SAMPLING OF BITUMINOUS PAVING MIXTURES
FOP FOR AASHTO T 168

Scope

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

Apparatus

- Shovel
- Sample containers: such as cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers
- Scoops, trowels, or other equipment to obtain mix
- Sampling plate: Thick metal plate, minimum 8 gauge, sized to accommodate sample requirements, with a wire attached to one corner long enough to reach from the center of the paver to the outside of the farthest auger extension. Holes ¼ in. in diameter should be provided in each corner.
- Cookie cutter sampling device: Formed steel angle with two 100 mm by 150 mm by 9 mm (4 in. by 6 in. by 3/8 in.) handles, sized to accommodate sample requirements. Minimum 2 in. smaller than the sampling plate when used together.

Example: Sampling plate 380 mm (15 in.) square and a cookie cutter sampling device 330 mm (13 in.) square.

- Mechanical sampling device

Sample Size

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

General

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

- For dense graded mixture samples use cardboard boxes, stainless steel bowls or other agency-approved containers.

- For hot open graded mixture samples use stainless steel bowls. Do not put open graded mixture samples in boxes until they have cooled to the point that bituminous material will not migrate from the aggregate.

Attached Sampling Devices

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

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

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

3. Repeat until proper sample size has been obtained.

4. Transfer the HMA to an agency-approved container without loss of material.
Sampling from Haul Units

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

2. Identify one sampling location in each quadrant.

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

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

Sampling from Roadway Prior to Compaction (Plate Method)

Plate method using the “cookie cutter” sampling device.

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

- Laying HMA on grade or untreated base material requires Method 1.
- Laying HMA on existing asphalt or laying a second lift of HMA requires Method 2.

SAFETY:

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

Method 1 requires a plate to be placed in the roadway in front of the paving operation and therefore there is always concern with moving, operating equipment. It is safest to stop the paving train while a plate is installed in front of the paver. When this is not possible the following safety rules must be followed.

1. The plate placing operation must be at least 3 m (10 ft.) in front of the paver or pickup device. The technician placing the plate must have eye contact and communication with the paving machine operator. If eye contact cannot be maintained at all time, a third person must be present to provide communication between the operator and the technician.

2. No technician is to be between the asphalt supply trucks and the paving machine. The exception to this rule is if the supply truck is moving forward creating a windrow, in which case the technician must be at least 3 m (10 ft.) behind the truck.
If at any time the Engineer feels that the sampling technique is creating an unsafe condition, the operation is to be halted until it is made safe or the paving operation will be stopped while the plate is being placed.

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

1. Following the safety rules detailed above, the technician is to:
   a. Smooth out a location in front of the paver at least 0.5 m (2 ft.) inside the edge of the mat.
   b. Lay the plate down diagonally with the direction of travel, keeping it flat and tight to the base with the lead corner facing the paving machine.
2. Secure the plate in place by driving a nail through the hole in the lead corner of the plate.
3. Pull the wire, attached to the outside corner of the plate, taut past the edge of the HMA mat and secure with a nail.
4. Let the paving operation proceed over the plate and wire. Immediately proceed with the sampling.
5. Using the exposed end of the wire, pull the wire up through the fresh HMA to locate the corner of the plate. Place the “cookie cutter” sample device, just inside the end of the wire; align the cutter over the plate. Press “cookie cutter” device down through the HMA to the plate.
6. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. Care shall be taken to prevent contamination of bituminous mixes by dust or other foreign matter, and to avoid segregation of aggregate and bituminous materials.
7. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose HMA.

**Method 2 - Obtaining a Sample on Asphalt Surface:**

1. After the paving machine has passed the sampling point, immediately place the “cookie cutter” sampling device on the location to be sampled. Push the cutter down through the HMA until it is flat against the underlying asphalt mat.
2. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. The hole made from the sampling must be filled by the contractor with loose HMA.
Identification and Shipping

1. Identify sample containers as required by the agency.

2. Ship samples in containers that will prevent loss, contamination, or damage.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented
REDUCING SAMPLES OF HOT MIX ASPHALT (HMA) TO TESTING SIZE
FOP FOR AASHTO R 47

Scope

This procedure covers sample reduction of Hot Mix Asphalt (HMA) to testing size in accordance with AASHTO R 47-14. The reduced portion is to be representative of the original sample.

Apparatus

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

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

**Sampling**

Obtain samples according to the FOP for AASHTO T 168.

**Sample Preparation**

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

**Selection of Procedure (Method)**

Refer to agency requirements when determining the appropriate method(s) of sample reduction. In general, the selection of a particular method to reduce a sample depends on the initial size of the sample vs. the size of the sample needed for the specific test to be performed. It is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. This decreases the time needed for reduction and minimizes temperature loss. Further reduction of the remaining HMA may be performed by a combination of the following methods, as approved by the agency. The methods for reduction are:

- Mechanical Splitter Method
  - Type A (Quartermaster)
  - Type B (Riffle Splitter)

- Quartering Method
  - Full Quartering
  - By Apex

- Incremental Method
Procedure

**Mechanical Splitter Type A (Quartermaster)**

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will contact HMA.

2. Close and secure hopper gates.

3. Place the four sample receptacles in the splitter so that there is no loss of material.

4. Remove the sample from the agency-approved container(s) and place in the mechanical splitter hopper. Avoid segregation, loss of HMA or the accidental addition of foreign material.

5. Release the handle, allowing the HMA to drop through the divider chutes and discharge into the four receptacles.

6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.

7. Close and secure the hopper gates.

8. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.

9. Combine the material contained in the receptacles from opposite corners and repeat the splitting process until an appropriate sample size is obtained.

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

**Mechanical Splitter Type B (Riffle)**

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed 110°C (230°F).

2. Clean the splitter and apply a light coating of approved release agent to the surfaces that will come in contact with HMA (hopper or straight-edged pan, chutes, receptacles).

3. Place two empty receptacles under the splitter.

4. Carefully empty the HMA from the agency-approved container(s) into the hopper or straight-edged pan without loss of material. Uniformly distribute from side to side of the hopper or pan.
5. Discharge the HMA at a uniform rate, allowing it to flow freely through the chutes.

6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.

7. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.

8. Using one of the two receptacles containing HMA, repeat the reduction process until the HMA contained in one of the two receptacles is the appropriate size for the required test.

9. After each split, remember to clean the splitter hopper and chute surfaces if needed.

10. Retain and properly identify the remaining unused HMA sample for further testing if required by the agency.

**Quartering Method**

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed the maximum mixing temperature from the job mix formula (JMF).

2. If needed, apply a light coating of release agent to quartering template.

3. Dump the sample from the agency approved container(s) into a conical pile on a hard, “non-stick,” clean, level surface where there will be neither a loss of material nor the accidental addition of foreign material. The surface can be made non-stick by the application of an approved asphalt release agent, or sheeting.

4. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one or lifting both opposite corners.

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

6. Divide the flattened cone into four equal quarters using the quartering template or straightedges assuring complete separation.

7. Reduce to appropriate sample mass by full quartering or by apex.
**Full Quartering**

1. Remove two diagonally opposite quarters, including all of the fine material.

2. Remove the quartering template, if used.

3. Combine the remaining quarters.

4. Remix and form a conical pile.

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 or straightedges assuring complete separation.

7. Remove two diagonally opposite quarters, including all of the fine material.

8. Repeat until appropriate sample mass is obtained. The final sample must consist of the two remaining diagonally opposite quarters.

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

**By Apex**

1. Using a straightedge, slice through a quarter of the HMA from the center point to the outer edge of the quarter.

2. Pull or drag the material from the quarter with two straight edges or hold one edge of the straightedge in contact with quartering device.

3. Remove an equal portion from the diagonally opposite quarter and combine these increments to create the appropriate sample mass.

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

5. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.
Incremental Method

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

2. Place the sample from the agency approved container(s) into a conical pile on that surface.

3. Mix the material thoroughly by turning the entire sample over a minimum of four times:
   a. Use a flat-bottom scoop; or
   b. Alternately lift each corner of the sheeting and pull it over the sample diagonally toward the opposite corner, causing the material to be rolled.

4. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one or lifting both opposite corners.

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

6. Remove one quarter of the length of the loaf and place in a container to be saved; by either:
   a. Pull sheeting over edge of counter and drop material into container.
   b. Use a straightedge to slice off material and place into container.

7. Obtain an appropriate sample mass for the test to be performed.
   a. Pull sheeting over edge of counter and drop cross sections of the material into container until proper sample mass has been obtained.
   b. Use a straightedge to slice off cross sections of the material until proper sample mass has been obtained and place into container.

*Note 1:* When reducing the sample to test size it is advisable to take several small increments, determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size, use the sample as reduced for the test.

8. Repeat Step 7 until all the samples for testing have been obtained or until final quarter is reached.

9. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.
MOISTURE CONTENT OF ASPHALT MIXTURES BY OVEN METHOD
FOP FOR AASHTO T 329

Scope

This procedure covers the determination of moisture content of asphalt mixtures in accordance with AASHTO T 329-15.

