, and tools should be heated to the mid-point of the mixing temperature range ± 5°C (± 9°F). An initial or “butter” mix is required to condition the mixing equipment. Mix a minimum of three asphalt concrete specimens to cover the approximate range of the design asphalt content. Mix one at the design asphalt content, one 1.0 percent above, and one 1.0 percent below, use the same grade and type of asphalt as will be used in the asphalt concrete mixture to be tested. Mix 7000-9000g for each specimen.

4. Fill the sample pan one-half full, evenly distributing the sample in the pan. Level the asphalt concrete mixture with a spatula or trowel and spade as necessary to compact, avoiding segregation of the mix. Fill the remainder of the pan until the asphalt concrete mixture is mounded slightly above the top of the pan. Record the weight of the asphalt concrete mixture in the pan. This is the weight that is to be used for all calibration and test samples using this calibration. Level the top of the asphalt concrete mixture using a spatula or trowel and spade as necessary to compact, avoiding segregation of the mix. Use the metal plate to consolidate the asphalt concrete mixture until it is level with the top edge of the pan. All specimens should be compacted at the mid-point of the mixing temperature range ± 5°C (± 9°F) to ensure that the mix will compact properly.

5. Place each calibration pan into the gauge and proceed in accordance with the manufacturer’s instructions for operation of the equipment and the sequence of operations. Count each calibration sample for 16 minutes.

   **Note:** Do not forget to perform and record a background count as per the manufacturer’s instructions.

6. For gauges that generate the calibration internally, print out the formula coefficients (“A” Values), the coefficient of fit and the calculated percent difference for each calibration point. The coefficient of fit must be between 0.998 and 1.000 for dense graded mix or 0.995 and 1.000 for open graded mix. Calibration points must have a calculated percent difference of less than 0.09 percent. If either requirement is not met, the calibration must be redone.

7. Store the acceptable calibration in the gauge’s memory, using the job mix formula and the Contract number or an easily recognizable calibration number, according to the manufacturer’s instructions.

8. For gauges other than the Troxler, prepare a calibration curve by plotting the calibration sample gauge readings versus asphalt cement content on linear graph paper, choosing convenient scale factors for gauge readings and asphalt cement content.

9. Calculate the correlation factor for gauges without internal calculations according to the following formula:
\[ CorrelationFactor = \sqrt{1 - \frac{\sum (Y_i - \hat{Y}_i)^2}{\sum (Y_i - \bar{Y}_i)^2}} \]

where:
\( Y_i \) = actual percent asphalt values for each sample
\( \hat{Y}_i \) = calculated percent asphalt values from curve
\( \bar{Y}_i \) = mean value of the actual percentages asphalt, and
\( i \) = number of calibration samples.
Appendix B ATM 405

1. Cross Calibration (Troxler 3241)

1. Cross calibrating creates a relationship between the field gauge and a master gauge. This allows testing of production mix with a field gauge without the need to perform physical calibrations. When several gauges are cross calibrated, the mix calibrations may be transferred to each. The master gauge is normally located where the calibration sample pans are fabricated.

2. The central lab shall prepare the cross calibration samples. Prepare six calibration samples, using a locally available specification aggregate, with binder contents between 3 and 8 percent at 1 percent increments or per the gauge manufacturer’s instructions. Mix the samples so that each pan of mix equals the base mass ± 5 g. Run each sample in the master gauge using a 16 minute count in the normal calibration mode. After all samples are run, the gauge will automatically calculate a coefficient of fit. The coefficient of fit must be at least 0.999.

3. Seal each pan to prevent change in hydrogen content and repeat steps 1 and 2. Sealed pans must meet same criteria.

4. Run each of the six sealed calibration samples in the field gauge while in cross calibration mode utilizing a 16 minute count. For each calibration sample, input the information from the master gauge into the field gauge. When the six cross calibration samples have been counted, print out the cross calibration data. The coefficient of fit must be .999 or 1.000. If this requirement is met, the master gauge and the field gauge are cross calibrated.

2. Calibration Transfer

When the field gauge has been cross calibrated with the master gauge a calibration transfer can be performed. JMD calibrations can now be transferred to the field gauge, using input data only. This transfer would be in lieu of calibrating the field gauge with a JMD calibration. Follow the manufacturer’s instructions to perform this transfer.
### PERFORMANCE EXAM CHECKLIST

**ASPHALT BINDER CONTENT OF BITUMINOUS MIXTURES BY THE NUCLEAR METHOD**  
**ATM 405**

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Precautions for gauge adequately described? Run background count?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>2. Sample obtained as per AASHTO T 168? 250-300 degrees?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>3. Sample reduced as per WAQTC FOP for AASHTO R 47?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>4. First layer properly consolidated?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>5. Second layer properly consolidated?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>6. Sample compacted using the correct size leveling plate?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>7. Mass checks within ±5 g of base mass?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>8. Temperature of mix recorded (if necessary)?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>9. Correct calibration used?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>10. 16 minute count taken and uncorrected binder content recorded to 0.01 percent?</td>
<td>____</td>
<td>____</td>
</tr>
<tr>
<td>11. Corrected binder content correctly determined and recorded to nearest 0.1 percent?</td>
<td>____</td>
<td>____</td>
</tr>
</tbody>
</table>

**Comments:**  
First trial: Pass [ ] Fail [ ]  
Second trial: Pass [ ] Fail [ ]

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Signature of Examiner ________________________________
DETERMINING THE ASPHALT BINDER CONTENT OF HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD (See Addendum for DOT&PF Guidelines)
WAQTC FOP FOR AASHTO T 308

Scope

This procedure covers the determination of asphalt binder content of hot mix asphalt (HMA) by ignition of the binder at 538°C (1000°F) or less in a furnace; samples may be heated by convection or direct infrared irradiation (IR). The aggregate remaining after burning can be used for sieve analysis using the FOP for AASHTO T 30.

Two methods, A and B, are presented.

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

Background on Test Method

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

Sampling

1. Obtain samples of HMA in accordance with the FOP for AASHTO T 168.
2. Reduce HMA samples in accordance with the FOP for AASHTO R 47.
3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 125 ±5°C (257 ±9°F) until soft enough.
4. Test sample size shall conform to the mass requirement shown in Table 1.

Note 1: When the mass of the test specimen exceeds the capacity of the equipment used or for large samples of fine mixes, the test specimen may be divided into suitable increments, tested, and the results appropriately combined through a weighted average for calculation of the binder content.

Table 1

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size* (mm in.)</th>
<th>Minimum Mass Specimen g</th>
<th>Maximum Mass Specimen g</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 (1 ½)</td>
<td>4000</td>
<td>4500</td>
</tr>
<tr>
<td>25.0 (1)</td>
<td>3000</td>
<td>3500</td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>2000</td>
<td>2500</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>1500</td>
<td>2000</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>1200</td>
<td>1700</td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>1200</td>
<td>1700</td>
</tr>
</tbody>
</table>

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

Note 2: The apparatus must be calibrated for the specific mix design. See “Correction Factors” at the end of this FOP.

There are two methods – A and B. The apparatus for the two methods are the same except that the furnace for Method A has an internal balance.

- Ignition Furnace: A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature at 578°C (1072°F).

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

Note 3: The furnace shall be designed to permit the operator to change the ending mass loss percentage from 0.01 percent to 0.02 percent.

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

- Sample Basket Assembly: consisting of sample basket(s), catch pan, and basket guards. Sample basket(s) will be of appropriate size allowing samples to be thinly spread and allowing air to flow through and around the sample particles. Sets of two or more baskets shall be nested. A catch pan: of sufficient size to hold the sample basket(s) so that aggregate particles and melting binder falling through the screen mesh are caught. Basket guards will completely enclose the basket and be made of screen mesh, perforated stainless steel plate, or other suitable material.

Note 4: Screen mesh or other suitable material with maximum and minimum openings of 2.36 mm (No. 8) and 600 µm (No. 30) respectively has been found to perform well.

- Thermometer, or other temperature measuring device, with a temperature range of 10 -260°C (50-500°F).

- Oven capable of maintaining 125 ±5°C (257 ±9°F).

- Balance or scale: Capacity sufficient for the sample mass and conforming to the requirements of M 231, Class G2.

- Safety equipment: Safety glasses or face shield, high temperature gloves, long sleeved jacket, a heat resistant surface capable of withstanding 650°C (1202°F), a protective cage capable of surrounding the sample baskets during the cooling period, and a particle mask for use during removal of the sample from the basket assembly.
• Miscellaneous equipment: A pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

**Procedure – Method A (Internal Balance)**

1. For the convection-type furnace, preheat the ignition furnace to 538°C (1000°F) or to the temperature determined in the “Correction Factor” section, Step 9 of this method. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.

2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.

3. Determine and record the mass to the nearest 0.1 g of the sample basket assembly.

4. Evenly distribute the sample in the sample basket assembly, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.

5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as \( M_i \).

6. Record the correction factor or input into the furnace controller for the specific HMA.

7. Input the initial mass of the sample \( M_i \) into the ignition furnace controller. Verify that the correct mass has been entered.

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

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

   **Note 5:** Furnace temperature will drop below the set point when the door is opened, but will recover when the door is closed and ignition begins. Sample ignition typically increases the temperature well above the set point – relative to sample size and binder content.

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

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

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

   **Note 6:** An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used

11. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 minutes).
12. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as $M_f$.

13. Use the asphalt binder content percentage from the printed ticket. Subtract the moisture content from the printed ticket asphalt binder content and report the difference as the corrected asphalt binder content.

\[ P_b = BC - MC - C_f \] (if not input in the furnace controller)

where:
- $P_b$ = the corrected asphalt binder content as a percent by mass of the HMA
- $BC$ = asphalt binder content shown on printed ticket
- $MC$ = moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, $MC=0$)
- $C_f$ = correction factor as a percent by mass of the HMA sample

14. Asphalt binder content percentage can also be calculated using the formula from “Method B” Step 16.

**Procedure – Method B (External Balance)**

1. Preheat the ignition furnace to 538°C (1000°F) or to the temperature determined in the “Correction Factor” section (Step 9). Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.

3. Determine and record the mass of the sample basket assembly to the nearest 0.1 g.

4. Place the sample basket(s) in the catch pan. Evenly distribute the heated sample in the sample basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.

5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as ($M_i$).

6. Record the correction factor for the specific HMA.

7. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Burn the HMA sample in the furnace for 45 minutes or the length of time determined in the “Correction Factors” section.

8. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample and allow it to cool to room temperature (approximately 30 min).

9. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

10. Place the sample basket assembly back into the furnace.
11. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.

12. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 min.).

13. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

14. Repeat Steps 10 through 13 until the change in measured mass of the sample after ignition does not exceed 0.01 percent of the previous sample mass after ignition.

Note 6: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

15. Record the final value obtained as $M_f$, the final mass of the sample after ignition.

16. Calculate the asphalt binder content of the sample as follows:

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

where:
- $P_b =$ the corrected asphalt binder content as a percent by mass of the HMA sample
- $M_f =$ the final mass of aggregate remaining after ignition
- $M_i =$ the initial mass of the HMA sample prior to ignition
- $C_f =$ correction factor as a percent by mass of the HMA sample
- $MC =$ moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, $MC=0$).

Gradation

1. Empty contents of the basket(s) into a flat pan, being careful to capture all material. Use a small wire brush to ensure all residual fines are removed from the baskets.

Note 7: Particle masks are a recommended safety precaution.

2. Perform the gradation analysis in accordance with the FOP for AASHTO T 30.

Report

Results shall be reported on standard forms approved by the agency. Include:

- Method of test (A or B)
- Corrected asphalt binder content, $P_b$, per agency standard
- Correction factor, $C_f$, to 0.01%
- Temperature compensation factor (if applicable)
- Total percent loss
- Sample mass
- Moisture content to 0.01%
• Test temperature

Attach the original printed ticket with all intermediate values (continuous tape) to the report for furnaces with internal balances.
Correction Factors

Asphalt Binder and Aggregate

Asphalt binder content results may be affected by the type of aggregate in the mixture and by the ignition furnace. Asphalt binder and aggregate correction factors must, therefore, be established by testing a set of correction specimens for each Job Mix Formula (JMF) mix design. Each ignition furnace will have its own unique correction factor determined in the location where testing will be performed.

This procedure must be performed before any acceptance testing is completed, and repeated each time there is a change in the mix ingredients or design. Any changes greater than 5% in stockpiled aggregate proportions should require a new correction factor.

All correction samples will be prepared by a central / regional laboratory unless otherwise directed.

**Asphalt binder correction factor:** A correction factor must be established by testing a set of correction specimens for each Job Mix Formula (JMF). Certain aggregate types may result in unusually high correction factors (> 1.00%). Such mixes should be corrected and tested at a lower temperature as described below.

**Aggregate correction factor:** Due to potential aggregate breakdown during the ignition process, a correction factor will need to be determined for the following conditions:

a. Aggregates that have a proven history of excessive breakdown

b. Aggregate from an unknown source.

This correction factor will be used to adjust the acceptance gradation test results obtained according to the FOP for AASHTO T 30.

Procedure

1. Obtain samples of aggregate in accordance with the FOP for AASHTO T 2.
2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO T 40.

*Note 8:* Include other additives that may be required by the JMF.

3. Prepare an initial, or “butter,” mix at the design asphalt binder content. Mix and discard the butter mix prior to mixing any of the correction specimens to ensure accurate asphalt content.

4. Prepare two correction specimens at the JMF design asphalt binder content. Aggregate used for correction specimens shall be sampled from material designated for use on the project. An agency approved method will be used to combine aggregate. An additional “blank” specimen shall be batched and tested for aggregate gradation in accordance with the FOP for AASHTO T 30. The gradation from the “blank” shall fall within the agency specified mix design tolerances.

5. Place the freshly mixed specimens directly into the sample basket assembly. If mixed specimens are allowed to cool prior to placement in the sample basket assembly, the specimens must be dried to constant mass according to the FOP for AASHTO T 329. Do not preheat the sample basket assembly.

6. Test the specimens in accordance with Method A or Method B of the procedure.

7. Once both of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven tickets, if available.
8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15%, repeat with two more specimens and, from the four results, discard the high and low result. Determine the correction factor from the two original or remaining results, as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen to 0.01%. The asphalt binder correction factor, \( C_f \), is the average of the differences expressed as a percent by mass of HMA.

9. If the asphalt binder correction factor exceeds 1.00%, the test temperature must be lowered to 482 ±5°C (900 ±8°F) and new samples must be burned.

10. For the direct IR irradiation-type burn furnaces, the default burn profile should be used for most materials. The operator may select burn-profile **Option 1** or **Option 2** to optimize the burn cycle. Option 1 is designed for aggregate that requires a large aggregate 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.

**Note 9:** The temperature for determining the asphalt binder content of HMA samples by this procedure shall be the same temperature determined for the correction samples.

11. Perform a gradation analysis on the residual aggregate in accordance with the FOP for AASHTO T 30, if required. The results will be utilized in developing an “Aggregate Correction Factor” and should be calculated and reported to 0.1%.

12. From the gradation results subtract the percent passing for each sieve, for each sample, from the percent passing each sieve of the “Blank” specimen gradation results from Step 4.

13. Determine the average difference of the two values. If the difference for any single sieve exceeds the allowable difference of that sieve as listed in Table 2, then aggregate gradation correction factors (equal to the resultant average differences) for all sieves shall be applied to all acceptance gradation test results determined by the FOP for AASHTO T 30. If the 75 µm (No. 200) is the only sieve outside the limits in Table 2, apply the aggregate correction factor to only the 75 µm (No. 200) sieve.

### Table 2

**Permitted Sieving Difference**

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Allowable Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sizes larger than or equal to 2.36 mm (No.8)</td>
<td>± 5.0%</td>
</tr>
<tr>
<td>Sizes larger than to 75 µm (No.200) and smaller than 2.36 mm (No.8)</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>Sizes 75 µm (No.200) and smaller</td>
<td>± 0.5%</td>
</tr>
</tbody>
</table>
Addendum WAQTC FOP for AASHTO T 308

Following are guidelines for the use of WAQTC FOP for AASHTO T 308 by the State of Alaska DOT&PF.

1. Delete Step 9 in Correction Factors – Procedure.
2. Unless otherwise specified, Method A (using step 14 calculation) shall be used.
3. Asphalt binder content shall be calculated with masses determined on an external balance. This applies to all test samples as well as calibration samples.
4. Nominal Maximum size shall be determined by the Job Mix Formula target value gradation.
5. Determine $M_f$ approximately 30 minutes after removing from oven. $M_f$ shall be determined no later than 3 hours after removal from oven.
6. Corrected asphalt binder content reported to 0.1%.
7. Use of the printed ticket is optional.
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MOISTURE CONTENT OF HOT MIX ASPHALT (HMA) BY OVEN METHOD
FOP FOR AASHTO T 329

Scope

This procedure covers the determination of moisture content of HMA in accordance with AASHTO T 329.

Summary

A test specimen of HMA is dried in a forced-air ventilated or convection oven to constant mass.

Apparatus

- Balance or scale: 2 kg (4.4 lb) capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Forced-air, ventilated, or convection oven: Capable of maintaining the temperature surrounding the sample at 163 ±14°C (325 ±25°F).
- Sample Container: Clean, dry, not affected by heat and of sufficient size to contain a test sample without danger of spilling.
- Thermometer or other suitable device with a temperature range of 10-260°C (50-500°F).

Sample

The test sample shall be obtained in accordance with the FOP for AASHTO T 168, and reduced in accordance with the FOP for AASHTO R 47. The size of the test sample shall be a minimum of 1000 g.

Procedure

1. Preheat the oven to a minimum of 105°C (221°F), but do not exceed the Job Mix Formula (JMF) mixing temperature. If the mixing temperature is not supplied, a temperature of 163 ± 14°C (325 ± 25°F) is to be used.
   
   **Note 1:** For repeatability between laboratories, the preferred practice is to dry the sample at no less than 9°C (15°F) below the JMF mixing temperature.

2. Determine and record the mass of the sample container, including release media, to the nearest 0.1 g.
3. Place the test sample in the sample container.
4. Determine and record the temperature of the test sample.
5. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.
6. Calculate the initial, moist mass (M_i) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 5.
7. The test sample shall be initially dried for 90 ± 5 minutes, and its mass determined. Then it shall be dried at 30 ± 5 min intervals until constant mass is achieved.
8. Cool the sample container and test sample to ±9°C (15°F) of the temperature determined in Step 4.
9. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.
   
   **Note 3:** Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

10. Calculate the final, dry mass (M_f) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 9.

   **Note 4:** Moisture content and the number of samples in the oven will affect the rate of drying at any given time. Placing wet samples in the oven with nearly dry samples could affect the drying process.

### Calculations

**Constant Mass:**

Calculate constant mass using the following formula:

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

Where:

- \( M_p \) = previous mass measurement
- \( M_n \) = new mass measurement

**Moisture Content:**

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

\[
\text{Moisture Content} = \frac{M_i - M_f}{M_f} \times 100
\]

Where:

- \( M_i \) = initial, moist mass
- \( M_f \) = final, dry mass

### Report

Results shall be reported on standard forms approved for use by the agency. Report the moisture content to 0.01 percent.
MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE
FOP FOR AASHTO T 30 (See Addendum for DOT&PF Guidelines)

Scope

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

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

Apparatus

- Balance or scale: Capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass
  or readable to 0.1 g and conform to AASHTO M 231
- Sieves, conforming to AASHTO M 92
- Mechanical sieve shaker
- Suitable drying equipment (see FOP for AASHTO T 255)
- Containers and utensils: A pan or vessel of a size sufficient to contain the sample covered with water
  and to permit vigorous agitation without loss of any part of the sample or water

Sample Sieving

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

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

Time Evaluation

The minimum time requirement should be evaluated for each shaker at least annually by the following
method: Continue shaking for a sufficient period and in such a manner that, after completion, not more
than 0.5 percent by mass of the total sample passes any sieve during one minute of continuous hand
sieving.

Provide a snug-fitting pan and cover, and hold 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, turning the sieve about one-sixth of a revolution at intervals of about 25 strokes.
In determining sufficiency of sieving for sizes larger than 4.75 mm (No. 4), limit the material on the
sieve to a single layer of particles.
Overload Determination

Additional sieves may be necessary to keep from overloading the specified sieves. The sample may also be sieved in increments. For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 6 kg/m² (4 g/in²) of sieving surface. For sieves with openings 4.75 mm (No. 4) and larger, the mass (in g) shall not exceed the product of 2500 x (sieve opening in mm) x (effective sieving area in m²). See Table 1.

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<tr>
<th>Sieve Size mm (in.)</th>
<th>203 φ (8)</th>
<th>305 φ (12)</th>
<th>305 x 305 (12 x 12)</th>
<th>350 x 350 (14 x 14)</th>
<th>372 x 580 (16 x 24)</th>
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<tr>
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<td>0.0670</td>
<td>0.0929</td>
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<td>0.2158</td>
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<td>90 (3 1/2)</td>
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<td></td>
<td>* 15,100</td>
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<td>75 (3)</td>
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<td>50 (2)</td>
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<td>1100</td>
<td>2700</td>
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<td></td>
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<td>400</td>
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</table>

Procedure

1. Using the aggregate sample obtained from the FOP for AASHTO T 308, determine and record the mass of the sample to 0.1 g. This mass shall agree with the mass of the aggregate remaining after ignition (Mf from T 308) within 0.1%.

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

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

Note 1: The use of a mechanical apparatus to perform the washing operation is not precluded. Some mechanical washing equipment with some samples may cause degradation of the sample. When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation. Use care not to overflow or overload the 75µ (No. 200) sieve.
4. Agitate vigorously to ensure complete separation of the material finer than 75µm (No. 200) from
coarser particles and bring the fine material into suspension above the coarser material.

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

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

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

8. Remove the upper sieve and rinse the material retained on the 0.75 mm (No. 200) sieve until water
passing through the sieve is reasonably clear.

9. Return all material retained on the nested sieves to the washed sample by flushing with water.

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

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

12. Place sieves in mechanical shaker and shake for the minimum time determined to provide complete
separation for the sieve shaker being used (approximately 10 minutes).

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

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

   Note 3: Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller
   sieves.

Calculation

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

2. Divide the masses for each sieve (individual/cumulative) by the total dry mass before washing and
multiply by 100 to determine the percent retained on and passing each sieve. Calculate the percent
retained and passing each sieve to the nearest 0.1%.

3. Apply the Aggregate Correction Factor to the calculated percent passing, as required in the FOP for
AASHTO T 308 “Correction Factors” Steps 11 through 13, to obtain the reported percent passing.
Report percentages to the nearest 1% except for the percent passing the 75 µm (No. 200) sieve,
which shall be reported to the nearest 0.1%.
PERCENT RETAINED:

Where:

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

\[
IPR = \frac{IMR}{M} \times 100 \quad \text{OR} \quad CPR = \frac{CMR}{M} \times 100
\]

PERCENT PASSING and REPORTED PERCENT PASSING:

Where:

- PP = Calculated Percent Passing
- PCP = Previous Calculated Percent Passing
- RPP = Reported Percent Passing

\[
PP = PCP - IPR \quad \text{OR} \quad PP = 100 - CPR
\]

RPP = PP + Aggregate Correction Factor
Report

Results shall be reported on standard forms approved for use by the agency. Depending on the agency, this may include:

- Mass retained on each sieve
- Percent retained on each sieve
- Cumulative mass retained on each sieve
- Cumulative percent retained on each sieve
- Calculated percent passing each sieve to 0.1%
- Aggregate Correction Factor for each sieve from AASHTO T 308
- Reported percent passing

Report percentages to the nearest 1 percent except for the percent passing the 75 µm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.
Addendum WAQTC FOP for AASHTO T 30

Following are guidelines for the use of WAQTC FOP for AASHTO T 30 by the State of Alaska DOT&PF.

1. Calculate the minus 0.075 mm (No. 200) by dividing the sum of the loss from washing plus the mass of the material in the pan by the initial sample weight.

2. If the percent difference between $M_f$ and $M$ exceeds 0.1%, neither the asphalt binder content from WAQTC FOP for AASHTO T 308 nor the sieve analysis shall be used for acceptance. A new portion of the sample shall be tested for acceptance for both asphalt binder content and gradation in accordance with WAQTC FOPs for AASHTO T 308 and T 30.

3. Calculate the percent difference between $M$ (T 30) and $M_f$ (T 308) according to the following formula:

$$\%\text{Difference} = \left| \frac{M_f - M}{M_f} \right| \times 100$$
THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT (HMA) (See Addendum for DOT&PF Guidelines)
FOP FOR AASHTO T 209

Scope

This procedure covers the determination of the maximum specific gravity (G_{mm}) of uncompacted hot mix asphalt (HMA) paving mixtures in accordance with AASHTO T 209. Two methods using two different containers – bowl and flask – are covered.

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

Apparatus

- Balance or scale: Minimum 10,000 g capacity, readable to 0.1 g conforming to AASHTO M 231
- Container: A glass, metal, or plastic bowl or volumetric flask capable of holding a 2,000 g sample and withstanding a partial vacuum
- Container cover: A glass plate or a metal or plastic cover with a vented opening
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 4.0 kPa (30 mm Hg)
- Residual pressure manometer or vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (0.9°F)
- Bleeder valve to adjust vacuum
- Timer

Standardization of Flask

Use a volumetric flask that is standardized to accurately determine the mass of water, at 25 ±0.5°C (77 ±0.9°F), in the flask. The volumetric flask shall be standardized periodically in conformance with procedures established by the agency.
Test Sample Preparation

1. Obtain samples in accordance with the FOP for AASHTO T 168 and reduce according to the FOP for AASHTO R 47.

2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.018 for the bowl method and 0.011 for the flask method, the test must be re-run.

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size mm (in.)</th>
<th>Minimum Mass g</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 or greater (1 1/2)</td>
<td>4000</td>
</tr>
<tr>
<td>19 to 25 (3/4-1)</td>
<td>2500</td>
</tr>
<tr>
<td>12.5 or smaller (1/2)</td>
<td>1500</td>
</tr>
</tbody>
</table>

Procedure – General

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

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.

2. Cool the sample to room temperature.

3. Determine and record the mass of the dry bowl or flask, including the cover, to the nearest 0.1 g.

4. Place the sample in the bowl or flask.

5. Determine and record the mass of the dry bowl or flask, cover, and sample to the nearest 0.1 g.

6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A”.

7. Add sufficient water at approximately 25°C ±1°C (77°F ±1.8°F) to cover the sample by about 25 mm (1 in.).

   **Note 1:** The release of entrapped air may be facilitated by the addition of a wetting agent. Check with the agency to see if this is permitted and, if it is, for a recommended agent.

8. Place the lid on the bowl or flask and attach the vacuum line. To ensure a proper seal between the flask and the lid, wet the O-ring or use a petroleum gel.

9. Remove entrapped air by subjecting the contents to a partial vacuum of 3.7 ±0.3 kPa (27.5 ±2.5 mm Hg) residual pressure for 15 ±2 minutes.

10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2 minute intervals. This agitation facilitates the removal of air.
11. Turn off the vacuum pump, slowly open the release valve, and remove the lid. When performing the flask method, complete steps 12B through 16B within 10±1 minutes.

Procedure – Bowl

12A. Suspend and immerse the bowl and contents in water at 25 ±1.0°C (77 ±1.8°F) for 10 ±1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.

13A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.

14A. Empty and re-submerge the bowl following Step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.

15A. Determine and record the submerged weight of the sample the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 13A. Designate this submerged weight as “C”.

Procedure – Flask

12B. Immediately fill the flask with water without reintroducing air.

13B. Stabilize the temperature of the flask and contents in a water bath so that the final temperature is within 25 ±1°C (77 ±1.8°F).