Overview

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

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

Apparatus

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

Sample

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

Procedure

1. Preheat the oven to the Job Mix Formula (JMF) mixing temperature range. 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.
   
   *Note 2*: When using paper or other absorptive material to line the sample container ensure it is dry before determining initial mass of sample container.
3. Place the test sample in the sample container.

4. Determine and record the temperature of the test sample.

5. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

6. Calculate the initial, moist mass ($M_i$) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 5.

7. The test sample shall be initially dried for 90 ±5 minutes, and its mass determined. Then it shall be dried at 30 ±5 min intervals until further drying does not alter the mass by more than 0.05 percent.

8. Cool the sample container and test sample to ±9°C (±15°F) of the temperature determined in Step 4.

9. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

   Note 3: Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

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

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

**Calculations**

**Constant Mass:**

Calculate constant mass using the following formula:

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

Where:

- $M_p$ = previous mass measurement
- $M_n$ = new mass measurement
Example:

Mass of container: 232.6 g

Mass of container and sample after first drying cycle: 1361.8 g

Mass, $M_p$, of possibly dry sample: $1361.8 \text{ g} - 232.6 \text{ g} = 1129.2 \text{ g}$

Mass of container and possibly dry sample after second drying cycle: 1360.4 g

Mass, $M_n$, of possibly dry sample: $1360.4 \text{ g} - 232.6 \text{ g} = 1127.8 \text{ g}$

$$\frac{1129.2 \text{ g} - 1127.8 \text{ g}}{1129.2 \text{ g}} \times 100 = 0.12\%$$

0.12 percent is not less than 0.05 percent, so continue drying the sample.

Mass of container and possibly dry sample after third drying cycle: 1359.9 g

Mass, $M_n$, of dry sample: $1359.9 \text{ g} - 232.6 \text{ g} = 1127.3 \text{ g}$

$$\frac{1127.8 \text{ g} - 1127.3 \text{ g}}{1127.8 \text{ g}} \times 100 = 0.04\%$$

0.04 percent is less than 0.05 percent, so constant mass has been reached.

Moisture Content:

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

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

Where:

$M_i$ = initial, moist mass

$M_f$ = final, dry mass
Example:

\[ M_i = 1134.9 \text{ g} \]
\[ M_r = 1127.3 \text{ g} \]

\[
Moisture \ Content = \frac{1134.9 \ g - 1127.3 \ g}{1127.3 \ g} \times 100 = 0.674, \text{ say } 0.67\%
\]

Report

- Results on forms approved by the agency
- Sample ID
- Moisture content to 0.01 percent
DETERMINING THE ASPHALT BINDER CONTENT OF ASPHALT MIXTURES BY THE IGNITION METHOD
FOP FOR AASHTO T 308

Scope
This procedure covers the determination of asphalt binder content of asphalt mixtures by ignition of the binder in accordance with AASHTO T 308-18.

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

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

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

Two methods, A and B, are presented.

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

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

- Ignition Furnace: A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature at 538 ± 5°C (1000 ± 9°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 asphalt binder content, test time, and test temperature. The furnace shall
provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes. Perform lift test according to manufacturer’s instructions weekly during use, if applicable.

*Note 2:* The furnace shall be designed to permit the operator to change the ending mass loss percentage from 0.01 percent to 0.02 percent.

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

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

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

- **Oven capable of maintaining 110 ±5°C (230 ±9°F).**

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

- **Safety equipment:** Safety glasses or face shield, high temperature gloves, long sleeved jacket, a heat resistant surface capable of withstanding 650°C (1202°F), a protective cage capable of surrounding the sample baskets during the cooling period, and a particle mask for use during removal of the sample from the basket assembly.

- **Miscellaneous equipment:** A pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

**Sampling**

1. Obtain samples of asphalt mixture in accordance with the FOP for AASHTO T 168.

2. Reduce asphalt mixture samples in accordance with the FOP for AASHTO R 47.

3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 110 ±5°C (230 ±9°F) until soft enough.
4. Test sample size shall conform to the mass requirement shown in Table 1.

*Note 3:* When the mass of the test specimen exceeds the capacity of the equipment used or for large samples of fine mixes, the test specimen may be divided into suitable increments, tested, and the results appropriately combined through a weighted average for calculation of the asphalt binder content.

<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.

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

1. For the convection-type furnace, preheat the ignition furnace to $538 \pm 5^\circ C \ (1000 \pm 9^\circ F)$ or to the temperature determined in the “Correction Factor” section, Step 9 of this method. Manually record the furnace temperature (set point) before the initiation of the test if the furnace does not record automatically. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.

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

3. Determine and record the mass 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 at room temperature 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 asphalt mixture.
7. Input the initial mass of the sample \((M_i)\) into the ignition furnace controller. Verify that the correct mass has been entered.

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

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

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

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

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

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

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

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

12. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as \(M_f\).

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.

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

Corrected asphalt binder content:

\[ P_b = BC - MC - C_f \]

*If correction factor is not entered into the furnace controller

where:

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

Procedure – Method B (External Balance)

1. Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the “Correction Factor” section, Step 9 of this method. Manually record the furnace temperature (set point) before the initiation of the test if the furnace does not record automatically.

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

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

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

5. Determine and record the total mass of the sample and sample basket assembly at room temperature 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 asphalt mixture.
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 asphalt mixture sample in the furnace for 45 minutes or the length of time determined in the “Correction Factors” section.

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

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

10. Place the sample basket assembly back into the furnace.

11. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.

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

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

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

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

15. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as $M_f$.

16. Calculate the asphalt binder content of the sample.
Calculations

Calculate the asphalt binder content of the sample as follows:

\[ P_b = \frac{M_i - M_f}{M_i} \times 100 - MC - C_f \]

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

Example

Correction Factor = 0.42%
Moisture Content = 0.04%
Initial Mass of Sample and Basket = 5292.7 g
Mass of Basket Assembly = 2931.5 g
\( M_i \) = 2361.2 g
Total Mass after First ignition + basket = 5154.4 g
Sample Mass after First ignition = 2222.9 g
Sample Mass after additional 15 min ignition = 2222.7 g

\[
\frac{2222.9 \text{ g} - 2222.7 \text{ g}}{2222.9 \text{ g}} \times 100 = 0.009\%
\]

Not greater than 0.01 percent, so \( M_f = 2222.7 \text{ g} \)
\[ P_b = \frac{2361.2 \, g - 2222.7 \, g}{2361.2 \, g} \times 100 - 0.42\% - 0.04\% = 5.41\% \]

\[ P_b = 5.41\% \]

**Gradation**

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

   *Note 7:* Particle masks are a recommended safety precaution.

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

**Report**

- Results on forms approved by the agency
- Sample ID
- Method of test (A or B)
- Corrected asphalt binder content, \( P_b \), per agency standard
- Correction factor, \( C_r \), to 0.01 percent
- Temperature compensation factor (Method A only)
- Total percent loss
- Sample mass
- Moisture content to 0.01%
- Test temperature

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

(Mandatory Information)

Asphalt Binder and Aggregate

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

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

Historical data or scientific studies may be used to determine the correction factor(s) in lieu of using this testing procedure if the testing agency provides reference to the studies/data. All correction samples will be prepared by a central / regional laboratory unless otherwise directed.

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

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

a. Aggregates that have a proven history of excessive breakdown

b. Aggregate from an unknown source.

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

**Procedure**

1. Obtain samples of aggregate in accordance with the FOP for AASHTO R 90.

2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO R 66. 
   
   *Note 8:* Include other additives that may be required by the JMF.

3. Prepare an initial, or “butter,” mix at the design asphalt binder content. Mix and discard the butter mix before mixing any of the correction specimens to ensure accurate asphalt content.
4. Prepare two correction specimens at the JMF design asphalt binder content. Aggregate used for correction specimens shall be sampled from material designated for use on the project. An agency approved method will be used to combine aggregate. An additional “blank” specimen shall be batched and tested for aggregate gradation in accordance with the FOP for AASHTO T 30. The gradation from the “blank” shall fall within the agency specified mix design tolerances.

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

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

7. Once both of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven tickets, if available.

8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat with two more specimens and, from the four results, discard the high and low result. Determine the correction factor from the two original or remaining results, as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen to 0.01 percent. The asphalt binder correction factor, \( C_t \), is the average of the differences expressed as a percent by mass of asphalt mixture.

9. If the asphalt binder correction factor exceeds 1.00 percent, the test temperature must be lowered to 482 ± 5°C (900 ± 9°F) and new samples must be burned. The temperature for determining the asphalt binder content of asphalt mixture samples by this procedure shall be the same temperature determined for the correction samples.

10. For the direct IR irradiation-type burn furnaces, the default burn profile should be used for most materials. The operator may select burn-profile Option 1 or Option 2 to optimize the burn cycle. The burn profile for testing asphalt mixture samples shall be the same burn profile selected for correction samples.

   **Option 1** is designed for aggregate that requires a large asphalt binder correction factor (greater than 1.00 percent) – typically very soft aggregate (such as dolomite).