Note 2: In lieu of placing the flask in the water bath, determine the temperature of the water in the flask and make the appropriate density correction using Table 2 when the temperature is outside 25 ±1°C (77 ±1.8°F).

14B. Finish filling the flask, place the cover or a glass plate on the flask, and eliminate all air from the flask.

Note 3: When using the metal flask and cover, place the cover on the flask and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling flask to avoid reintroducing air into the water.

15B. Towel dry the outside of the flask and cover.

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

Procedure – Mixtures Containing Uncoated Porous Aggregate

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

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.
2. Spread sample before an electric fan to remove surface moisture.
3. Determine the mass of the sample when the surface moisture appears to be gone.
4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.
5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as “ASSD”.

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

**Calculation**

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

**Bowl Procedure**

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

where:

- $A$ = mass of dry sample in air, g
- $C$ = submerged weight of sample in water, g

**Flask Procedure**

$$G_{mm} = \frac{A}{A + D - E} \times R$$

or

$$G_{mm} = \frac{A}{ASSD + D - E} \times R$$

(for mixtures containing uncoated aggregate materials)

where:

- $A$ = Mass of dry sample in air, g
- $ASSD$ = Mass of saturated surface-dry sample in air, g
- $D$ = Mass of flask filled with water at 25°C (77°F), g, determined during the Standardization of Flask procedure
- $E$ = Mass of flask filled with water and the test sample at test temperature, g
- $R$ = Factor from Table 2 to correct the density of water – use when a test temperature is outside 25 ±1°C (77 ±1.8°F)

Average

$$2.470 - 2.466 = 0.004 \quad 0.004 ÷ 2 = 0.002 \quad 0.002 + 2.466 = 2.468$$

Or $$2.470 + 2.466 = 4.936 \quad 4.936 ÷ 2 = 2.468$$
Table 2

Temperature Correction Factor

<table>
<thead>
<tr>
<th>°C</th>
<th>°F</th>
<th>“R”</th>
<th>°C</th>
<th>°F</th>
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<td>1.00059</td>
<td>25.9</td>
<td>78.6</td>
<td>0.99976</td>
</tr>
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<td>1.00057</td>
<td>26.0</td>
<td>78.8</td>
<td>0.99973</td>
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<td>1.00054</td>
<td>26.1</td>
<td>79.0</td>
<td>0.99971</td>
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<td>22.9</td>
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<td>0.99968</td>
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<td>0.99965</td>
</tr>
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<td>1.00047</td>
<td>26.4</td>
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<td>0.99963</td>
</tr>
<tr>
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<td>1.00045</td>
<td>26.5</td>
<td>79.7</td>
<td>0.99960</td>
</tr>
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</table>
Theoretical Maximum Density

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

Theoretical maximum density kg/m³ = Gmm x 997.1 kg/ m³
or
Theoretical maximum density lb/ft³ = Gmm x 62.245 lb/ft³

Report

Results shall be reported on standard forms approved for use by the agency. Report Gmm to three decimal places. Report the theoretical maximum density to 1 kg/m³ (0.1 lb/ft³).
Following are guidelines for the use of WAQTC FOP for AASHTO T 209 by the State of Alaska DOT&PF.

1. The flask method is to be used in all Theoretical Maximum Specific Gravity determinations.
2. Replace Table 1 to the following:

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size* mm (in.)</th>
<th>Minimum Mass g</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 (1)</td>
<td>2500</td>
</tr>
<tr>
<td>19 (3/4)</td>
<td>2000</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>1500</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>1000</td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>0500</td>
</tr>
</tbody>
</table>

Table 1:
Test Sample Size for Maximum Specific Gravity
BULK SPECIFIC GRAVITY OF COMPACTED HOT MIX ASPHALT (HMA) USING SATURATED SURFACE-DRY SPECIMENS (See Addendum for DOT&PF Guidelines) FOP FOR AASHTO T 166

BULK SPECIFIC GRAVITY OF COMPACTED HOT MIX ASPHALT (HMA) USING PARAFFIN-COATED SPECIMENS FOP FOR AASHTO T 275

Scope

This procedure covers the determination of bulk specific gravity (G_{mb}) of compacted hot mix asphalt (HMA) using three methods – A, B, and C – in accordance with AASHTO T 166. These three methods are for use on specimens not having open or interconnecting voids and/or absorbing more than 2.0 percent water by volume. A fourth and fifth method – D & E – in accordance with AASHTO T 275 and covering specimens having open or interconnecting voids and/or absorbing more than 2.0 percent water by volume is also included.

Overview

- Method A: Suspension
- Method B: Volumeter
- Method C: Rapid test for A or B
- Method D: Suspension for coated specimen
- Method E: Volumeter for coated specimen

Test Specimens

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

Terminology

Constant Mass: AASHTO T 166 defines constant mass as the mass at which further drying at 52 ±3°C (125 ±5°F) does not alter the mass by more than 0.05 percent. It also states that samples shall initially be dried overnight and that mass determinations shall be made at 2-hour drying intervals. AASHTO T 166 also states that recently molded laboratory samples that have not been exposed to moisture do not need drying.

Apparatus - Method A (Suspension)

- Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.
- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
• Water bath: For immersing the specimen in water while suspended under the balance or scale, and equipped with an overflow outlet for maintaining a constant water level.

• Towel: Damp cloth towel used for surface drying specimens.

• Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.

• Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.

• Thermometer: Having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

Procedure - Method A (Suspension)

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

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

2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as “A”.

3. Fill the water bath to overflow level with water at 25 ±1°C (77 ±1.8°F) and allow the water to stabilize.

4. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

5. Immerse the specimen for 4 ±1 minutes.

6. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as “C”.

7. Steps 7 through 9 must be completed within 5 seconds. Remove the sample from the water and quickly surface dry with a damp cloth towel.

8. Zero or tare the balance.

9. Determine and record the mass of the SSD specimen to nearest 0.1 g. Designate this mass as “B”. Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen.

Calculations - Method A (Suspension)

\[ G_{mb} = \frac{A}{B - C} \]

where:

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

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

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

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: Thermostatically controlled to 25 ±0.5°C (77±0.9°F).
- Thermometer: Range of 19 to 27°C (66 to 80°F), and graduated in 0.1°C (0.2°F) subdivisions.
- Volumeter: Calibrated to 1200 mL or appropriate capacity for test sample and having a tapered lid with a capillary bore.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Towel: Damp cloth towel used for surface drying specimens.

Procedure - Method B (Volumeter)

1. Dry the specimen to constant mass, if required.
   
   Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as “A”.

3. Immerse the specimen in the temperature-controlled water bath for at least 10 minutes.

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

5. Steps 5 and 6 must be completed within 5 seconds. At the end of the ten minute period, remove the specimen from the water bath and quickly surface dry with a damp cloth towel.

6. Determine and record the mass of the SSD specimen to the nearest 0.1 g. Designate this mass as “B”. Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen.

7. Place the specimen in the volumeter and let stand 60 seconds.

8. Bring the temperature of the water to 25 ±1°C (77 ±1.8°F) and cover the volumeter, making sure some water escapes through the capillary bore of the tapered lid.

9. Wipe the volumeter dry.

10. Determine and record the mass of the volumeter and specimen to the nearest 0.1 g. Designate this mass as “E”.

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

Calculations - Method B (Volumeter)
\[ G_{mb} = \frac{A}{B + D - E} \]

where:
A = Mass of dry specimen in air, g
B = Mass of SSD specimen in air, g
D = Mass of volumeter filled with water at 25 ±1°C (77 ±1.8°F), g
E = Mass of volumeter filled with specimen and water, g

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

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

See Methods A or B.

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

**Procedure - Method C (Rapid Test for Method A or B)**

1. Determine which method to perform, A or B. Proceed with Method A or B, except that the dry mass, A, is determined last. In method A and B, start on Step 3 and complete that procedure, then continue as follows to determine mass “A”.
2. Place the specimen on a large, flat-bottom pan of known mass.
3. Heat at a minimum of 105°C (221°F), until the specimen can be easily separated to the point where the fine aggregate particles are not larger than 6.3 mm (1/4 in.). In no case should the Job Mix Formula mixing temperature be exceeded.
4. Dry to constant mass. Constant mass is defined as the mass at which further drying at the temperature in Step 3 does not change by more than 0.05% after an additional 2 hour drying time.
5. Cool in air to 25 ±5°C (77 ±9°F).
6. Determine and record the mass of the pan and specimen to the nearest 0.1 g.
7. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the pan from the mass determined in Step 6. Designate this mass as “A”.

**Calculations - Method C (Rapid Test for Method A or B)**

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

**Materials - Method D Suspension (Coated Specimens/AASHTO T 275)**

- Paraffin or parafilm: Used to coat test specimens.
Apparatus - Method D Suspension (Coated Specimens/AASHTO T 275)

- Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.
- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
- Water bath: For immersing the specimen in water while suspended under the balance or scale, and equipped with an overflow outlet for maintaining a constant water level.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.

Procedure - Method D Suspension (Coated Specimens/AASHTO T 275)

1. Dry the specimen to constant mass, if required.
2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as “A”.
3. Coat the specimen on all surfaces with melted paraffin, or parafilm coating, sufficiently thick to seal all voids.
4. Allow coating to cool in air at 25 ±5°C (77 ±9°F) for 30 minutes.
5. Determine and record the mass of the coated specimen to the nearest 0.1 g. Designate this mass as “D”.
6. Fill the water bath to overflow level with water at 25 ±1°C (77 ±1.8°F).
7. Immerse the specimen in water at 25 ±1°C (77 ±1.8°F) for 4 ±1 minutes.
8. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as “E”.
9. Determine the specific gravity of paraffin or parafilm at 25 ±1°C (77 ±1.8°F) from the manufacturer’s literature or other suitable source. Designate this specific gravity as “F”.
Calculations - Method D Suspension (Coated Specimens/AASHTO T 275)

\[ G_{mb} = \frac{A}{D - E - \left(\frac{D - A}{F}\right)} \]

where:
A = Mass of dry specimen in air, g
D = Mass of specimen with paraffin coating in air, g
E = Weight of specimen with paraffin coating in water, g
F = Specific gravity of paraffin or parafilm at 25 ±1°C (77 ±1.8°F)

Apparatus - Method E Volumeter (Coated Specimens/AASHTO T 275)

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: Thermostatically controlled to 25 ±0.5°C (77±0.9°F).
- Thermometer: Range of 19 to 27°C (66 to 80°F), and graduated in 0.1°C (0.2°F) subdivisions.
- Volumeter: Calibrated to 1200 mL or appropriate capacity for test sample and having a tapered lid with a capillary bore.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Towel: Damp cloth towel used for surface drying specimens.

Procedure - Method E Volumeter (Coated Specimens/AASHTO T 275)

1. Dry the specimen to constant mass, if required.
2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as “A”.
3. Coat the specimen on all surfaces with paraffin, or parafilm coating, sufficiently thick to seal all voids.
4. Allow coating to cool in air at 25 ±5°C (77 ±9°F) for 30 minutes.
5. Determine and record the mass of the coated specimen to the nearest 0.1g. Designate this mass as “C”.
6. Fill the volumeter with distilled water at 25 ±1°C (77 ±1.8°F) and place the coated specimen in the volumeter.
7. Bring the temperature of the water to 25 ±1°C (77 ±1.8°F) and cover the volumeter, making sure some water escapes through the capillary bore of the tapered lid.
8. Wipe the volumeter dry.

9. Determine and record the mass of the volumeter and specimen to the nearest 0.1 g. Designate this mass as “E”.

10. Determine the specific gravity of paraffin or parafilm at 25 ±1°C (77 ±1.8°F) or from the manufacturer’s literature or other suitable source. Designate this specific gravity as “F”.

Calculations - Method E Volumeter (Coated Specimens/AASHTO T 275)

\[
G_{mb} = \frac{A}{D - \left[ E - C + \left( \frac{C - A}{F} \right) \right]}
\]

where:

- \( A \) = Mass of dry specimen in air, g
- \( C \) = Mass of specimen with paraffin coating in air, g
- \( D \) = Mass of volumeter filled water at 25 ±1°C (77 ±1.8°F), g
- \( E \) = Mass of volumeter filled with specimen with paraffin coating and in water at 25 ±1°C (77 ±1.8°F), g
- \( F \) = Specific gravity of paraffin or parafilm at 25 ±1°C (77 ±1.8°F)

Report

Results shall be reported on standard forms approved for use by the agency. Report the \( G_{mb} \) to 3 decimal places and absorption to 2 decimal places. Report the method performed.
Addendum WAQTC FOP for AASHTO T 166/T 275

Following are guidelines for the use of WAQTC FOP for AASHTO T 166/T 275 by the State of Alaska DOT&PF.

1. Report compaction to the 0.1%. Calculate as follows:

\[ C_p = \left( \frac{G_{mb}}{G_{mm}} \right) \times 100 \]

Where:
- \( C_p \) = Percent Compaction
- \( G_{mm} \) = Theoretical Maximum Specific Gravity
- \( G_{mb} \) = Bulk Specific Gravity

2. Method C/A is the only accepted method for AKDOT&PF projects, regardless of the absorption calculated.

3. As an alternate to drying to constant mass in an oven, ASTM D 7227 may be used.
IN-PLACE DENSITY OF BITUMINOUS MIXES USING THE NUCLEAR MOISTURE-DENSITY GAUGE (See Addendum for DOT&PF Guidelines)
FOP FOR WAQTC TM 8

Scope

This test method describes a test procedure for determining the density of bituminous mixes by means of a nuclear gauge employing either direct transmission or backscatter methods. Correlation with densities determined under the FOP for AASHTO T 166 is required by some agencies.

Apparatus

- Nuclear density gauge with the factory-matched standard reference block.
- Drive pin, guide/scraper plate, and hammer for testing in direct transmission mode.
- Transport case for properly shipping and housing the gauge and tools.
- Instruction manual for the specific make and model of gauge.
- Radioactive materials information and calibration packet containing:
  - Daily standard count log
  - Factory and laboratory calibration data sheet
  - Leak test certificate
  - Shippers’ declaration for dangerous goods
  - Procedure memo for storing, transporting and handling nuclear testing equipment
  - Other radioactive materials documentation as required by local regulatory requirements

Material

- Filler material: Fine-graded sand from the source used to produce the asphalt pavement or other agency approved materials.