   **Option 2** is designed for samples that may not burn completely using the default burn profile.

11. Perform a gradation analysis on the residual aggregate in accordance with the FOP for AASHTO T 30, if required. The results will be utilized in developing an “Aggregate Correction Factor” and should be calculated and reported to 0.1 percent.
12. From the gradation results subtract the percent passing for each sieve, for each sample, from the percent passing each sieve of the “Blank” specimen gradation results from Step 4.

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

**Table 2**  
**Permitted Sieving Difference**

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Permitted Sieving 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 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>

**Examples:**

<table>
<thead>
<tr>
<th>Sieve Size mm (in.)</th>
<th>Correction Factor Blank Sample % Passing</th>
<th>Correction Factor Sample #1 % Passing</th>
<th>Correction Factor Sample #2 % Passing</th>
<th>Difference 1 / 2</th>
<th>Avg. Diff.</th>
<th>Sieves to adjust</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0 (3/4)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0/0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>86.3</td>
<td>87.4</td>
<td>86.4</td>
<td>-1.1/-0.1</td>
<td>-0.6</td>
<td></td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>77.4</td>
<td>76.5</td>
<td>78.8</td>
<td>+0.9/-1.4</td>
<td>-0.3</td>
<td></td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>51.5</td>
<td>53.6</td>
<td>55.9</td>
<td>-2.1/-4.4</td>
<td>-3.3</td>
<td></td>
</tr>
<tr>
<td>2.36 (No. 8)</td>
<td>34.7</td>
<td>36.1</td>
<td>37.2</td>
<td>-1.4/-2.5</td>
<td>-2.0</td>
<td></td>
</tr>
<tr>
<td>01.18 (No. 16)</td>
<td>23.3</td>
<td>25.0</td>
<td>23.9</td>
<td>-1.7/-0.6</td>
<td>-1.2</td>
<td></td>
</tr>
<tr>
<td>0.600 (No. 30)</td>
<td>16.4</td>
<td>19.2</td>
<td>18.1</td>
<td>-2.8/-1.7</td>
<td>-2.3</td>
<td></td>
</tr>
<tr>
<td>0.300 (No. 50)</td>
<td>12.0</td>
<td>11.1</td>
<td>12.7</td>
<td>+0.9/-0.7</td>
<td>+0.1</td>
<td></td>
</tr>
<tr>
<td>0.150 (No. 100)</td>
<td>8.1</td>
<td>9.9</td>
<td>6.3</td>
<td>-1.8/+1.8</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>75 µm (No. 200)</td>
<td>5.5</td>
<td>5.9</td>
<td>6.2</td>
<td>-0.4/-0.7</td>
<td>-0.6</td>
<td>-0.6</td>
</tr>
</tbody>
</table>

In this example, all gradation test results performed on the residual aggregate (FOP for AASHTO T 30) would have an aggregate correction factor applied to the percent passing the 75 µm (No. 200) sieve. The correction factor must be applied because the average difference on the 75 µm (No. 200) sieve is outside the tolerance from Table 2.
In the following example, aggregate correction factors would be applied to each sieve because the average difference on the 4.75 mm (No. 4) is outside the tolerance from Table 2.

<table>
<thead>
<tr>
<th>Sieve Size mm (in.)</th>
<th>Correction Factor</th>
<th>Correction Factor</th>
<th>Correction Factor</th>
<th>Difference</th>
<th>Avg. Diff.</th>
<th>Sieves to adjust</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blank Sample % Passing</td>
<td>Sample #1 % Passing</td>
<td>Sample #2 % Passing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0/0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>86.3</td>
<td>87.4</td>
<td>86.4</td>
<td>-1.1/-0.1</td>
<td>-0.6</td>
<td>-0.6</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>77.4</td>
<td>76.5</td>
<td>78.8</td>
<td>+0.9/-1.4</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>51.5</td>
<td>55.6</td>
<td>57.9</td>
<td>-4.1/-6.4</td>
<td>-5.3</td>
<td>-5.3</td>
</tr>
<tr>
<td>2.36 (No. 8)</td>
<td>34.7</td>
<td>36.1</td>
<td>37.2</td>
<td>-1.4/-2.5</td>
<td>-2.0</td>
<td>-2.0</td>
</tr>
<tr>
<td>0.18 (No. 16)</td>
<td>23.3</td>
<td>25.0</td>
<td>23.9</td>
<td>-1.7/-0.6</td>
<td>-1.2</td>
<td>-1.2</td>
</tr>
<tr>
<td>0.600 (No. 30)</td>
<td>16.4</td>
<td>19.2</td>
<td>18.1</td>
<td>-2.8/-1.7</td>
<td>-2.3</td>
<td>-2.3</td>
</tr>
<tr>
<td>0.300 (No. 50)</td>
<td>12.0</td>
<td>11.1</td>
<td>12.7</td>
<td>+0.9/-0.7</td>
<td>+0.1</td>
<td>+0.1</td>
</tr>
<tr>
<td>0.150 (No. 100)</td>
<td>8.1</td>
<td>9.9</td>
<td>6.3</td>
<td>-1.8/+1.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>0.150 (No. 100)</td>
<td>8.1</td>
<td>9.9</td>
<td>6.3</td>
<td>-1.8/+1.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>75 µm (No. 200)</td>
<td>5.5</td>
<td>5.9</td>
<td>6.2</td>
<td>-0.4/-0.7</td>
<td>-0.6</td>
<td>-0.6</td>
</tr>
</tbody>
</table>
THEORETICAL MAXIMUM SPECIFIC GRAVITY ($G_{mm}$) AND DENSITY OF HOT MIX ASPHALT (HMA) PAVING MIXTURES
FOP FOR AASHTO T 209

Scope

This procedure covers the determination of the maximum specific gravity ($G_{mm}$) of uncompacted hot mix asphalt (HMA) paving mixtures in accordance with AASHTO T 209-12. Two methods using different containers – bowl and pycnometer / volumetric flask – are covered.

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

Apparatus

- Balance or scale: 10,000 g capacity, readable to 0.1 g
- Container: A glass, metal, or plastic bowl, pycnometer or volumetric flask between 2000 and 10,000 mL as required by the minimum sample size requirements in Table 1 sample and capable of withstanding a partial vacuum
- Pycnometer / volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 4.0 kPa (30 mm Hg)
- Residual pressure manometer or vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Automatic vacuum control unit (optional)
- Timer
**Standardization of Pycnometer or Volumetric Flask**

Use a pycnometer / volumetric flask that is standardized to accurately determine the mass of water, at 25 ±0.5°C (77 ±1°F), in the pycnometer / volumetric flask. The pycnometer / volumetric flask shall be standardized periodically in conformance with procedures established by the agency.

**Test Sample Preparation**

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

2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.014 the test must be re-run.

<table>
<thead>
<tr>
<th>Nominal Maximum* Aggregate Size mm (in.)</th>
<th>Minimum Mass g</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 or greater (1½)</td>
<td>4000</td>
</tr>
<tr>
<td>19 to 25 (3/4 to 1)</td>
<td>2500</td>
</tr>
<tr>
<td>12.5 or smaller (1/2)</td>
<td>1500</td>
</tr>
</tbody>
</table>

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

**Procedure – General**

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

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

2. Cool the sample to room temperature.

3. Determine and record the mass of the dry container to the nearest 0.1 g.

4. Place the sample in the container.

5. Determine and record the mass of the dry container and sample to the nearest 0.1 g.

6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A.”
7. Add sufficient water at approximately 25° C (77° F) to cover the sample by about 25 mm (1 in.).

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

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

9. Remove entrapped air by subjecting the 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. Release the vacuum. Increase the pressure to atmospheric pressure in 10 to 15 seconds if the vacuum release is not automated. Turn off the vacuum pump and remove the lid. When performing the pycnometer / volumetric flask method, complete steps 12B through 16B within 10±1 minute.

**Procedure – Bowl**

12A. Fill the water bath to overflow level with water at 25 ±1°C (77 ±2°F) and allow the water to stabilize.

13A. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

14A. Suspend and immerse the bowl and contents in water at 25 ±1°C (77 ±2°F) for 10 ±1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.

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

16A. Refill the water bath to overflow level.

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

18A. Determine and record the submerged weight of the sample to the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 15A. Designate this submerged weight as “C.”
**Procedure – Pycnometer or Volumetric Flask**

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

13B. Stabilize the temperature of the pycnometer / volumetric flask and contents so that the final temperature is within 25 ±1°C (77 ±2°F).

14B. Finish filling the pycnometer / volumetric flask with water that is 25 ±1°C (77 ±2°F), place the cover or a glass plate on the pycnometer / volumetric flask, and eliminate all air.

*Note 2:* When using a metal pycnometer and cover, place the cover on the pycnometer and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling the pycnometer to avoid reintroducing air into the water.

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

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

**Procedure – Mixtures Containing Uncoated Porous Aggregate**

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

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.

2. Spread sample in a flat shallow pan and place before an electric fan to remove surface moisture.

3. Determine the mass of the sample when the surface moisture appears to be gone.

4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.

5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as “ASSD.”

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

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

**Bowl Procedure**

\[
G_{mm} = \frac{A}{A - C} \quad \text{or} \quad G_{mm} = \frac{A}{A_{SSD} - C}
\]

(for mixes containing uncoated aggregate materials)

where:

- $A$ = mass of dry sample in air, g
- $A_{SSD}$ = Mass of saturated surface dry sample in air, g
- $C$ = submerged weight of sample in water, g

**Example:**

\[
A = 1432.7 \text{ g} \\
A_{SSD} = 1434.2 \text{ g} \\
C = 848.6 \text{ g}
\]

\[
G_{mm} = \frac{1432.7 \text{ g}}{1432.7 \text{ g} - 848.6 \text{ g}} = 2.453 \quad \text{or} \quad G_{mm} = \frac{1432.7 \text{ g}}{1434.2 \text{ g} - 848.6 \text{ g}} = 2.447
\]

**Pycnometer / Volumetric Flask Procedure**

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

(for mixes containing uncoated materials)

where:

- $A$ = Mass of dry sample in air, g
- $A_{SSD}$ = Mass of saturated surface-dry sample in air, g
- $D$ = Mass of pycnometer / volumetric flask filled with water at 25°C (77°F), g, determined during the Standardization of Pycnometer / Volumetric Flask procedure
- $E$ = Mass of pycnometer / volumetric flask filled with water and the test sample at test temperature, g
Example (in which two increments of a large sample are averaged):

<table>
<thead>
<tr>
<th>Increment 1</th>
<th>Increment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = 2200.3 g</td>
<td>A = 1960.2 g</td>
</tr>
<tr>
<td>D = 7502.5 g</td>
<td>D = 7525.5 g</td>
</tr>
<tr>
<td>E = 8812.0 g</td>
<td>E = 8690.8 g</td>
</tr>
<tr>
<td>Temperature = 26.2°C</td>
<td>Temperature = 25.0°C</td>
</tr>
</tbody>
</table>

\[ G_{m1} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.0\ g} = 2.470 \]

\[ G_{m2} = \frac{1960.2\ g}{1960.2\ g + 7525.5\ g - 8690.8\ g} \times 1.00000 = 2.466 \]

Allowable variation is: 0.014

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

Average:

\[ 2.470 + 2.466 = 4.936 \quad 4.936 \div 2 = 2.468 \]
Theoretical Maximum Density

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

Theoretical maximum density kg/m³ = G_{mm} \times 997.1 kg/m³

2.468 \times 997.1 kg/m³ = 2461 kg/m³

or

Theoretical maximum density lb/ft³ = G_{mm} \times 62.245 lb/ft³

2.468 \times 62.245 lb/ft³ = 153.6 lb/ft³

Report

- Results on forms approved by the agency
- Sample ID
- G_{mm} to three decimal places
- Theoretical maximum density to 1 kg/m³ (0.1 lb/ft³)
BULK SPECIFIC GRAVITY \((G_{mb})\) OF COMPACTED ASPHALT MIXTURES USING SATURATED SURFACE-DRY SPECIMENS
FOP FOR AASHTO T 166

Scope

This procedure covers the determination of bulk specific gravity \((G_{mb})\) of compacted asphalt mixtures using three methods – A, B, and C – in accordance with AASHTO T 166-16. This FOP is for use on specimens not having open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both. When specimens have open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both, AASHTO T 275 or AASHTO T 331 should be performed.

Overview

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

Test Specimens

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

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

Terminology

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

Apparatus - Method A (Suspension)

- Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.

- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.

- Water bath: For immersing the specimen in water while suspended under the balance or scale and equipped with an overflow outlet for maintaining a constant water level.
• Towel: Damp cloth towel used for surface drying specimens.

• Oven: Capable of maintaining a temperature of 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.

• Vacuum device: refer to AASHTO R 79 (optional)

**Procedure - Method A (Suspension)**

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

1. Dry the specimen to constant mass, if required.
   a. Oven method
      i. Initially dry overnight at 52 ±3°C (125 ±5°F).
      ii. Determine and record the mass of the specimen (M_p).
      iii. Return the specimen to the oven for at least 2 hours.
      iv. Determine and record the mass of the specimen (M_n).
      v. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
      vi. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
      vii. Constant mass has been achieved, sample is defined as dry.
   b. Vacuum dry method
      i. Perform vacuum drying procedure according to AASHTO R 79.
      ii. Determine and record the mass of the specimen (M_p).
      iii. Perform a second vacuum drying procedure.

   *Note 1:* To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.
iv. Determine and record the mass of the specimen (Mn).

v. Determine percent change by subtracting the new mass determination (Mn) from the previous mass determination (Mp) divide by the previous mass determination (Mp) multiply by 100.

vi. Continue drying until there is less than 0.05 percent change in specimen mass (constant mass).

vii. Constant mass has been achieved, sample is defined as dry.

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

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

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

5. Immerse the specimen shaking to remove the air bubbles. Place the specimen on its side in the suspension apparatus. Leave it immersed for 4 ±1 minutes.

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

7. Remove the sample from the water and quickly surface dry with a damp cloth towel within 5 seconds.

8. Zero or tare the balance.

9. Immediately determine and record the mass of the SSD specimen to nearest 0.1 g. Designate this mass as “B.” Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen. Do not to exceed 15 seconds performing Steps 7 through 9.
Calculations - Method A (Suspension)

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, g
- \( M_n \) = new mass measurement, g

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

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

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

where:

- \( G_{mb} \) = Bulk specific gravity
- \( A \) = Mass of dry specimen in air, g
- \( B \) = Mass of SSD specimen in air, g
- \( C \) = Weight of specimen in water at 25 ±1°C (77 ±1.8°F), g

Example:

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

\[
\% \text{ Water Absorbed (by volume)} = \frac{4842.4 \text{ g} - 4833.6 \text{ g}}{4842.4 \text{ g} - 2881.3 \text{ g}} \times 100 = 0.45\%
\]
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.
- Vacuum device: AASHTO R 79 (optional)

Procedure - Method B (Volumeter)

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

1. Dry the specimen to constant mass, if required.
   a. Oven method:
      i. Initially dry overnight at 52 ±3°C (125 ±5°F).
      ii. Determine and record the mass of the specimen (Mp).
      iii. Return the specimen to the oven for at least 2 hours.
      iv. Determine and record the mass of the specimen (Mn).
      v. Determine percent change by subtracting the new mass determination (Mn) from the previous mass determination (Mp) divide by the previous mass determination (Mp) multiply by 100.
      vi. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
      vii. Constant mass has been achieved, sample is defined as dry.
Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

b. Vacuum dry method

   i. Perform vacuum drying procedure according to AASHTO R 79.

   ii. Determine and record the mass of the specimen (Mp).

   iii. Perform a second vacuum drying procedure.

   iv. Determine and record the mass of the specimen (Mn).

   v. Determine percent change by subtracting the new mass determination (Mn) from the previous mass determination (Mp) divide by the previous mass determination (Mp) multiply by 100.

   vi. Continue drying until there is less than 0.05 percent change in specimen mass (constant mass).

   vii. Constant mass has been achieved, sample is defined as dry.

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.

5. Wipe the volumeter dry. Determine the mass of the volumeter to the nearest 0.1 g. Designate this mass as “D.”

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

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

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

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

10. Wipe the volumeter dry.

11. Determine and record the mass of the volumeter and specimen to the nearest 0.1 g. Designate this mass as “E.”
Note 2: Method B is not acceptable for use with specimens that have more than 6 percent air voids.

Calculations - Method B (Volumeter)

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, g
- \( M_n \) = new mass measurement, g

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

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

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

where:

- \( G_{mb} \) = Bulk specific gravity
- \( A \) = Mass of dry specimen in air, g
- \( B \) = Mass of SSD specimen in air, g
- \( D \) = Mass of volumeter filled with water at 25 ±1°C (77 ±1.8°F), g
- \( E \) = Mass of volumeter filled with specimen and water, g

Example:

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

\[
\% \text{ Water Absorbed (by volume)} = \frac{4842.4 \text{ g} - 4833.6 \text{ g}}{4842.4 \text{ g} + 2924.4 \text{ g} - 5806.0 \text{ g}} \times 100 = 0.45\%
\]
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. Start on Step 3 of Method A or B, and complete that procedure, then determine dry mass, “A,” as follows.

2. Determine and record mass of a large, flat-bottom container.

3. Place the specimen in the container.

4. Place in an oven at a minimum of 105°C (221°F). Do not exceed the Job Mix Formula mixing temperature.

5. Dry until the specimen can be easily separated into fine aggregate particles that are not larger than 6.3 mm (¼ in.).

6. Determine and record the mass of the specimen (M_p).

7. Return the specimen to the oven for at least 2 hours.

8. Determine and record the mass of the specimen (M_n).

9. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p), divide by the previous mass determination (M_p), multiply by 100.

10. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).