Radiation Safety

This method does not purport to address all of the safety problems associated with its use. This test method involves potentially hazardous materials. The gauge utilizes radioactive materials that may be hazardous to the health of the user unless proper precautions are taken. Users of this gauge must become familiar with the applicable safety procedures and governmental regulations. All operators will be trained in radiation safety prior to operating nuclear density gauges. Some agencies require the use of personal monitoring devices such as a thermoluminescent dosimeter or film badge. Effective instructions, together with routine safety procedures such as source leak tests, recording and evaluation of personal monitoring device data, etc., are a recommended part of the operation and storage of this gauge.
Calibration

Calibrate the nuclear gauge as required by the agency. This calibration may be performed by the agency using the manufacturer’s recommended procedures or by other facilities approved by the agency. Verify or re-establish calibration curves, tables, or equivalent coefficients every 12 months.

Standardization

1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day’s testing.

2. Standardize the nuclear gauge at the construction site at the start of each day’s work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired and/or recalibrated.

3. Record the standard count for both density and moisture in the daily standard count log. The exact procedure for standard count is listed in the manufacturer’s Operator’s Manual.

Note 1: New standard counts may be necessary more than once a day. See agency requirements.

Test Site Location

1. Select a test location(s) randomly and in accordance with agency requirements. Test sites should be relatively smooth and flat and meet the following conditions:
   a. At least 10 m (30 ft) away from other sources of radioactivity.
   b. At least 3 m (10 ft) away from large objects.
   c. If the gauge will be closer than 600 mm (24 in.) to any vertical mass, or less than 300 mm (12 in.) from a vertical pavement edge, use the gauge manufacturer’s correction procedure.

Overview

There are two methods for determining the in-place density of HMA. See agency requirements for method selection.

- Direct Transmission
- Backscatter
Procedure

Direct Transmission

1. Maximum contact between the base of the gauge and the surface of the material under test is critical.

2. Use the guide and scraper plate as a template and drill a hole to a depth of at least 7 mm (1/4 in.) deeper than the measurement depth required for the gauge.

3. Place the gauge on the prepared surface so the source rod can enter the hole. Insert the probe in the hole and lower the source rod to the desired test depth using the handle and trigger mechanism. Position the gauge with the long axis of the gauge parallel to the direction of paving. Pull the gauge so that the probe is firmly against the side of the hole.

4. Take one four-minute test and record the wet density (WD) reading.

Backscatter

1. Maintain maximum contact between the base of the gauge and the surface of the material under test. Use filler material to fill surface voids. Spread a small amount of filler material over the test site surface and distribute it evenly. Strike off the surface with a straightedge (such as a lathe or flat-bar steel) to remove excess material.

2. Place the gauge on the test site. Using a crayon (not spray paint), mark the outline or footprint of the gauge. Extend the probe to the backscatter position.

3. Take a one-minute test and record the wet density reading.

4. Rotate the gauge 90 degrees about the probe. Mark the outline or footprint of the gauge.

5. Take another one-minute test and record the wet density reading.

6. If the difference between the two one-minute tests is greater than 40 kg/m³ (2.5 lb/ft³), retest in both directions.

7. The density reported for each test site shall be the average of the two individual one-minute wet density readings.

Calculation of Results

Percent compaction is determined by comparing the in-place wet density as determined by this method to the appropriate agency density standard. See appropriate agency policy for use of density standards.

\[
\frac{\text{Corrected Reading}}{\text{Maximum Density}} \times 100 = \% \text{ compaction}
\]
Correlation with Cores

**Note 2:** When density correlation with the FOP for AASHTO T 166 is required, correlation of the nuclear gauge with pavement cores shall be made on the first day’s paving (within 24 hours) or from a test strip constructed prior to the start of paving. Cores must be taken before traffic is allowed on the pavement.

1. Determine the number of cores required for correlation from the agency’s specifications. Cores shall be located on the first day’s paving or on the test strip. Locate the test sites in accordance with the agency’s specifications. Follow the “Procedure” section above to establish test sites and obtain densities using the nuclear gauge.

2. Obtain a pavement core from each of the test sites in accordance with WAQTC TM 11. The core should be taken from the center of the nuclear gauge footprint. If direct transmission was used, locate the core at least 25 mm (1 in.) away from the edge of the drive pin hole.

3. Determine the density of the cores by the FOP for AASHTO T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface Dry Specimens.

4. Calculate a correlation factor for the nuclear gauge reading as follows:
   
   a. Calculate the difference between the core density and nuclear gauge density at each test site to the nearest 1 kg/m³ (0.1 lb/ft³). Calculate the average difference and standard deviation of the differences for the entire data set to the nearest 1 kg/m³ (0.1 lb/ft³).
   
   b. If the standard deviation of the differences is equal to or less than 40 kg/m³ (2.5 lb/ft³), the correlation factor applied to the nuclear density gauge reading shall be the average difference calculated above in 4.a.
   
   c. If the standard deviation of the differences is greater than 40 kg/m³ (2.5 lb/ft³), the test site with the greatest variation from the average difference shall be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b.
   
   d. If the standard deviation of the modified data set still exceeds the maximum specified in 4.b, additional test sites will be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b. If the data set consists of less than five test sites, additional test sites shall be established.

**Note 3:** The exact method used in calculating the nuclear gauge correlation factor shall be defined by agency policy.
**Note 4:** The above correlation procedure must be repeated if there is a new job mix formula. Adjustments to the job mix formula beyond tolerances established in the contract documents will constitute a new job mix formula. A correlation factor established using this procedure is only valid for the particular gauge and in the mode and at the probe depth used in the correlation procedure. If another gauge is brought onto the project, it shall be correlated using the same procedure. Multiple gauges may be correlated from the same series of cores if done at the same time.

**Note 5:** For the purpose of this procedure, a job mix formula is defined as the percent and grade of paving asphalt used with a specified gradation of aggregate from a designated aggregate source. A new job mix formula may be required whenever compaction of the wearing surface exceeds the agency’s specified maximum density or minimum air voids.

**Report**

Results shall be reported on standard forms approved by the agency. Include the following information:

- Location of test and thickness of layer tested
- Mixture type
- Make, model and serial number of the nuclear moisture-density gauge
- Mode of measurement, depth, calculated wet density of each measurement and any adjustment data
- Standard density
- Percent compaction and/or percent air voids
- Name and signature of operator
Addendum WAQTC TM 8

Following are guidelines for the use of WAQTC TM 8 by the State of Alaska DOT&PF.

1. Testing under this method shall be used for quality control and when specified, acceptance testing.

2. All density testing on HMA done under this method shall be done in Backscatter only.

3. Report percent compaction to the nearest 0.1%
Relative Standard Density by the Control Strip Method   ATM 412

1. Scope
This method describes a procedure for determining the relative standard density of a material by the control strip testing method. This is applicable to granular materials that are bound together with asphalt binders and/or portland cement.

2. Significance and Use
In testing some HMAs, determining the standard density may be difficult with conventional test methods used in the laboratory. When these problems occur a method that allows the determination of a relative standard density in the field can facilitate the verification of compaction efforts. This method describes a procedure to determine the relative standard density to be used in these circumstances.

3. Apparatus
- Nuclear Moisture/Density Gauge—Calibrate and standardize in accordance with WAQTC TM 8.
- Compaction equipment that meets the requirements of the contract and of sufficient size and compaction energy to compact the material.

4. Site Preparation
1. The Engineer will designate the location and the size of the control strip, as well as minimum compaction equipment to be used.
2. The subgrade will be compacted to a minimum density equal to that required for the material being tested. When the compaction is complete, the Engineer will approve the surface.
3. A representative lift of the material being evaluated will be placed and prepared for compaction.

5. Procedure
1. Attention should be paid to the requirements of the product being placed so that any binder content, temperature and/or moisture requirements are maintained in an acceptable range.
2. A minimum of 3 test locations will be selected within the control strip. The locations will be in the middle 1/2 of the control strip and at least 12 in from the edge of the control strip. The Engineer will select test locations.
3. The locations will be marked in such a way as not to be lost during the compaction of the control strip. This can be accomplished by marking the side of the strip with stakes or surveyors tape, or by marking with paint beside the location on the control strip.
4. Test time (15 second or 1 minute) using 1 reading or average of two will be as approved by the Engineer
5. Care should be taken when preparing the test location so that it is flat and the surface voids filled. If necessary, use a small quantity of dry sand to fill the voids. This layer will in no case be more than 1/8 in in depth.
6. After the first pass with the compaction equipment, an initial density test is taken and recorded.
   Note 1: One pass of the roller will be defined as one roll over the location.
7. After each subsequent pass and for each piece of compaction equipment used, a test is taken at each location and recorded.
8. Continue the compaction and testing cycle until either of these conditions is met.
a. There is less than 1 lb/ft³ increase in the density of the averaged density tests for each location on two consecutive passes.

b. There is less than 16 kg/m³ (1 lb/ft³) increase in the density of the average of all three locations for two consecutive passes.

9. Select ten random locations on the completed control strip and test by averaging two one minute counts at each location in accordance with TM 8. Average the results from the ten locations and this value will be the relative standard density for this material.

Note 2: It may be necessary to repeat the procedure for additional roller types depending on the material to be tested and the requirements of sequencing for the finished surface.

10. Additional control strips may be required if there are changes in the material, lift thickness or compaction equipment.

6. Calculations

1. The Relative Standard Density value will be calculated as follows:

\[
D_S = \frac{A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + A_9 + A_{10}}{10}
\]

Where:

- \(D_S\) = Relative Standard Density for the material.
- \(A_n\) = Average Density for random test location \(n\).

7. Report

- Report the average density for each pass
- Report the standard density to the nearest 0.1 lb/ft³
SAMPLING BITUMINOUS MATERIAL AFTER COMPACTION (OBTAINING CORES)
WAQTC TM 11 (See Addendum for DOT&PF Guidelines)

Scope

- This method describes the process for removal of a sample of compacted bituminous material from a pavement for laboratory testing by obtaining test cores after compaction has been completed. Core diameter(s) may range in size from 2 in. to 12 in.

- The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

Significance And Use

- Samples obtained in accordance with the procedure given in this practice may be used for measuring pavement thickness, density, and acceptance testing.

- When cores are used to determine nuclear gauge correlation, see WAQTC TM 8.

- When cores are used to determine pavement density, the Bulk Specific Gravity \((G_{mb})\) is determined according to WAQTC FOP for AASHTO T 166 / T 275.

Apparatus

- Coring Machine – To minimize distortion of the compacted bituminous cores, a motor driver core machine shall be used to secure the sample that is capable of obtaining a core the full depth of the bituminous material being placed.

- Core Bit – The cutting edge of the core drill bit shall be of hardened steel or other suitable material with diamond chips embedded in the metal cutting edge.

- Separation Equipment – Cores shall be separated with a saw or other method(s) that provides a clean smooth plane representing the layer to be measured, or tested.

- Retrieval Device – A retrieval device for removing core samples from holes that will preserve the integrity of the core. The device may be a steel rod of suitable length and with a diameter that will fit into the space between the core and the pavement material. There shall be a 90 degree bend at the top to form a handle and a 90 degree bend at the bottom, approximately 50 mm (2 in.) long, forming a hook to assist in the retrieval of the core.
Material

- Water, ice, dry ice, liquid nitrogen, or other cooling material.

Safety

- This method does not purport to address all of the safety problems associated with its use. This test method involves potentially hazardous conditions.

Test Site Location

- The quantity of cores to be obtained shall be determined by the test procedure to be performed or agency requirements.
- Determine the location of the core(s) as required by the agency.

Procedure

- For freshly placed bituminous materials, the core shall be taken when the material has had sufficient amount of time to cool to prevent damage to the core.
- Cores may be taken by cooling the pavement to allow for immediate removal. Cooling may be expedited with the use of water, ice water, ice, or dry ice.
- Place the coring machine and core bit over the selected location.
- Start the flow of coolant to ensure removal of the cuttings and to minimize the generation of heat caused by friction.
- Keep the core bit perpendicular to the bituminous surface during the coring process. If any portion of the coring machine shifts during the operation, the core may break or distort.
- Constant downward pressure should be applied on the core bit. Failure to apply constant pressure, or too much pressure, may cause the bit to bind or distort the core.
- Continue the coring operation until the desired depth is achieved.
- If necessary, use a retrieval device to remove the core.
- If the core is damaged to a point that it can not be utilized for its intended purpose, a new core shall be obtained within 12 in. of the original location.
- Clearly identify the core without damaging it.
**Filling Core Holes**

- The hole made from the coring operation shall be filled with a material that will not become dislodged. If a bituminous material is available and used, it shall be compacted into the hole. A fast set concrete product may be used in lieu of a bituminous material.

**Transporting Cores**

- Transport cores on a smooth surface, top side down in a container(s) that prevents damage from jarring, rolling, hitting together, and/or impact with any object.

- Prevent cores from freezing or from excessive heat, 54°C (130°F), during transport.

*Note #1:* In extreme ambient temperature conditions, an insulated container should be used during transport.

- If the core is damaged to a point that it can not be utilized for its intended purpose the core will not be used for acceptance tests.

**Separate the Layers**

- When necessary to separate two or more pavement courses, lifts, or layers; separate by using a saw to cut the core on the designated lift line. Water must be sprayed on the saw blade to minimize the generation of excessive heat.

*Note #2:* Lift lines are often more visible by rolling the core on a flat surface.

**Length Determination**

- Measure the thickness of the designated lift to 3 mm. (0.1 in). Three or more measurements shall be taken around the core and averaged.