11. Constant mass has been achieved, sample is defined as dry.


13. Determine and record the mass of the container and dry specimen to the nearest 0.1 g.

14. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the container from the mass determined in Step 13. Designate this mass as “A.”
Calculations - Method C (Rapid Test for Method A or B)

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

Report

- Results on forms approved by the agency
- Sample ID
- $G_{mb}$ to 0.001
- Absorption to 0.01 percent
- Method performed.
SAMPLING ASPHALT MATERIALS
FOP FOR AASHTO R 66

Scope

This procedure covers obtaining samples of liquid asphalt materials in accordance with AASHTO R 66-16. Sampling of solid and semi-solid asphalt materials – included in AASHTO R 66 – is not covered here.

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

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

Terminology

- Asphalt binder: Asphalt cement or modified asphalt cement that binds the aggregate particles into a dense mass.
- Asphalt emulsion: A mixture of asphalt binder and water.
- Cutback asphalt: Asphalt binder that has been modified by blending with a chemical solvent.

Procedure

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

Containers

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

All samples shall be put in 1 L (1 qt) containers and properly identified on the outside of the container with contract number, date sampled, data sheet number, brand and grade of material, and sample number. Include lot and sublot numbers when appropriate.
• Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion. The sample container should be completely filled to minimize a skin formation on the sample.

• Asphalt binder and cutbacks: Use metal cans.

   Note: The sample container shall not be submerged in solvent, nor shall it be wiped with a solvent saturated cloth. If cleaning is necessary, use a clean dry cloth.

Report

• On forms approved by the agency

• Sample ID

• Date

• Time

• Location

• Quantity represented
MEchanical Analysis of Extracted Aggregate
FOP for AASHTO T 30

Scope

This procedure covers mechanical analysis of aggregate recovered from asphalt mix samples in accordance with AASHTO T 30-15. This FOP utilizes the aggregate recovered from the ignition oven used in AASHTO T 308. AASHTO T 30 was developed for analysis of extracted aggregate and thus includes references to extracted bitumen and filter element, which do not apply in this FOP.

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

Apparatus

- Balance or scale: Capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g

- Sieves, meeting the requirements of FOP for AASHTO T 27/T 11.

- Mechanical sieve shaker, meeting the requirements of FOP for AASHTO T 27/T 11.

- Mechanical Washing Apparatus (optional)

- Suitable drying equipment, meeting the requirements of the FOP for AASHTO T 255.

- Containers and utensils: A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water

Sample Sieving

- In this procedure, it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification. Intermediate sieves are added for additional information or to avoid overloading sieves, or both.

- The sieves are nested in order of increasing size from the bottom to the top, and the test sample, or a portion of the test sample, is placed on the top sieve.

- The loaded sieves are shaken in a mechanical shaker for approximately 10 minutes, refer to Annex A; Time Evaluation.
**Mass Verification**

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

**Calculation**

\[
\text{Mass verification} = \frac{M_f(T308) - M_{(T30)}}{M_f(T308)} \times 100
\]

Where:

- $M_f(T308)$ = Mass of aggregate remaining after ignition from the FOP for AASHTO T 308
- $M_{(T30)}$ = Mass of aggregate sample obtained from the FOP for AASHTO T 308

**Example:**

\[
\text{Mass verification} = \frac{2422.5 \text{ g} - 2422.3 \text{ g}}{2422.5 \text{ g}} \times 100 = 0.01\%
\]

Where:

- $M_f(T308) = 2422.5 \text{ g}$
- $M_{(T30)} = 2422.3 \text{ g}$

**Procedure**

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

2. Place the test sample in a container and cover with water. Add a detergent, dispersing agent, or other wetting solution to the water to assure a thorough separation of the material finer than the 75µm (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.
3. Agitate vigorously to ensure complete separation of the material finer than 75µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device. Maximum agitation is 10 min.

   Note 1: When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation. Use care not to overflow or overload the 75µm (No. 200) sieve.

4. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 µm (No. 200) sieve.

5. Add water to cover material remaining in the container, agitate, and repeat Step 4. Continue until the wash water is reasonably clear.

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

7. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed.

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

9. Dry the washed test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the “dry mass after washing.”

10. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75 µm (No. 200).

11. Place the test sample, or a portion of the test sample, on the top sieve. Place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

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

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

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

13. Perform the Check Sum calculation – Verify the total mass after sieving of material agrees with the dry mass after washing within 0.2 percent. Do not use test results for acceptance if the Check Sum result is greater than 0.2 percent.
14. Calculate the total percentages passing, and the individual or cumulative percentages retained, to the nearest 0.1 percent by dividing the individual sieve masses or cumulative sieve masses by the total mass of the initial dry sample.

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

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

**Calculations**

**Check Sum**

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

**Percent Retained**

**Individual**

\[
\text{IPR} = \frac{\text{IMR}}{M_{T30}} \times 100
\]

**Cumulative**

\[
\text{CPR} = \frac{\text{CMR}}{M_{T30}} \times 100
\]

Where:

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

**Individual**

$$PP = PCP - IPR$$

**Cumulative**

$$PP = 100 - CPR$$

Where:

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

**Reported Percent Passing**

$$RPP = PP + ACF$$

Where:

- RPP = Reported Percent Passing
- ACF = Aggregate Correction Factor (if applicable)

**Example**

Dry mass of total sample, before washing ($M_{T30}$): 2422.3 g

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

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

\[
check \ sum = \frac{2296.2 \ g - 2295.3 \ g}{2296.2 \ g} \times 100 = 0.04\%
\]

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

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

\[
IPR = \frac{63.5 \ g}{2422.3 \ g} \times 100 = 2.6\%
\]

or

\[
CPR = \frac{2289.6 \ g}{2422.3 \ g} \times 100 = 94.5\%
\]

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

\[
PP = 8.1\% - 2.6\% = 5.5\%
\]

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

\[
PP = 100.0\% - 94.5\% = 5.5\%
\]

Reported Percent Passing

\[
RPP = 5.5\% = (-0.6\%) = 4.9\%
\]
### Individual Gradation on All Sieves

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Individual Mass Retained (IMR)</th>
<th>Individual Percent Retained (IPR)</th>
<th>Percent Passing (PP)</th>
<th>Agg. Corr. Factor from T 308 (ACF)</th>
<th>Reported Percent Passing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm (in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>346.9</td>
<td>14.3</td>
<td>100.0 − 14.3 = 85.7</td>
<td></td>
<td>86</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>207.8</td>
<td>8.6</td>
<td>85.7 − 8.6 = 77.1</td>
<td></td>
<td>77</td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>625.4</td>
<td>25.8</td>
<td>77.1 − 25.8 = 51.3</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>2.36 (No. 8)</td>
<td>416.2</td>
<td>17.2</td>
<td>51.3 − 17.2 = 34.1</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>1.18 (No. 16)</td>
<td>274.2</td>
<td>11.3</td>
<td>34.1 − 11.3 = 22.8</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>0.600 (No. 30)</td>
<td>152.1</td>
<td>6.3</td>
<td>22.8 − 6.3 = 16.5</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>0.300 (No. 50)</td>
<td>107.1</td>
<td>4.4</td>
<td>16.5 − 4.4 = 12.1</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>0.150 (No. 100)</td>
<td>96.4</td>
<td>4.0</td>
<td>12.1 − 4.0 = 8.1</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>0.075 (No. 200)</td>
<td>63.5</td>
<td>2.6</td>
<td>8.1 − 2.6 = 5.5</td>
<td>-0.6 (5.5 − 0.6 =)</td>
<td>4.9</td>
</tr>
<tr>
<td>minus 75 µm (No. 200) in the pan</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total mass after sieving = sum of sieves + mass in the pan = 2295.3 g

Dry mass of total sample, before washing (M\textsubscript{T30}): 2422.3 g

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.
## Cumulative Gradation on All Sieves

<table>
<thead>
<tr>
<th>Sieve Size mm (in.)</th>
<th>Cumulative Mass Retained g (CMR)</th>
<th>Determine CPR Divide CMR by M and multiply by 100</th>
<th>Cumulative Percent Retained (CPR)</th>
<th>Determine PP by subtracting CPR from 100.0</th>
<th>Percent Passing (PP)</th>
<th>Agg. Corr. Factor from T 308 (ACF)</th>
<th>Reported Percent Passing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0 (3/4)</td>
<td>0</td>
<td>0.0</td>
<td>100.0</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>346.9</td>
<td>$\frac{346.9}{2422.3} \times 100 = 14.3$</td>
<td>100.0 − 14.3 = 85.7</td>
<td></td>
<td>86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>554.7</td>
<td>$\frac{554.7}{2422.3} \times 100 = 22.9$</td>
<td>100.0 − 22.9 = 77.1</td>
<td></td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>1180.1</td>
<td>$\frac{1180.1}{2422.3} \times 100 = 48.7$</td>
<td>100.0 − 48.7 = 51.3</td>
<td></td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.36 (No. 8)</td>
<td>1596.3</td>
<td>$\frac{1596.3}{2422.3} \times 100 = 65.9$</td>
<td>100.0 − 65.9 = 34.1</td>
<td></td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.18 (No. 16)</td>
<td>1870.5</td>
<td>$\frac{1870.5}{2422.3} \times 100 = 77.2$</td>
<td>100.0 − 77.2 = 22.8</td>
<td></td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.600 (No. 30)</td>
<td>2022.6</td>
<td>$\frac{2022.6}{2422.3} \times 100 = 83.5$</td>
<td>100.0 − 83.5 = 16.5</td>
<td></td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.300 (No. 50)</td>
<td>2129.7</td>
<td>$\frac{2129.7}{2422.3} \times 100 = 87.9$</td>
<td>100.0 − 87.9 = 12.1</td>
<td></td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.150 (No. 100)</td>
<td>2226.1</td>
<td>$\frac{2226.1}{2422.3} \times 100 = 91.9$</td>
<td>100.0 − 91.9 = 8.1</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.075 (No. 200)</td>
<td>2289.6</td>
<td>$\frac{2289.6}{2422.3} \times 100 = 94.5$</td>
<td>100.0 − 94.5 = 5.5</td>
<td></td>
<td>5.5</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>minus 75 µm (No. 200) in the pan</td>
<td>2295.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total mass after sieving = 2295.3 g

Dry mass of total sample, before washing ($M_{T30}$): 2422.3 g

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

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

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

1. Shake the sample over nested sieves for approximately 10 minutes.

2. Provide a snug-fitting pan and cover for each sieve, and hold in a slightly inclined position in one hand.

3. Hand-shake each sieve by striking the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes.

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

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

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m² (4 g/in²) of sieving surface.