**Report**

- Core information shall be reported on standard agency forms. Include the following information:
  
  - The date the cores were obtained
  - Location of test and thickness of layer tested
  - The lift being evaluated
  - Type of material being evaluated
  - Mix Design Lab Number
  - Average thickness of each core (to the nearest 3 mm or 0.1 in.)
Addendum WAQTC TM 11

Following are guidelines for the use of WAQTC TM 11 by the State of Alaska DOT&PF.

1. While saw cutting is the preferred method, the different layers in a core may be separated by freezing and use of a chisel and hammer or by use of a hammer and chisel alone if a saw is not available. Care must be taken to protect the core from deformation or damage during the separation. If the core is deformed or damaged, it must be discarded and a new core taken.
2. Core locations – Joint cores shall be centered on the longitudinal joint. Mat cores shall be located at least 12” from all joints.
3. Core Locations – core locations shall be independent of other sampling.
4. When determining mat depth (thickness), determine and record the length (height) of the core to 5 mm (¼”).
5. Damaged cores shall be replaced by cores located within 12” of the original test.
6. When material is sampled by other than DOT&PF personnel or their agent(s), the sampling must be witnessed and possession taken immediately by DOT&PF personnel or their agent(s).
Anti-Strip Requirements of Hot Mix Asphalt ATM 414

1. Scope

This method, an adaptation of AASHTO T 182, describes a procedure for determining the retention of a bituminous film by aggregate in the presence of water. It is applicable to asphalt cements, cutback asphalts and emulsified asphalts.

2. Apparatus

- Balance or scale: Capacity sufficient for the principle sample mass, readable to 0.1 percent of the total sample mass and meeting the requirements of AASHTO M 231.
- Thermostatically controlled oven capable of maintaining any required constant temperature between 49-150 ± 1°C (120-300 ± 1°F).
- A 9.5 mm (⅜") and a 4.75 mm (No. 4) mm sieve conforming to AASHTO M 92.
- 600 ml beakers, low form glass or plastic type.
- Thermostatically controlled water bath capable of maintaining a temperature of 49º ± 1ºC (120° ± 2°F).
- Miscellaneous equipment including a steel spatula with stiff blade (approximately ½" wide x 4" long (25 mm x 100 mm), glass or plastic containers for mixing samples, and air-tight containers of suitable size for storing bitumen and anti-strip mixtures.

3. Sample Preparation

1. Aggregate:
   a. The test aggregate shall be processed in the same manner as that which would be used during the construction process.
   b. Dry the aggregate to a constant weight in accordance with WAQTC FOP for AASHTO T 255.
   c. Separate the aggregate by sieving to obtain the minus 9.5 mm (⅜") plus (No.4) material. Reduce this material, in accordance with WAQTC FOP for AASHTO T 248, Method A, to obtain approximately 1200 g.

2. Anti-stripping additive used in testing will be the same brand and type proposed for use on the project.

3. Bitumen and/or emulsified asphalts will be the same type and grade proposed for use in mix design.

4. Procedure

1. For asphalt cement and/or cutback asphalt samples:
   a. Thoroughly mix the bitumen samples with the anti-strip additive in the proportions of 0.25 percent, 0.50 percent, and 0.75 percent or as required. If necessary to store this mixture, use airtight containers.

      Note 1: After the additive is added to the bitumen standards they shall not be reheated in excess of preheat temperatures as outlined in (1) and (2) below.

   b. Make up 1 or more aggregate specimens per additive content by placing 100 ± 1 gram of the aggregate to be tested into individual mixing containers.

   c. Preheat aggregate specimens to the temperature of the respective bitumen below:

      (1) Asphalt cements: Preheat in oven at a temperature within the binders mixing temperature range for no longer than 30 minutes.

      (2) Cut-back asphalts: Grades 30 to 250. No preheat required.
Grades 800 to 3000: Preheat at 60-90°C (140-195 °F) for no longer than 30 minutes.

d. Preheat the bitumen at the respective temperatures above until it can be poured.

e. Add 5.5 ± 0.5 g of bitumen-additive mixture to the aggregate specimen(s).

f. Mix the bitumen and aggregate thoroughly until uniformly coated.

g. The bitumen-aggregate specimen(s) shall be oven-cured at a temperature 60 ± 1°C (140 ± 2°F) for a minimum of 18 hours but no more than 24 hours.

h. Remove the sample(s) from the oven and re-mix to obtain a uniform coating. Allow the specimen(s) to cool to a temperature of 49°C (120°F) or less.

i. Place 50 ± 1 g of each of the coated aggregates into individual 600 ml. beakers.

j. Add 400 ml distilled water, cover and place in an oven or water bath maintained at 49º ± 1°C (120 ± 2°F) for 24 hours. If a water bath is used, the container(s) shall not be submerged so as to allow bath water into the beakers.

2. For emulsified asphalts (anionic/cationic):

   IMPORTANT: ANTI-STRIPPING ADDITIVE WILL NOT BE USED WITH EMULSIFIED ASPHALTS.

   a. Preheat the emulsified asphalt to 38 ± 1°C (100 ± 2°F). Mix the asphalt thoroughly.

   b. Make up 3 aggregate samples by placing 100 ± 1 g of the aggregate into individual containers.

   c. Preheat aggregate specimens to the emulsified asphalt preheat temperature listed in Step 1.c (2).

   d. Add 8.0 ± 0.5 g of each emulsion to the 100 g samples of aggregate and mix until the stones are uniformly coated.

   e. The emulsion-coated aggregate shall be cured at 132º ± 3ºC (270 ± 5°F) for a minimum of 18 hours but no more than 24 hours.

   f. Follow Steps 1.h thru 1.j.

5. Observations

1. Without disturbing or agitating the coated aggregate, remove any film floating on the water surface.

2. By observation through the water from above, estimate to the nearest 10 percent of the total visible surface area the aggregate coated with bitumen. Any thin brownish translucent areas are to be considered fully coated.

3. Average the results if more than one specimen was prepared for each additive content.

6. Report

Report the results on Department forms. The results will include the following:

- The visible bitumen/emulsion-covered area estimated to the nearest 10 percent for each additive content tested.
- The lowest percentage of additive required to obtain a 70 percent bitumen coating on the aggregate.
- Type and grade of bitumen/emulsion used.
- Brand of anti-stripping agent use.
1. **Scope**

This method describes the Marshall Mix Design procedure for determining the optimum asphalt content, stability, flow and void properties of hot bituminous mixtures containing; aggregates with maximum sizes of (1") or less, Recycled Asphalt Pavements (RAP), mixes utilizing rubber, and Warm Mix Asphalt (WMA). As recommended by AASHTO R 12, this method is adapted from the Asphalt Institute "Mix Design Methods for Asphalt Concrete and Other Hot Mix Types", Manual Series No. 2 (MS-2). It also includes information and procedures from AASHTO T 245 and AASHTO R 30.

- Ovens and hot plates thermostatically controlled to maintain the various required temperatures within ± 3°C (5°F).
- Temperature measuring devices:
  - For asphalt cement and mixes: having a range of 10-200°C (50-400°F) and sensitive to 3°C (5°F).
  - For the water bath: readable and sensitive to ± 0.2°C (0.5°F) at 60°C (140°F).
- Balance or scale: Capacity sufficient for the principal sample mass, readable to 0.1 percent or 0.1 g of the total sample mass and meeting the requirements of AASHTO M 231.
- Sieve shaker meeting the requirements of WAQTC FOP for AASHTO T 27/T 11.
- Mechanical mixer with a wire whip mixing blade capable of producing a well coated, homogeneous mixture and mixing bowls. Means of maintaining the mixture at mixing temperature, such as a heat lamp mounted below the mixer.
  
  Note 1: The Hobart Kitchen Aid Model K-5A with wire whip Model K5A-WW has been found satisfactory.
- The mold assemblies, compaction pedestal, mold holder, extruder, breaking head and flow meter or stress-strain recorder shall conform to AASHTO T 245.
- If rubber is being used in the mix, weights of at least 5 lbs in mass and slightly smaller than 4-inches in diameter will be required. The weights should be of such diameter to loosely fit inside the 4-inch Marshall molds.
- Mechanical compaction device conforming to AASHTO T 245. The device shall be equipped with a counter that will automatically shut off the machine at the required number of blows. The device will be calibrated annually in accordance with ASTM D 2168.
- Paper discs of heavy weight non-absorbent paper stock, 100 mm (4") diameter.
  
  Note 2: The Humboldt H-1341P paper disc has been found satisfactory.
- The water bath shall be at least 150 mm (6") deep and shall be thermostatically controlled so as to maintain a temperature of 60 ± 1°C (140 ± 1.8°F). The bath shall be equipped with an agitator to keep the water in constant circulation. It shall have a perforated false bottom or shelf for supporting the specimens a minimum of 2" (50 mm) above the bottom of the bath. The bath shall have a flat surface area large enough to allow the specimens to set singly with water flowing freely around each specimen. Stacking specimens is prohibited.
- Loading jack consisting of either a motor-driven screw jack, a hydraulic jack or other mechanical loading devices.
device which shall produce a uniform loading head movement rate of 50 mm (2") per minute, independent of the load being applied. The loading frame shall have a minimum load capacity of 25 KN (5000 lb).

- Load measuring device of 25 KN (5000 lb) minimum capacity, sensitive to 50 N (10 lb) or less, and capable of measuring displacement to 0.0025 mm (0.0001"). This device may be a load-cell or a ring dynamometer assembly.

- Flowmeter—the flowmeter shall consist of a guide sleeve and a gage. The activation pin of the gage 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 gage 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") divisions.

- Data measuring/recording/display devices capable of the capacity and sensitivity of the load-measuring device and or flowmeter.

- Miscellaneous equipment including scale or caliper readable to 0.25 mm (0.01"), sample containers (metal pans, bowls or beakers), spatulas, spoons, marking crayons, heat resistant gloves, straight-edge, etc.

- Bituminous Mix Design Worksheet, Bituminous Mix Design Report, and 0.45 Gradation Chart paper.

2. Synopsis

Aggregate properties important to bituminous mixes shall be determined as required. For Hot Mix Asphalt (HMA) mixes this will include: gradation of each submitted aggregate and, after combining according to the proposed Job Mix Formula (JMF), the plasticity index, fracture, flat & elongated, and bulk specific gravity of the coarse & fine aggregate. For Stone Mastic Asphalt (SMA) mixes, in addition to the tests listed for HMA mixes, the unit mass of the combined coarse aggregate and the apparent specific gravity of the mineral filler will be required.

A minimum of four (4) sets of three (3) specimens each, shall be prepared, mixed and compacted at different asphalt contents. These asphalt contents shall be by mass of total mix and will be at 0.5 percent increments. These specimens will be tested for Unit Mass, Marshall Stability & Flow, Percent Air Voids in Total Mix (VTM), Percent Voids in Mineral Aggregate (VMA), Percent Voids Filled with Asphalt (VF), and (for SMA mixes) Voids in Coarse Aggregate (VCA). The final results will define the VTM over that parameters specification range and should define the maximum values of the Stability and Unit Mass of the mix and the minimum value for VMA.

Three (3) specimens shall be prepared, mixed and tested to determine the maximum specific gravity in accordance with WAQTC FOP for AASHTO T 209.

Calibration specimens will be prepared as required by the Acceptance testing program for the project. The calibrations may include any of the following:

- JMF Calibration Points for the Nuclear Asphalt Content Gauge for ATM 405.
- Ignition Furnace Calibration Points for each Ignition Furnace System for WAQTC FOP for AASHTO T 308.

When RAP is incorporated in the mix design, an extraction device as described in AASHTO T 164 is required to determine the asphalt content and the aggregate properties of the RAP proposed for use in the mix. The contractor will submit asphalt content and gradations from 10 representative samples collected from the proposed RAP source. The contractor will submit 3 representative samples to be tested for verification of the contractors asphalt content and gradation properties for the stockpile.

The Theoretical Maximum Specific Gravity will be determined on a representative portion of the RAP, in
accordance with AASHTO T 209. The effective specific gravity will be used as RAP aggregate bulk specific gravity, for mix designs that incorporate more than 15% RAP in the mix. With mixes containing 15% or less RAP use the virgin aggregate specific gravities.

3. Determination of Asphalt Cement Properties

If not provided by the supplier, determine the following:

4.1 Verify compliance of the asphalt cement plus additives to specifications; in addition, determine the specific gravity at 25°C (77°F) of the asphalt cement in accordance with AASHTO T 228/ASTM D 70.

4.2. Establish the temperature-viscosity properties of the cement in accordance with ASTM D 2493 with the viscosities determined in accordance with the following as required by the project specifications:

AASHTO T 201 & T 202
ASTM D 2170 & D 2171 Or AASHTO T 315 & T 316

4.3 Select the mixing and compaction temperatures using the temperature-viscosity data. Determine, unless otherwise specified, the mixing temperature at 170 ± 20 centistokes and the compaction temperature at 280 ± 30 centistokes.

Note 3: Modified asphalts may not adhere to the equiviscosity requirements noted; the manufacturer's recommendations should be requested and used to determine mixing and compaction temperatures. Practically the mixing temperature should not exceed 165°C (330°F) and the compaction temperature should not be lower than 115°C (240°F).

4. Determination of Rubber Properties

5.1 Perform a gradation of the rubber product in accordance with WAQTC FOP for AASHTO T 27/T 11. Washing is not required.

5.2 Obtain the specific gravity of the rubber from the manufacturer.

5. Preparation of Aggregate

The aggregates used for the mix design will represent the aggregates in the contractor's stockpiles. The laboratory will use the aggregate as presented by the contractor and prepare the aggregate in the same manner as it will be handled during production. In no event will the aggregate be washed in the preparation of any test specimens other than the dust correction procedure.

RAP shall be considered an aggregate for the purposes of batching material. The oil content of RAP will be considered asphalt cement. Virgin aggregate and cement will be adjusted accordingly. Dry RAP at temperatures less then 60°C prior to use. RAP will be added to the aggregate at time of batching.

6.1 Mix the aggregates from the individual stockpiles at the blend ratio specified by the contractor.

   Separate the combined aggregates by dry sieving into individual specification sieve sizes including the minus 75 µm (No. 200) material. As the material is being dry sieved, separation will not be as efficient as when using washed samples. Therefore sieving time must be increased to separate as efficiently as possible. Sieving times should be increased to 15 minutes for coarse aggregate separation and 15-20 minutes for fine aggregate. The increased sieving time may be determined in accordance with WAQTC FOP for AASHTO T 27/T 11 (See Note 5).

   Separate sufficient aggregate to perform all required tests (i.e. Marshall Stability, Calibration Points for Nuclear Content Gauge, Ignition Furnace, and aggregate properties as required).

6.2 Using the contractor proposed gradation calculate the initial cumulative masses for each specification sieve
size by the following:

\[ X = \frac{(100 - P_N)}{100} \times E_i \]

where:

- \( X \) = Cumulative aggregate batch masses for sieve size \( N \), record to the nearest 1 g,
- \( P_N \) = Percent passing from proposed gradation for sieve size \( N \), and
- \( E_i \) = Initial total aggregate mass for a Marshall specimen.

Note 4: The initial aggregate mass may be chosen based on experience or a mass such as 1200 g may be assumed at this point. If a mass is assumed, a trial specimen to determine if height adjustment in accordance with the methodology of Preparation of Test Specimens, Step 1 a thru c will be required.

6.3 Aggregate Batching Correction:

As the JMF gradation was determined in accordance with WAQTC FOP for AASHTO T 27/T 11, which washed the sample in some manner, and the material for the mix design has been separated by dry sieving which will not completely separate the aggregate, a correction must be made to the material separated for the mix design to ensure that the proper amount of aggregate but especially the minus 75 µm (No. 200) material is included in the test specimens. If this is not done, batching material in accordance with the methodology outlined in this method will result in the mix design having a higher percentage of aggregate, fine sand and/or silt than the contractor's JMF proposes.

a. Prepare a wash gradation sample.
   Calculate the initial batch masses for the wash gradation.

b. Perform a wash gradation in accordance with WAQTC FOP for AASHTO T 27/T 11.

c. Compute the adjusted cumulative batch masses for each of the sieve sizes by the following formula:

\[ Z_{Ni} = \frac{X^2}{Y} \]

where:

- \( Z_{Ni} \) = corrected cumulative batch mass for sieve size \( N \),
- \( X \) = pre-wash cumulative batch mass for sieve size \( N \),
- \( Y \) = post-wash cumulative batch mass for sieve size \( N \).

Note 5: In some cases, the adjusted cumulative batch masses will result in decreasing batch masses instead of increasing batch masses. This indicates that the dry sieving operation did not efficiently separate the fine aggregate, leaving too much 75 µm (No. 200) and minus 75 µm (No. 200) material in the larger aggregate sizes. If this occurs, resieve the sizes showing the decreasing batch masses, combining the separated material with the material already separated and perform Step 6.3 a thru c again.

d. Tabulate the overall adjusted cumulative batch.

6.4 Prepare samples from the separated aggregate for the determination of the:

- Plastic Index in accordance with WAQTC FOP for AASHTO T 90,
- Percentage of Fracture in Coarse Aggregate in accordance with WAQTC FOP for AASHTO T 335,
- Unit weight of fine and coarse aggregate in accordance with T 84 and WAQTC FOP for AASHTO T 85 respectively,
- Flat and elongated Particles in accordance with ATM 306, if required, and
- Sand Equivalent in accordance with WAQTC FOP for AASHTO T 176, if required.
6. Estimate Projected Optimum Asphalt and Rubber Content

7.1 Estimate the projected optimum asphalt content. This value can be based on any or all of these sources:

a. Experience. This is the most important method of estimating projected optimum asphalt content. The projected optimum asphalt content will be estimated to the nearest 0.5 percent with four (4) sets of three (3) specimens prepared to bracket the projected optimum at 0.5 percent intervals.

The following methods may be used where no experience exists for the proposed material and/or JMF target values.

b. Computational formula:

\[ P = 0.035a + 0.045b + Kc + F \]

where:

- \( P \) = projected optimum asphalt content of mix, percent by mass of mix,
- \( a \) = percent retained on the 2.36 mm (No. 8) sieve, expressed as a whole number
- \( b \) = percent passing the 2.36 mm (No. 8) sieve minus the percent passing on the 75 µm (No. 200) sieve, expressed as a whole number
- \( c \) = percent passing the 75 µm (No. 200) sieve, expressed to the 0.1 percent
- \( K \) = 0.15 for 11 to 15 percent passing the 75 µm (No. 200) sieve, or 0.18 for 6 to 10 percent passing the 75 µm (No. 200) sieve, or 0.20 for 5 percent or less passing the 75 µm (No. 200) sieve, and
- \( F \) = asphalt absorption. In the absence of other data, use 0.7 percent.

The projected optimum asphalt content will be rounded to the nearest 0.5 percent with specimens prepared as indicated under step 1.a.

c. Dust-Asphalt Ratio: Since the Dust-Asphalt Ratio specification is typically 0.6 to 1.2, using the larger of the D/A limits will give the projected minimum effective asphalt content for the JMF p200 target. Solving the Dust-Asphalt ratio formula for the projected minimum asphalt content percent (effective asphalt content plus absorbed asphalt):

\[ \text{Max. D/A} = \left( \frac{p200}{P} \right) \]

for \( P \) results in \( P = \left( \frac{p200}{\text{Max. D/A}} \right) \)

where:

- \( P \) = projected minimum effective asphalt content of mix, percent by mass of mix,
- \( p200 \) = percent passing the 75 µm (No. 200) sieve, and
- Max. D/A = dust-to-asphalt ratio.

The total projected asphalt content may be estimated by:

\[ P_m = P + F \]

where:

- \( P_m \) = projected minimum asphalt content, percent
- \( P \) = projected minimum effective asphalt content of mix, percent
- \( F \) = asphalt absorption, percent. In the absence of other data use 0.7 percent.

d. Percent rubber will be determined by the Regional Materials Engineer. Rubber will be calculated as a percent of aggregate.
This projected minimum asphalt content will be rounded to the nearest 0.5 percent with specimens prepared for at this projected minimum value and at least three (3) more above this value at 0.5 percent intervals.

7. Preparation of Test Specimens

8.1 Marshall Stability and Flow: Batch a minimum of four (4) sets of three (3) aggregate specimens each. However, if the initial total aggregate mass for the Marshall specimen was estimated without prior experience, a single Marshall specimen will be batched, mixed at the projected optimum asphalt content, compacted and the thickness of the compacted specimen measured to determine if the aggregate mass must be adjusted. If rubber is used in the mix it will be added at this time.

a. Thickness Adjustment

1) The height of the compacted specimen must be within the specimen thickness limitations of 62-65 mm (2.45-2.55"). If it is not, adjust the total mass of the aggregate as shown below and recalculate the individual sieve masses to bring the specimens within this range.

2) Prepare an aggregate batch to the masses calculated above and calculate the mass of asphalt required for the estimated optimum asphalt content as shown below. Mix and compact the trial specimen in accordance with the requirements of sections 9 and 11.

3) If thickness adjustment is necessary, adjust $E_i$, the initial total aggregate mass, by the following:

$$E_a = \frac{2.5 \times E_i}{H} \quad \text{(USC)} \quad \text{or} \quad \frac{63.5 \times E_i}{H} \quad \text{(SI)}$$

where:
- $E_a$ = adjusted total aggregate mass,
- $E_i$ = initial total aggregate mass, and
- $H$ = specimen thickness 0.1 mm (0.01") actually obtained.

4) If necessary, adjust each $Z_{Ni}$ from Step 6.3c by:

$$Z_{Na} = \frac{E_a}{E_i} \times Z_{Ni}$$

where:
- $Z_{Na}$ = adjusted cumulative batch mass for sieve size N,
- $E_a$ = adjusted total aggregate mass,
- $E_i$ = initial total aggregate mass,
- $Z_{Ni}$ = corrected cumulative batch mass for sieve size N.

5) Using either the corrected cumulative sieve masses ($Z_{Na}$) determined in Preparation of Aggregate, Step 6.4c or the adjusted cumulative sieve masses ($Z_{Na}$) determined in Step 1a, above, prepare three (3) aggregate specimens for each asphalt content. The aggregate for each specimen will be batched and placed in a container and dry-mixed thoroughly.

b. Calculate the mass of the asphalt cement for each set of specimens by:

$$AW = \frac{E_i (or E_a) \times P_{bN}}{100 - P_{bN}}$$

where:
- $AW$ = mass of asphalt cement, to the nearest 0.1 g,
- $E_i$ (or $E_a$) = initial (or adjusted, see below) aggregate mass, and
- $P_{bN}$ = asphalt content for set N, to the nearest 0.1 percent.
8.2 Maximum Specific Gravity of Mixture.

a. For each sieve size, calculate the cumulative masses for a maximum specific gravity (Rice) test specimen by the following formula:

\[ R_N = \frac{Q}{E_i} \times Z_{Ni} \]

where:
- \( R_N \) = cumulative batch mass for the maximum specific gravity specimen for sieve size N,
- \( E_i \) = initial total aggregate mass,
- \( Z_{Ni} \) = corrected cumulative batch mass for sieve size N, and
- \( Q \) = minimum sample mass required by WAQTC FOP for AASHTO T 209.

b. Prepare three (3) test specimens to these masses for performance of WAQTC FOP for AASHTO T 209.

8.3 Coarse Aggregate Properties.

a. For each coarse aggregate sieve size, calculate the cumulative masses for the required test specimens of coarse aggregate for the required test procedures by the following formula:

\[ C_N = \frac{Q}{No. \ 4 \ Z_N} \times Z_{Ni} \]

where:
- \( C_N \) = cumulative batch mass for the maximum specific gravity specimen for sieve size N, for the 4.75 mm (No. 4) and larger sieves only,
- \( Q \) = minimum sample mass required for the required tests,
- \( No. \ 4 \ Z_N \) = initial total aggregate mass of 4.75 mm (No. 4), and
- \( Z_{Ni} \) = adjusted cumulative batch mass for sieve size N.

b. Prepare the required number of test specimens to the minimum sample size required by the test procedure for the performance of the following or other specified tests as required:

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<tr>
<th>Test Procedure</th>
<th>Designation</th>
<th>Title</th>
<th>Number of Specimens</th>
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<tr>
<td>WAQTC FOP for AASHTO T 335</td>
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<td>Fracture</td>
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<td>ATM 306</td>
<td>Flat-Elongated</td>
<td>1</td>
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<tr>
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<td>AASHTO T 19 (SMA only)</td>
<td>Bulk Density</td>
<td>3</td>
</tr>
</tbody>
</table>

8.4 Fine Aggregate Properties.

a. For each fine aggregate sieve size, calculate the cumulative masses for the specific fine aggregate property test by the following formula:

\[ F_N = \left( \frac{Q}{E_i - Z_{4i}} \right) \times \left( Z_{Ni} - Z_{4i} \right) \]

where:
- \( F_N \) = cumulative batch mass for the fine aggregate specific gravity specimen for sieve size N, for the minus 4.75 mm (No. 4) sieves only,
- \( Q \) = sample mass required for the specified test,
\[ E_i = \text{initial total aggregate mass}, \]
\[ Z_{N_i} = \text{initial cumulative batch mass for sieve size } N, \text{ and} \]
\[ Z_{4i} = \text{initial cumulative batch mass for the 4.75 mm (No. 4) sieve}. \]

b. Prepare the required number of test specimens to the minimum sample size required by the test procedure for the performance of the following or other specified tests as required:

<table>
<thead>
<tr>
<th>Test Procedure</th>
<th>Designation</th>
<th>Title</th>
<th>Number of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAQTC FOP for AASHTO T 90</td>
<td>Plastic Index</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>AASHTO T 84</td>
<td>Specific Gravity</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>WAQTC FOP for AASHTO T 176</td>
<td>Sand Equivalent</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

8.5 Mineral Filler Specific Gravity.
If the JMF p200 is greater than 6 percent, the minus 75 µm (No. 200) material will be treated as mineral filler and the apparent specific gravity of this material will be determined in accordance with AASHTO T 100.

8. Preparation of Asphalt Cement
Heat a minimum of 1 L (1 qt) of asphalt cement to the mid-point of the mixing temperature range.
It is best to use the asphalt cement as soon as it reaches mixing temperature. If this is not possible, maintain the asphalt cement at this temperature in a covered container rather than reheat it.

9. Preparation of Mixtures and Mixture Conditioning

10.1 Place the aggregate specimens for Marshall Stability & Flow and Maximum Specific Gravity in the oven and heat to the mid-point of the asphalt cement mixing temperature range.

10.2 "Butter" the mixing bowl with asphalt cement and fine aggregate mixture that will coat the mixing area of the bowl. Remove any excess material.

10.3 Place the heated specimen into the mixing bowl.

10.4 Form a crater in the dry blended aggregate large enough to hold the asphalt cement, place the mixing bowl on the scale and weigh into the aggregate crater, to the nearest 0.1 g, the required amount of pre-heated asphalt cement.

10.5 Mechanically mix the aggregate and asphalt cement rapidly until thoroughly coating the aggregate and return to the oven.

10.6 After mixing, spread the mixture in a pan to an even thickness of 25-50 mm (1-2 inches). Place the mixture and pan in a forced-draft oven at the midpoint of the compaction temperature range for 120 ± 5 minutes. Stir the mixture after 60 ± 5 minutes to maintain uniform conditioning. Highly absorptive aggregates may require a longer conditioning time.

10. Equipment Preparation

11.1 Thoroughly clean the mold assemblies (molds, bases and collars) and heat in an oven to the mid-point of the asphalt cements compaction temperature range.

11.2 Thoroughly clean the face of the compaction hammer and heat on a hot plate to a temperature within the asphalt cements compaction temperature range.
11. Compaction of Specimens

12.1 Place the pre-heated mold assembly into the mold holder on the compaction pedestal. Place a paper disc, or acetate disc if rubber is used in mix, in the bottom of the mold.