- For sieves with openings 4.75 mm (No. 4) and larger, the mass (in kg) shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table B1.

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

### TABLE B1

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

<table>
<thead>
<tr>
<th>Sieve Size mm (in.)</th>
<th>203 dia (8)</th>
<th>305 dia (12)</th>
<th>305 by 305 (12 x 12)</th>
<th>350 by 350 (14 x 14)</th>
<th>372 by 580 (16 x 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0285</td>
<td>0.0670</td>
<td>0.0929</td>
<td>0.1225</td>
<td>0.2158</td>
</tr>
<tr>
<td>90 (3 1/2)</td>
<td>*</td>
<td>15,100</td>
<td>20,900</td>
<td>27,600</td>
<td>48,500</td>
</tr>
<tr>
<td>75 (3)</td>
<td>*</td>
<td>12,600</td>
<td>17,400</td>
<td>23,000</td>
<td>40,500</td>
</tr>
<tr>
<td>63 (2 1/2)</td>
<td>*</td>
<td>10,600</td>
<td>14,600</td>
<td>19,300</td>
<td>34,000</td>
</tr>
<tr>
<td>50 (2)</td>
<td>3600</td>
<td>8400</td>
<td>11,600</td>
<td>15,300</td>
<td>27,000</td>
</tr>
<tr>
<td>37.5 (1 1/2)</td>
<td>2700</td>
<td>6300</td>
<td>8700</td>
<td>11,500</td>
<td>20,200</td>
</tr>
<tr>
<td>25.0 (1)</td>
<td>1800</td>
<td>4200</td>
<td>5800</td>
<td>7700</td>
<td>13,500</td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>1400</td>
<td>3200</td>
<td>4400</td>
<td>5800</td>
<td>10,200</td>
</tr>
<tr>
<td>16.0 (5/8)</td>
<td>1100</td>
<td>2700</td>
<td>3700</td>
<td>4900</td>
<td>8600</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>890</td>
<td>2100</td>
<td>2900</td>
<td>3800</td>
<td>6700</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>670</td>
<td>1600</td>
<td>2200</td>
<td>2900</td>
<td>5100</td>
</tr>
<tr>
<td>6.3 (1/4)</td>
<td>440</td>
<td>1100</td>
<td>1500</td>
<td>1900</td>
<td>3400</td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>330</td>
<td>800</td>
<td>1100</td>
<td>1500</td>
<td>2600</td>
</tr>
<tr>
<td>-4.75 (-No. 4)</td>
<td>200</td>
<td>470</td>
<td>650</td>
<td>860</td>
<td>1510</td>
</tr>
</tbody>
</table>
ASPHALT MIXTURE SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR FOP FOR AASHTO T 312

Scope
This procedure covers preparing specimens, using samples of plant produced asphalt mixtures, for determining the mechanical and volumetric properties of asphalt mixtures in accordance with AASHTO T 312-15.

Apparatus
- Superpave Gyratory Compactor (SGC) meeting the requirements of AASHTO T 312
- Molds meeting the requirements of AASHTO T 312
- Chute, mold funnel or both (Optional)
- Scale meeting the requirements of AASHTO M 231 Class G 5
- Oven, thermostatically controlled, capable of maintaining set temperature within ±3°C (±5°F)
- Thermometers accurate to ±1°C (±2°F) between 10 and 232°C (50 - 450°F)

Note 1: Non-Contact thermometers are not acceptable.
- Miscellaneous pans, spoons, spatulas, hot pads, gloves, paper discs, markers, etc.

Equipment Requirements
The calibration shall be performed on the SGC per the Manufacturer’s instructions. See agency requirements for the calibration frequency.

The mold and base plate dimensions shall be checked every twelve months or 80 hours of operation to determine that they are within the tolerances listed in AASHTO T 312.

Equipment Preparation
Prepare the equipment in accordance with manufacturer’s recommendations. At a minimum preparation includes:
- Warm-up gyratory compactor
- Verify machine settings
  - Internal Angle: 1.16 ±0.02°
  - Ram Pressure: 600 kPa ±18 kPa
  - Number of gyrations
Note 2: The number of gyrations ($N_{des}$) is obtained from the Job Mix Formula (JMF).

- Lubricate bearing surfaces
- Prepare recording device as required
- Pre-heat molds and plates at the compaction temperature range (minimum of 30 min.) or before reuse reheat (minimum of 5 min.)

Note 3: The use of multiple molds will speed up the compaction process.

- Pre-heat chute, mold funnel, spatulas, and other apparatus (not to exceed the maximum compaction temperature)

Sample Preparation

Laboratory Prepared Asphalt Mixtures

This is a sample produced during the Mix Design process using aggregate and binder that is combined in the laboratory. When designing asphalt mixtures using the gyratory compactor, refer to AASHTO T 312 and AASHTO R 35.

Plant Produced Asphalt Mixtures

- Determine initial sample size, number of gyrations ($N_{des}$), and compaction temperature range from the Job Mix Formula (JMF).
- Obtain the sample in accordance with the FOP for AASHTO T 168.
- Reduce the sample in accordance with the FOP for AASHTO R 47.
- The sample size should be such that it results in a compacted specimen that is $115 \pm 5$mm at the desired number of gyrations.

Note 4: Replicate specimens are generally prepared. Refer to agency requirements.

If the material is not in the compaction temperature range:

1. Place the appropriate sample mass into a container.
2. Spread to a depth of 1 to 2 in. for even heating of mixture.
3. Place in the oven until the material is within the compaction temperature range.

Note 5: The material properties may be altered when the times of delivery of the test sample and the placement of the material on the roadway are different.
Compaction Procedure

Follow the manufacturer’s recommended loading procedure. This may require the steps below to be performed in a different order. Steps 1 through 8 must be performed before the sample and mold cools below minimum compaction temperature.

1. Remove pre-heated mold and plate(s) from the oven (verify mold and plate(s) has been cleaned if previously used).
2. Place the base plate and paper disc in bottom of mold.
3. Place the mix into the mold in a single lift (care should be taken to avoid segregation or loss of material).
4. Level the mix in the mold.
5. Place a paper disc and the heated upper plate (if required) on top of the leveled sample.
6. Load the mold into the compactor; check settings.
7. Start the compaction process.
   a. Check the pressure (600 ±18 kPa).
   b. Check the angle (1.16 ±0.02°).
8. Upon completion of the compaction process, record the number of gyrations and specimen height.

Note 6: If the specimen is not 115 ±5mm follow agency requirements.

9. Extrude the specimen from the mold; a brief cooling period may be necessary before fully extruding some specimens to ensure the specimens are not damaged.

Note 7: Clean molds after each use.

10. Carefully remove the paper discs.
11. Cool the compacted specimen to room temperature.
12. Identify the specimen with chalk or other marker.

Report

- On forms approved by the agency
- Sample ID
- Number of gyrations
- Specimen height
VOLUMETRIC PROPERTIES OF HOT MIX ASPHALT (HMA)
WAQTC TM 13

Scope

This procedure covers the determination of volumetric properties of plant produced Hot Mix Asphalt, i.e., air voids ($V_a$), voids in mineral aggregate ($V_{MA}$), voids filled with asphalt binder ($V_{FA}$), effective asphalt binder content ($P_{be}$) and Dust to Binder Ratio ($P_{#200}/P_{be}$). The in-production volumetric properties are then compared to agency specifications.