12.2 Stir the specimen thoroughly and place in the mold. Spade the mixture vigorously with a heated spatula 15 times around the perimeter and 10 times over the interior, remove the collar and smooth the surface of the mix to a slightly rounded shape.

12.3 Place a paper disc, or acetate disc if rubber is used in mix, on top of the specimen, position the compaction hammer, and apply the required number of blows with the compaction hammer.

12.4 Remove the base plate and collar, invert and re-assemble the mold, and apply the same number of blows to the face of the inverted specimen.

12.5 Remove the collar, base plate and paper discs, mark each biscuit for individual identification, and allow them to cool until the specimen can be extruded without damage or distortion.

    If rubber is used in the mix, do not remove the base plate or acetate discs. Place a minimum 5lb mass on top of specimen and let stand 24 hours. After 24 hours remove weight.

12.6 Extrude the specimen from the mold; transfer to a smooth, flat surface; allow it to stand and cool to room temperature. Acetate discs can be removed at this point. Specimens can be placed on a hot plate for a few seconds to facilitate removal.

12. Mix Sample Test Procedures

13.1 Measure and record the thickness of each compacted specimen and record to the nearest 0.25 mm (0.01”). Use either a device that will measure the average height or measure the height with a caliper at three (3) locations spaced evenly around the circumference of the specimen and average these results.

13.2 Determine the bulk specific gravity of each compacted specimen in accordance with WAQTC FOP for AASHTO T 166/T 275.

13.3 Stability and Flow.

    a. Bring the specimens to the specified temperature of 60 ± 1°C (140 ± 1.8°F) by immersing in the water bath for 30 to 40 minutes. Stacking specimens on top of each other is prohibited.

    b. Thoroughly clean and lubricate the guide rods, and clean the inside surfaces of the breaking heads before performing the stability and flow tests. Maintain the breaking head at a temperature of 21 to 38°C (70 to 100 °F).

    c. Remove the specimens one at a time from the water bath and place in the lower segment of the breaking head.

    d. Place the upper segment of the breaking head on the specimen, firmly seat the head on the specimen, and place the complete assembly in position on the loading jack.

    The elapsed time for the test from the removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 seconds.

    e. For machines using proving ring & flow meter:

        1) Place the flow meter over one of the guide rods and adjust the flow meter to zero; hold the sleeve firmly against the upper segment of the breaking head while the test load is applied.

        2) When the load to the specimen at a constant rate of 50.8 mm (2”) per minute until the maximum load is reached. The maximum load is indicated when the proving ring dial value decreases.

        3) Simultaneously read the proving ring dial to the nearest 0.0025 mm (0.0001”) and the flow meter to
the nearest 0.25 mm (0.01"). Record the readings as whole numbers (no decimal points) from the proving ring dial flow meter.

f. For machines using load cell and chart recorder/display:
   1) Turn on the recorder, adjust the pen to the zero position according to the manufacture's instructions, turn the range selector to the appropriate range (use the smallest range possible) and set the chart speed at 10” per minute (250 mm per minute).
   2) Apply the load to the specimen by means of the constant rate movement of the loading jack at 50 mm per minute (2” per minute) until the maximum is reached and the load, as indicated by the chart recorder, decreases.

4. Maximum Specific Gravity.
Determine the maximum specific gravity of the prepared specimens at or near the optimum asphalt content in accordance with WAQTC FOP for AASHTO T 209 as follows:

a. Choose a projected optimum asphalt content as described in Estimate Projected Optimum Asphalt Content.

b. Mix and condition the specimens in accordance with the provisions of Preparation of Mixtures and Mixture Conditioning.

c. Determine the maximum specific gravity in accordance with WAQTC FOP for AASHTO T 209 on the prepared specimens at the projected optimum asphalt content.

d. If the projected optimum asphalt content differs from the final optimum asphalt content, determined below in Determination of Optimum Asphalt Content, Selection of Final Optimum Asphalt Content, by 1 percent or more, prepare and determine a new maximum specific gravity at the final optimum asphalt content and recalculate the maximum specific gravities at the other asphalt contents, the voids total mix and the optimum asphalt content.

13. Calculations

14.1 Calculate the bulk specific gravity of each compacted specimen in accordance with WAQTC FOP for AASHTO T 166/T 275. Average the bulk specific gravities (Gmb) of all compacted specimens for each asphalt cement content.

Record the result to the nearest 0.001.

14.2 Calculate the unit weight for each asphalt content by:

\[ W_N = G_{mbN} \times 997.1 \text{ kg/m}^3 (62.245 \text{ lb/ft}^3) \]

where:

\[ W_N = \text{unit weight of set N}, \]

\[ G_{mbN} = \text{average bulk specific gravity of set N, and} \]

997.1 kg/m\(^3\) (62.245 lb/ft\(^3\)) = density of water at 25°C (77°F).

Record the result to the nearest 1 kg/m\(^3\) (0.1 lb/ft\(^3\)).

14.3 Calculate the maximum specific gravity of the mix at the selected asphalt content in accordance with WAQTC FOP for AASHTO T 209. Average the results and record the average to the nearest 0.001.

14.4 Calculate the maximum specific gravity for each asphalt content as follows:

a. Calculate the effective specific gravity of the aggregate by:
\[ G_{se} = \frac{100 - P_b}{100 - \frac{P_b}{G_{mm} - G_b}} \]

where:
- \(G_{se}\) = effective specific gravity of the aggregate,
- \(P_b\) = asphalt content at which \(G_{mm}\) was determined,
- \(G_{mm}\) = maximum specific gravity at \(P_b\),
- \(G_b\) = specific gravity of the asphalt at 25 °C (77°F).

Record the result to the nearest 0.001.

b. Calculate the maximum specific gravity for each asphalt content by:

\[ G_{mm} = \frac{100}{100 - \frac{P_{bN}}{G_{se}} + \frac{P_{bN}}{G_b}} \]

where:
- \(G_{mm}\) = maximum specific gravity for asphalt content \(P_{bN}\),
- \(G_{se}\) = effective specific gravity of the aggregate,
- \(P_{bN}\) = percent asphalt for set \(N\), and
- \(G_b\) = specific gravity of the asphalt at 25 °C (77°F).

Record the result to the nearest 0.001.

14.5 Calculate the percent air voids in total mix (VTM) for each asphalt content by:

\[ VTM = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100 \]

where:
- \(VTM\) = percent voids total mix,
- \(G_{mb}\) = average specific gravity of each content, and
- \(G_{mm}\) = maximum specific gravity of each content.

Record the result to the nearest 0.1 percent.

14.6 Calculate the percent voids in mineral aggregate (VMA) for each asphalt content by:

a. Calculate the blended aggregate bulk specific gravity by:

\[ G_{sb} = \frac{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots + \frac{P_N}{G_N}}{P_1 + P_2 + \ldots + P_N} \]

where:
- \(G_{sb}\) = blended aggregate bulk specific gravity,
- \(P_1, P_2, \ldots, P_N\) = percent of individual aggregate,
- \(G_1, G_2, \ldots, G_N\) = bulk specific gravity individual aggregate.

Record the result to the nearest 0.001.
b. Calculate the percent voids in mineral aggregate for each asphalt content by:

\[ VMA = 100 - \frac{G_{mb} (100 - P_b)}{G_{sb}} \]

where:
- \( VMA \) = percent voids in mineral aggregate for each content,
- \( G_{sb} \) = blended aggregate bulk specific gravity,
- \( G_{mb} \) = average bulk specific gravity for each content, and
- \( P_b \) = percent asphalt of each content.

Record the result to the nearest 0.1 percent.

14.7 Calculate the percent voids filled with asphalt (VFA) for each asphalt content by:

\[ VFA = 100 \times \frac{VMA - VTM}{VMA} \]

where:
- \( VFA \) = percent voids filled with asphalt for each content,
- \( VMA \) = percent voids in mineral aggregate for each content, and
- \( VTM \) = percent voids total mix for each content.

Record the result to the nearest whole percent.

14.8 Calculate the dust/asphalt ratio for each asphalt content by:

a. Calculate the asphalt absorption by:

\[ P_{ba} = 100 \left( \frac{G_{se} - G_{sb}}{G_{sb} \times G_{se}} \right) G_b \]

where:
- \( P_{ba} \) = absorbed asphalt, percent by mass of aggregate,
- \( G_{se} \) = effective specific gravity of aggregate,
- \( G_{sb} \) = bulk specific gravity of aggregate, and
- \( G_b \) = gravity of asphalt.

b. Calculate the effective asphalt content for each asphalt content by:

\[ P_{be} = P_b - \left( \frac{P_{ba}}{100} \times (100 - P_b) \right) \]

where:
- \( P_{be} \) = effective asphalt content, percent by total mass of mix,
- \( P_b \) = asphalt content, percent by total mass of mix, and
- \( P_{ba} \) = absorbed asphalt, percent by mass of aggregate.

c. Calculate the dust/asphalt ratio by:

\[ D/A = \frac{p200}{P_{be}} \]

where:
- \( D/A \) = dust/asphalt ratio,
- \( p200 \) = percent passing the 75 µm (No. 200) sieve, and
- \( P_{be} \) = effective asphalt content, percent by total mass of mix.
14.9 Stability:

a. For machines using proving ring and flow meter, calculate the uncorrected stability from the dial readings by the following:

\[ S = (D \times m) + C \]

where:
- \( S \) = uncorrected stability load, in pounds,
- \( D \) = dial reading as a whole number
- \( m \) = slope from proving ring calibration, and
- \( C \) = constant from proving ring calibration.

Record the result to the nearest whole pound.

b. For machines using load cell and chart recorder/display, read and record the uncorrected stability to the accuracy allowed by the chart scale.

c. Stability values for each specimen that differ from the standard 63.5 mm (2.5") thickness will be corrected to the equivalent 63.5 mm (2.5") value by the following:

\[ CS = S \times t \]

where:
- \( CS \) = corrected stability,
- \( S \) = uncorrected stability, and
- \( t \) = thickness correction factor = \(-0.64x + 2.6\) for \( x \) in inches or \(-0.025x + 2.5875\) for \( x \) in mm.

(Equations derived from data presented in Table 2 of AASHTO T 245 for thicknesses from 2.4375" to 2.5625" (61.9 mm to 65.1 mm).

<table>
<thead>
<tr>
<th>Inches</th>
<th>mm</th>
<th>t-Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.45</td>
<td>62.2</td>
<td>1.03</td>
</tr>
<tr>
<td>2.46</td>
<td>62.5</td>
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</tr>
<tr>
<td>2.47</td>
<td>62.7</td>
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<td><strong>2.50</strong></td>
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</tr>
<tr>
<td>2.55</td>
<td>64.8</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Table based on data from AASHTO T 245 Table 2

d. Corrected stability values for each asphalt content averaged and recorded to the nearest 50 N (10 lb).

Flow:

a. For machines using the proving ring and flow meter, average the flow values for each asphalt content and record as a whole number (e.g. flow reading of 0.12 will be recorded as 12).
b. For machines using load cell and chart recorder:
   
   1) Extend the constant rate slope line to intersect the horizontal axis.
   
   2) Determine the maximum load point and draw a line perpendicular to the horizontal axis through this point to intersect the horizontal axis.
   
   3) From the point determined in (1) to the point determined in (2), read and record the flow as a whole number in 0.01" increments.
   
   4) Average the flow values for each asphalt content set and record to the nearest whole number.

14. **Determination of Optimum Asphalt Content**

For a mix to satisfy a specific project specifications graphical presentation of the results should be prepared prior to the selection of the optimum asphalt content.

**Graphical Presentation:**

Prepare a graphical plot of Asphalt Content vs. Unit Weight, Stability, Flow, Percent Voids Total Mix, Percent Voids in Mineral Aggregate, and Percent Voids Filled with a smooth curve that represents a best-fit for all values.

15.1 Determination of Optimum Asphalt Content:

a. **Determination of Preliminary Optimum Asphalt Content:** Choose the preliminary optimum asphalt content at the median of the Voids in Total Mix specification. All of the calculated and measured mix properties should then be evaluated by comparing them to the project mix design specifications. If all of the specifications are met, then this is the preliminary optimum asphalt content. If all of the specifications are not met, then some adjustment or compromise is necessary or the mix may need to be redesigned. Even if all of the specifications are met, a number of considerations should be evaluated before choosing the final optimum asphalt content.

b. **Selection of Final Mix Optimum Asphalt Content:** The final optimum asphalt content should be a compromise selected to balance all of the mix properties. Normally, the mix design specifications will produce a narrow range of acceptable asphalt contents that will pass all specifications. The asphalt content selection can be adjusted within this narrow range to achieve establishing the final optimum asphalt content. Establishing final optimum asphalt content is covered in detail in Asphalt Institute Manual MS-2, 6th Edition, Mix Design Methods, Chapter 5, Marshall Mix Design Method, Section D-5.15, Selection of Final Mix Design, pages 69 thru 77.

If this evaluation reveals no asphalt content which meets all project specifications or such a narrow range of asphalt contents meeting all project specifications as to be unfeasible and/or uneconomical to produce, the Materials Engineer may reject the proposed job mix design and require a new proposed job mix formula from the contractor.

15. **Report**

The report shall include the following:

- Project identification, Source/Supplier of mix and name of the general contractor.
- Aggregate quality identification(s), target gradation, blend ratio of individual stockpiles, blended bulk specific and effective specific gravities. Other properties that may be specified in the Contract such as: fineness modulus of the blended fine aggregate; percent fracture; percent flat and elongated; and the plasticity index of the blended fine aggregate.
- Asphalt cement quality identification, specific gravity at 77°F, and the maximum mixing temperature.
• Anti-strip additive brand/type and the minimum percent required.
• Asphalt content at the median of the percent voids in total mix specification and the approved optimum asphalt content.
• The following properties at the optimum asphalt content: maximum specific gravity, percent voids in total mix, percent voids in mineral aggregate, percent voids filled, stability, flow, unit mass and the dust-asphalt ratio.
• Graphical representation on a 0.45 power graph of the target gradation with the Lower Specification Limit (LSL)-Upper Specification Limit (USL).
• Graphical representation of asphalt content versus the following properties: unit weight, stability, flow, percent voids in total mix, percent voids in mineral aggregate and voids filled.
• Identification and address of the laboratory that performed the mix design, that laboratories mix design identification number and the signature/title of the professional engineer who reviewed and approved/disapproved the mix design.
Appendix ATM 417

1. Example Calculations

(See Example Worksheets.)