Definition of Terms

- $G_{mm}$ = theoretical maximum specific gravity (Gravity mix max)
- $G_{mb}$ = measured bulk specific gravity (Gravity mix bulk)
- $G_{sb}$ = oven-dry bulk specific gravity of aggregate (Gravity stone bulk)
- $G_{sa}$ = apparent specific gravity of aggregate (Gravity stone apparent)
- $G_{se}$ = effective specific gravity of aggregate (Gravity stone effective)
- $G_b$ = specific gravity of the binder (Gravity binder)
- $V_a$ = air Voids (Voids air)
- $V_{MA}$ = Voids in Mineral Aggregate
- $V_{FA}$ = Voids Filled with Asphalt (binder)
- $V_{ba}$ = absorbed binder volume (Voids binder absorbed)
- $V_{be}$ = effective binder volume (Voids binder effective)
- $P_b$ = percent binder content (Percent binder)
- $P_{ba}$ = percent absorbed binder (Percent binder absorbed)
- $P_{be}$ = percent effective binder content (Percent binder effective)
- $P_s$ = percent of aggregate (Percent stone)
- $DP$ = Dust proportion to effective binder ratio ($P_{#200}/P_{be}$)
Background

Whether a mix design is developed through a Marshall, Hveem, or Superpave mix design process there are basic volumetric requirements of all. Volumetric properties are the properties of a defined material contained in a known volume. HMA Volumetric properties can include bulk specific gravity, theoretical maximum specific gravity, air voids, and voids in mineral aggregate.

Many agencies specify values of the volumetric properties to ensure optimum performance of the pavement. The HMA must be designed to meet these criteria. In production the HMA is evaluated to determine if the mix still meets the specifications and is consistent with the original mix design (JMF). The production HMA may vary from the mix design and may need to be modified to meet the specified volumetric criteria.

To compare the in-production volumetric properties to agency specifications and the JMF a sample of loose HMA mix is obtained in accordance with FOP for AASHTO T 168. The sample is then compacted in a gyratory compactor to simulate the in-place HMA pavement after it has been placed, compacted, and the volumetric properties of the compacted sample are determined.

Each of the properties in the HMA phase diagram can be measured or calculated. For example: The mass of the aggregate is measured; the voids in mineral aggregate (VMA) is calculated; total asphalt binder can be measured but the amount available to act as a binder in the mix must be calculated because it is the quantity left after the aggregate has absorbed some of the asphalt binder.
The volumetric proportions of the asphalt binder and aggregate components of an asphalt mixture and their relationship to the other components are considered. The mass of the components and their specific gravities are used to determine the volumes of each of the components in the mix. The volumetric properties of a compacted HMA paving mixture: air voids ($V_a$), voids in mineral aggregate (VMA), voids filled with asphalt binder (VFA), and effective asphalt binder content ($P_{be}$) provide some indication of the mixtures probable performance.

**Volumetric Properties**

**Volumetric Relationship of HMA Constituents**

![HMA Cross Section and Volume Diagram]

**Required Values**

The specific gravities listed in Table 1 and the percent by mass of each of the components in the HMA are needed to determine the volumetric properties. Other values required are also listed. Some of these values are obtained from the JMF and some are measured from a plant produced HMA sample.
### Table 1

<table>
<thead>
<tr>
<th>Data</th>
<th>Test Method</th>
<th>Obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{sb}$: combined aggregate bulk specific gravity</td>
<td>AASHTO T 84 / T 85 or agency approved test method</td>
<td>JMF or performed at the beginning of placement</td>
</tr>
<tr>
<td>$G_b$: measured specific gravity of the asphalt binder</td>
<td>AASHTO T 228</td>
<td>JMF or from the supplier</td>
</tr>
<tr>
<td>$G_{mm}$: measured maximum specific gravity of the loose mix</td>
<td>FOP for AASHTO T 209</td>
<td>Performed on the field test sample</td>
</tr>
<tr>
<td>$G_{mb}$: measured bulk specific gravity of the compacted paving mix</td>
<td>FOP for AASHTO T 166</td>
<td>Performed on the field compacted specimen</td>
</tr>
<tr>
<td>$P_b$: percent asphalt binder</td>
<td>FOP for AASHTO T 308</td>
<td>Performed on the field test sample</td>
</tr>
<tr>
<td>$P_{-200}$: aggregate passing the #200 (75 µm) sieve</td>
<td>FOP for AASHTO T 30</td>
<td>Performed on the field test sample</td>
</tr>
</tbody>
</table>

### Air Voids ($V_a$)

Air voids are the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture. Appropriate air voids contribute to the stability of the HMA and help the pavement withstand the combined action of environment and traffic loads. The designated percent air voids allows for thermal expansion of the asphalt binder and contributes a cushion for future compaction. Air voids are expressed as a percent of the bulk volume of the compacted mixture ($G_{mb}$) when compared to the maximum specific gravity ($G_{mm}$).

\[
V_a = 100 \left[ \frac{(G_{mm} - G_{mb})}{G_{mm}} \right]
\]

Where:

- $V_a$ = air voids in compacted mixture, percent of total volume (report to 0.1)
- $G_{mm}$ = maximum specific gravity of paving mixture (AASHTO T 209)
- $G_{mb}$ = bulk specific gravity of compacted mixture (AASHTO T 166)
Percent Aggregate (Stone) ($P_s$)

$P_s$ is the percent aggregate (stone) content, expressed as a percentage of the total mass of the sample.

$$P_s = 100 - P_b$$

Where:
- $P_s$ = percent aggregate (stone) percent by total weight
- $P_b$ = asphalt binder content (AASHTO T 308)

Voids in the Mineral Aggregate (VMA)

VMA is the volume of intergranular void space between the aggregate particles of the compacted paving mixture that includes the air voids and the effective binder content, expressed as a percent of the total volume of the sample.

$$VMA = 100 - \left[ \frac{(G_{mb} \times P_s)}{G_{sb}} \right]$$

Where:
- $VMA$ = voids in mineral aggregate, percent of bulk volume (report to 0.1)
- $G_{sb}$ = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)
- $G_{mb}$ = bulk specific gravity of compacted mixture (AASHTO T 166)
- $P_s$ = aggregate content, percent by total weight = $100 - P_b$
- $P_b$ = asphalt binder content (AASHTO T 308) percent by total weight

Voids Filled with Asphalt (binder) (VFA)

VFA is the volume of space between the aggregate particles of the compacted paving mixture filled with asphalt binder, expressed as a percent of the total volume of the sample. The VFA increases as the asphalt binder content increases as it is the percent of voids that are filled with asphalt which doesn’t include the absorbed asphalt.

$$VFA = 100 \left[ \frac{(VMA - V_a)}{VMA} \right]$$

Where:
- $VFA$ = voids filled with asphalt, percent of VMA (report to 1)
- $VMA$ = voids in mineral aggregate, percent of bulk volume
- $V_a$ = air voids in compacted mixture, percent of total volume.
Effective Specific Gravity of the Aggregate (Stone) \( (G_{se}) \)

The \( G_{se} \) is used to quantify the asphalt binder absorbed into the aggregate particle. This is a calculated value based on the specific gravity of the mixture, \( G_{mm} \), and the specific gravity of the asphalt binder, \( G_b \). This measurement includes the volume of the aggregate particle plus the void volume that becomes filled with water during the test soak period minus the volume of the voids that absorb asphalt binder. Effective specific gravity lies between apparent and bulk specific gravity.

\( G_{se} \) is formally defined as the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

\[
G_{se} = \frac{P_s}{\left( \frac{100}{G_{mm}} \right) - \frac{P_b}{G_b}}
\]

Where:
- \( G_{se} \) = effective specific gravity of combined aggregate (report to 0.001)
- \( P_s \) = aggregate content, percent by total weight = \( 100 - P_b \)
- \( G_{mm} \) = maximum specific gravity of mix (AASHTO T 209)
- \( P_b \) = asphalt binder content (AASHTO T 308) percent by total weight
- \( G_b \) = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Absorbed (asphalt) Binder \( (P_{ba}) \)

\( P_{ba} \) is the total percent of the asphalt binder that is absorbed into the aggregate, expressed as a percentage of the mass of aggregate rather than as a percentage of the total mass of the mixture. This portion of the asphalt binder content does not contribute to the performance of the mix.

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

Where:
- \( P_{ba} \) = absorbed asphalt binder (report to 0.01) percent of aggregate
- \( G_{se} \) = effective specific gravity of combined aggregate
- \( G_{sb} \) = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)
- \( G_b \) = specific gravity of asphalt binder (JMF or asphalt binder supplier)
Percent of Effective (asphalt) Binder ($P_{be}$)

$P_{be}$ is the total asphalt binder content of a paving mixture minus the portion of asphalt binder that is lost by absorption into the aggregate particles, expressed as a percentage of the mass of aggregate. It is the portion of the asphalt binder content that remains as a coating on the outside of the aggregate particles. This is the asphalt content that controls the performance of the mix.

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

Where:
- $P_{be} =$ effective asphalt binder content (report to 0.01), percent by total weight
- $P_s =$ aggregate content, percent by total weight $= 100 - P_b$
- $P_b =$ asphalt binder content (AASHTO T 308) percent by total weight
- $P_{ba} =$ absorbed asphalt binder

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

The DP is the percent passing the No. 200 sieve of the gradation divided by the percent of effective asphalt binder. Excessive dust reduces asphalt binder film thickness on the aggregate which reduces the durability. Insufficient dust may allow excessive asphalt binder film thickness, which may result in a tender, unstable mix.

$$DP = \frac{P_{-\#200}}{P_{be}}$$

Where:
- $DP =$ Dust Proportion, (dust-to-binder ratio) (report to 0.01)
- $P_{-\#200} =$ aggregate passing the -#200 (75 µm) sieve, percent by mass of aggregate (AASHTO T 30)
- $P_{be} =$ effective asphalt binder content, percent by total weight
Mix Design and Production Values

Job Mix Formula

Table 2 includes example data required from the JMF. Some of these values are used in the example calculations.