See Section 8 of the standard for definitions of the variables.

Contractor Proposed JMF for a Type IIA HMA Mix Design

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Job Mix Formula</th>
<th>PreWash Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;, 100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1/2&quot;, 89</td>
<td>129</td>
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</tbody>
</table>

2. Preparation of Aggregate

2.1 Initial total aggregate mass: \( E_i = 1175.0 \) g

Calculate cumulative aggregate batch mass by:

\[
x = \frac{100 - \text{Percent Passing}}{100} \times E_i
\]

for No. 4 = \( \frac{100 - 52}{100} \times 1175.0 = 564 \) g

for No. 8 = \( \frac{100 - 36}{100} \times 1175.0 = 752 \) g

for No. 200 = \( \frac{100 - 5.1}{100} \times 1175.0 = 1115 \) g

Repeat for the other required sieve sizes.

2.2 Aggregate Batching Correction

a. Prepare a sample by batching a specimen with cumulative masses corresponding to cumulative aggregate batch masses calculated above, see the Pre Wash Mass column of Table 2.

b. Wash and sieve this prepared sample in accordance with WAQTC FOP for AASHTO T 27/T 11. Record the cumulative mass on the sieves in a Post Wash Column, see Table 3.

c. Calculate the adjusted cumulative batch mass for each sieve as follows, See Table 4 for other sieves:

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Alaska Test Methods Manual 417-16 Hot Mix Asphalt Design by Marshal Method
Revised 11/11/08 Effective 6/15/10
3. Estimate Projected Optimum Asphalt Content

3.1 Assuming that no experience with the current sources or contractor is available, the projected optimum and minimum asphalt content will be estimated by both the computational formula and dust/asphalt methods. Refer to Section 7 of the standard for additional information.

b. Computational Formula

\[
P = 0.035a + 0.045b + Kc + F
\]

\[
= 0.035 (100 - 36) + 0.045 (36 - 5) + (0.20 \times 5.1) + 0.7
\]

\[
= 5.4, \text{ round to 5.5%}
\]

Test specimens will be prepared and tested at 4.5 to 6.5 percent cement contents.

c. Dust/Asphalt Ratio

\[
\frac{A}{D} \text{, max} = \frac{p_{200}}{P} = \frac{4.7}{1.2} = 3.9, \text{ round to 4.0 percent}
\]

Test specimens will be prepared and tested at 4.0 to 6.0 percent cement contents.

Since the two methods give slightly different ranges, specimens should be prepared and tested at 4.0 to 6.5 percent cement contents.

4. Preparation of Test Specimens

4.1 Thickness Adjustment

The thickness of the trial specimen is 2.48 inches, thus requiring adjustment of the initial aggregate mass by:

\[
E_a = \frac{2.5 \times E_i}{H} = \frac{2.5 \times 1175}{2.48} = 1184.5 \text{ g}
\]

4.2 Adjust the final batch mass for each sieve by:

For No. 4 = \[\frac{1184.5}{1175} \times \frac{564^2}{542.4} = 591 \text{ g}\]

\[
Z_{Na} = \frac{E_a}{E_i} \times Z_{Ni}
\]

For No. 8 = \[\frac{1184.5}{1175} \times \frac{752^2}{734.7} = 776 \text{ g}\]

Repeat for the other required sieve sizes; see Table 4 for other sieves.

4.3 Calculate the mass of the asphalt cement for each set of specimens by:
Repeat for the other asphalt contents.

4.4 Calculate the cumulative masses for a maximum specific gravity (Rice) test specimen by:

\[
\text{For No. 4} = \frac{2000}{1175} \times 586.5 = 998 \text{ g}
\]

\[
R_N = \frac{Q}{E_i} \times Z_{Ni}
\]

\[
\text{For No. 8} = \frac{2000}{1175} \times 770 = 1310
\]

Repeat for the other required sieve sizes; see Table 4 for other sieves.

4.5 Coarse Aggregate Properties (such as Specific Gravity, Fracture, Flat-Elongated, Unit Weight, et al)

For each coarse aggregate sieve size, calculate the cumulative mass for the required test specimen(s) of coarse aggregate for the required test procedures by the following formula:

\[
C_N = \frac{Q}{\text{No. 4}} R_N
\]

For CA Specific Gravity for No. 4 = 3000 g

for 1/2" = \(\frac{3000}{998}\) x 221 = 664 g

Repeat for the other required sieve sizes, see Table 4 for other sieves.

For Other CA Property Tests substitute the appropriate Q.

4.6 Fine Aggregate Properties (such as Specific Gravity, Sand Equivalent, et al)

For each fine aggregate sieve size, calculate the cumulative masses for the required specimens of fine aggregate specific gravity by the following formula:

\[
F_N = \left(\frac{Q}{E_i - Z_{ii}}\right) \times (Z_{Ni} - Z_{ii})
\]

\[
\text{No. 8} = \left(\frac{1000}{1175.0 - 564}\right) \times (752.0 - 564) = 307 \text{ g}
\]

For FA Specific Gravity for

\[
\text{No. 200} = \left(\frac{1000}{1175.0 - 564}\right) \times (1115 - 564) = 924.1 \text{ g}
\]

Repeat for the other required sieve sizes, See Table 4 for other sieves.
5. Calculations

5.1 Calculate the maximum specific gravity for each asphalt content as follows:
   a. Calculate the effective specific gravity of the aggregate by:

\[
G_{se} = \frac{100 - P_b}{100} = \frac{100 - 5.0}{100 - 5.0} = 2.745
\]

\[
G_{mm} = \frac{100}{2.528 - 1.009} = 2.528
\]

b. Calculate the maximum specific gravity for each asphalt content by:

\[
G_{mm} = \frac{100}{100 - P_{bn}} + \frac{P_{bn}}{G_b}
\]

Repeat for other asphalt contents.

5.2 Calculate the percent air voids in total mix (VTM) for each asphalt content by:

\[
VTM = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100
\]

For 4.0% = \(\frac{2.568 - 2.403}{2.568}\) x 100 = 6.4

5.3 Calculate the percent voids in mineral aggregate (VMA) for each asphalt content by:
   a. Calculate the blended aggregate bulk specific gravity by:

\[
G_{sb} = \frac{100}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots + \frac{P_N}{G_N}} = \frac{100}{2.727 + 2.653} = 2.689
\]

b. Calculate the percent voids in mineral aggregate for each asphalt content by:

\[
VMA = 100 - \frac{G_{mb} (100 - P_b)}{G_{sb}}
\]

For 4.0% = 100 - \(\frac{2.403 (100 - 4.0)}{2.689}\) = 14.2

5.4 Calculate the percent voids filled (VFA) with asphalt for each asphalt content by:

\[
VFA = 100 \times \frac{VMA - VTM}{VMA}
\]

For 4.0% = 100 x \(\frac{14.2 - 6.4}{14.2}\) = 55

5.5 Calculate the dust/asphalt ratio for each asphalt content by:
   a. Calculate the asphalt absorption by:

\[
P_{ba} = 100 \left( \frac{G_{se} - G_{sb}}{G_{sb} \times G_{se}} \right) G_b
\]

For 4.0% = 100 \(\frac{2.745 - 2.689}{2.689 \times 2.745}\) 1.009 = 0.77

b. Calculate the effective asphalt content for each asphalt content by:

\[
P_{be} = P_b - \left( \frac{P_{ba}}{100} \times (100 - P_b) \right)
\]

For 4.0% = 4.0 - \(\frac{0.77}{100} \times (100 - 4.0)\) = 3.3
D/A = \frac{p^{200}}{P_{bc}} \quad \text{For } 4.0\% = \frac{4.7}{3.3} = 1.4

5.6 Stability:

c. Correct Stability values for each specimen that differs from the standard 63.5 mm (2.5") thickness by the following:

\[ CS = S \times t \]

for Set 1, Specimen 1 = 3145 \times 0.976 = 3070

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Job Mix</th>
<th>Cumulative Mass g</th>
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<td></td>
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Rutting Susceptibility using an Asphalt Pavement Analyzer ATM 419

1. Scope
This method describes a procedure for determining the rut susceptibility of hot mix asphalt using an Asphalt Pavement Analyzer (APA).

2. Apparatus
- Asphalt Pavement Analyzer (APA) – A thermostatically controlled device designed to test the rutting susceptibility of hot mix asphalt by applying repetitive linear loads to compacted test specimens through pressurized hoses.
  - The APA shall be thermostatically controlled to maintain the test temperature and conditioning chamber at any set point between 30-60 ± 1°C (85-140 ± 1°F).
  - The APA shall be capable of independently applying loads up to 450 N (100 lbf) to the three wheels. The loads shall be calibrated to the desired test load by a suitable device such as an external force transducer or proving ring.
  - The pressure in the test hoses shall be adjustable and capable of maintaining pressure up to 830 kPa (120 psi).
  - The APA shall be capable of testing six cylindrical specimens simultaneously.
  - The APA shall have a programmable master cycle counter that can be preset to the desired number of cycles for a test. The APA shall be capable to automatically stopping the test at the completion of the programmed number of cycles.
- Balance or scale: Capacity sufficient for the principle sample mass, readable to 0.1 percent or 0.1 g of the total sample mass and meeting the requirements of AASHTO M 231.
- Mixing utensils (bowls, spoon, spatula)
- Ovens and hot plates thermostatically controlled to maintain the various required temperatures within ± 3°C (5°F).
- Compaction device and molds

3. Test Specimens
Number of test specimens – A sample will consist of six 150 mm diameter x 75 mm (6 in diameter x 3 in) cylindrical specimens.

Production Mix
Samples of plant-produced mixtures shall be obtained in accordance with WAQTC FOP for AASHTO T 168. Samples shall be reduced to the appropriate test size in accordance with WAQTC FOP for AASHTO R 47 and compacted while the mixture is still hot. Reheating of loose plant mixture should be avoided.

Laboratory Prepared Mixtures
Mixture proportions will be batched in accordance to the desired Job Mix Formula. The required batch sizes are determined in accordance to ATM 417, Preparation of Aggregate and Preparation of Asphalt. The voids in total mix (VTM) target for the compacted specimens shall be 6.0 ± 1.0 percent unless otherwise directed.

The temperature to which the asphalt binder must be heated to achieve a viscosity of 170 ± 20 cSt (0.170 ± 0.020 Pa·s) or the mix design mixing temperature shall be the mixing temperature.
Prepare the mixture in accordance with ATM 417, Preparation of Mixtures and Mixture conditioning. The temperature to which the asphalt binder must be heated to achieve a viscosity of 290 ± 30 cSt (0.290 ± 0.030 Pa·s) or the mix design compaction temperature shall be the compaction temperature.

Roadway Core Specimens

Roadway core specimens shall be 150 mm (6 in) outside diameter with all surfaces of the perimeter perpendicular to the surface of the core within 5 mm (3/16 in). Cores shall be trimmed with a wet masonry saw to a height of 75 ± 3 mm (3 ± 1/8 in). Final adjustment of the core to the top of the testing molds shall be done with Plaster of Paris.

4. Compaction of Specimens

1. Superpave Gyratory Compaction

   • Apparatus (see AASHTO T 312).
   
   a. Compaction of the cylindrical specimens with the Superpave Gyratory Compactor will be performed in such a manner so that the target air void content of 6.0 ± 1.0 percent is obtained at the specified height of 75 ± 3 mm.
   
   b. Remove the mold and base plate from the oven set at the compaction temperature. Place a paper disc in the bottom of the mold assembly.
   
   c. Transfer the mixture to the mold with care to avoid segregation of the mixture.
   
   d. Place the mold and mixture in the Superpave Gyratory Compactor and begin compaction as described in the compactor’s operation manual.
   
   e. When the compaction procedure is completed, remove the mold and compacted specimen from the compactor. Extrude the specimen from the mold with care to avoid distorting the specimen until it is cooled.
   
   f. Compacted specimens should be left at room temperature (about 25°C or 77°F) and allowed to cool overnight.

5. Determining the Voids Total Mix

1. Determine the bulk specific gravity of the test specimens in accordance with WAQTC FOP for AASHTO T 166, Method A.
2. Determine the maximum specific gravity of the test mixture in accordance with WAQTC FOP for AASHTO T 209.
3. Determine the air void contents of the test specimens in accordance with AASHTO T 269.

6. Test Temperature

The test temperature shall be 105°F unless otherwise directed.

7. Initial Measurements

2. Place the rut depth measurement template over the specimen. Take initial measurements on three locations of each specimen. Record the measurement for each location to the nearest 0.01 mm.

8. Specimen Conditioning

1. Stabilize the testing chamber temperature at 105°F or as directed.
2. Place the test specimens into the testing molds and secure in the APA.
3. Push the sample holding tray in and secure. Close chamber doors.
4. Allow specimens to condition at the test temperature for 90 minutes.
5 Set PRESET COUNTER to 8000 cycles.

6 Start the testing. A complete test will take approximately 3.5 hours. At the end of the test cycle, the APA will stop.

7 Open the chamber doors, unlock and pull out the sample holding tray.

8 Remove specimens from the testing molds and take rut-depth measurements in the same manner as the Initial Measurements.

9. **Calculations**

The rut depth at each location is determined by subtracting the final measurement from the initial measurement. Determine the average rut depth for each specimen, use the average of all measurements to calculate the average rut depth.

The APA rut depth for the mixture is the average of six cylindrical specimens unless otherwise directed.

10. **Report**

The test report shall include the following information:

- The laboratory name and date of test.
- The mixture type and description.
- The average rut depth to the nearest 0.1 mm.
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