*Note:* Some of the targets may change after the HMA is in production based on field test data.

### Table 2

<table>
<thead>
<tr>
<th>JMF Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt binder grade</td>
<td>PG 64-28</td>
</tr>
<tr>
<td>(N_{\text{values}})</td>
<td></td>
</tr>
<tr>
<td>(N_{\text{ini}})</td>
<td>7</td>
</tr>
<tr>
<td>(N_{\text{des}})</td>
<td>75</td>
</tr>
<tr>
<td>(N_{\text{max}})</td>
<td>115</td>
</tr>
<tr>
<td>(G_{sb}) (combined specific gravity of the aggregate)</td>
<td>2.678</td>
</tr>
<tr>
<td>Target (P_b)</td>
<td>4.75%</td>
</tr>
<tr>
<td>Initial sample mass for gyratory specimens</td>
<td>4840 grams</td>
</tr>
<tr>
<td>Mixing temperature range</td>
<td>306 – 312 °F</td>
</tr>
<tr>
<td>Laboratory compaction</td>
<td></td>
</tr>
<tr>
<td>temperature range</td>
<td>286 – 294 °F</td>
</tr>
<tr>
<td>(G_b) (specific gravity of the asphalt binder)</td>
<td>1.020</td>
</tr>
</tbody>
</table>

**Target gradation**

<table>
<thead>
<tr>
<th>Sieve Size mm (in.)</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0 (3/4)</td>
<td>100</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>85</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>80</td>
</tr>
<tr>
<td>4.75 (No. 4)</td>
<td>50</td>
</tr>
<tr>
<td>2.36 (No. 8)</td>
<td>30</td>
</tr>
<tr>
<td>01.18 (No. 16)</td>
<td>25</td>
</tr>
<tr>
<td>0.600 (No. 30)</td>
<td>15</td>
</tr>
<tr>
<td>0.300 (No. 50)</td>
<td>10</td>
</tr>
<tr>
<td>0.150 (No. 100)</td>
<td>7</td>
</tr>
<tr>
<td>75 µm (No. 200)</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Sample Test Result

Tables 3 and 4 include data from test results performed on a field sample of HMA used in the example calculations.

Table 3

<table>
<thead>
<tr>
<th>Field Data</th>
<th>Test method</th>
<th>Example values</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&lt;sub&gt;b&lt;/sub&gt;</td>
<td>FOP for AASHTO T 308</td>
<td>4.60%</td>
</tr>
<tr>
<td>G&lt;sub&gt;mb&lt;/sub&gt;</td>
<td>FOP for AASHTO T 166</td>
<td>2.415</td>
</tr>
<tr>
<td>G&lt;sub&gt;mm&lt;/sub&gt;</td>
<td>FOP for AASHTO T 209</td>
<td>2.516</td>
</tr>
</tbody>
</table>

Table 4

<table>
<thead>
<tr>
<th>Sieve Analysis</th>
<th>Sieve Size mm (in.)</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOP for AASHTO T 30</td>
<td>19.0 (3/4)</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>12.5 (1/2)</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>9.5 (3/8)</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>4.75 (No. 4)</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>2.36 (No. 8)</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>01.18 (No. 16)</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>0.600 (No. 30)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>0.300 (No. 50)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>0.150 (No. 100)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>75 µm (No. 200)</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Sample Calculations

Air Voids (V<sub>a</sub>)

\[
V_a = 100 \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right)
\]

\[
V_a = 100 \left( \frac{2.516 - 2.415}{2.516} \right) = 4.01431\% \text{ report } 4.0\%
\]

Given:

\[G_{mm} = 2.516\]

\[G_{mb} = 2.415\]
Percent Aggregate (Stone) \((P_s)\)

\[
P_s = 100 - P_b
\]

\[
P_s = 100.0 - 4.60\% = 95.40\%
\]

Given:

\[
P_b = 4.60\%
\]

Voids in the Mineral Aggregate \((VMA)\)

\[
VMA = 100 - \left[ \frac{G_{mb} \times P_s}{G_{sb}} \right]
\]

\[
VMA = 100.0 - \left[ \frac{2.415 \times 95.40\%}{2.678} \right] = 13.96\% \text{ report } 14.0\%
\]

Given:

\[
G_{sb} = 2.678
\]

Voids Filled with Asphalt (binder) \((VFA)\)

\[
VFA = 100 \left[ \frac{VMA - V_a}{VMA} \right]
\]

\[
VFA = 100 \left[ \frac{(14.0\% - 4.0\%)}{14.0\%} \right] = 71.4\% \text{ report } 71\%
\]
**Effective Specific Gravity of the Aggregate (Stone) \((G_{se})\)**

\[
G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}} \right) - \left(\frac{P_b}{G_b}\right)}
\]

Given:

\[
G_b = 1.020
\]

**Percent of Absorbed (asphalt) Binder \((P_{ba})\)**

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

\[
P_{ba} = 100 \left[ \frac{(2.707 - 2.678)}{2.678 \times 2.707} \right] \times 1.020 =
\]

\[
P_{ba} = 100 \left[ \frac{0.0290}{7.24935} \right] \times 1.020 = 0.40804\% \text{ report 0.41}\%
\]

**Percent of Effective (asphalt) Binder \((P_{be})\)**

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

\[
P_{be} = 4.60 - \left[ \frac{0.41\%}{100} \times (100 - 4.60\%) \right] = 4.20886\% \text{ report 4.21}\%
Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

\[ DP = \frac{P_{-#200}}{P_{be}} \]

\[ DP = \frac{4.9\%}{4.21\%} = 1.16390 \text{ report 1.16} \]

Given:
\[ P_{-#200} = 4.9\% \]

Report

- Results on forms approved by the agency
- Sample ID
- Air Voids, \( V_a \) to 0.1 percent
- Voids in the Mineral Aggregate, \( VMA \) to 0.1 percent
- Voids Filled with Asphalt, \( VFA \) to nearest whole value
- Effective Specific Gravity of Aggregate (stone), \( Gse \) to 0.001
- Percent of Absorbed (asphalt) Binder, \( P_{ba} \) to 0.01
- Percent Effective (asphalt) Binder, \( P_{be} \) to 0.01
- Dust Proportion, \( DP \) to 0.01
Appendix - Formulas

Air Voids ($V_a$)

$$V_a = 100 \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right)$$

Where:

$V_a$ = air voids in compacted mixture, percent of total volume (report to 0.1)

$G_{mm}$ = maximum specific gravity of paving mixture (AASHTO T 209)

$G_{mb}$ = bulk specific gravity of compacted mixture (AASHTO T 166)

Percent Aggregate (Stone) ($P_s$)

$$P_s = 100 - P_b$$

Where:

$P_s$ = percent aggregate (stone) percent by total weight

$P_b$ = asphalt binder content (AASHTO T 308)

Voids in the Mineral Aggregate (VMA)

$$VMA = 100 - \left( \frac{G_{mb} \times P_s}{G_{sb}} \right)$$

Where:

VMA = voids in mineral aggregate, percent of bulk volume (report to 0.1)

$G_{sb}$ = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)

$G_{mb}$ = bulk specific gravity of compacted mixture (AASHTO T 166)

$P_s$ = aggregate content, percent by total weight = 100 – $P_b$

$P_b$ = asphalt binder content (AASHTO T 308) percent by total weight

Voids Filled with Asphalt (binder) (VFA)

$$VFA = 100 \left( \frac{VMA - V_a}{VMA} \right)$$

Where:

VFA = voids filled with asphalt, percent of VMA (report to 1)

VMA = voids in mineral aggregate, percent of bulk volume

$V_a$ = air voids in compacted mixture, percent of total volume.
Effective Specific Gravity of the Aggregate (Stone) \((G_{se})\)

\[
G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}
\]

Where:
- \(G_{se}\) = effective specific gravity of combined aggregate (report to 0.001)
- \(P_s\) = aggregate content, percent by total weight = 100 – \(P_b\)
- \(G_{mm}\) = maximum specific gravity of mix (AASHTO T 209)
- \(P_b\) = asphalt binder content (AASHTO T 308) percent by total weight
- \(G_b\) = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Absorbed (asphalt) Binder \((P_{ba})\)

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

Where:
- \(P_{ba}\) = absorbed asphalt binder (report to 0.01) percent of aggregate
- \(G_{se}\) = effective specific gravity of combined aggregate
- \(G_{sb}\) = bulk specific gravity of combined aggregate (AASHTO T 85 from Job Mix Formula)
- \(G_b\) = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Effective (asphalt) Binder \((P_{be})\)

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

Where:
- \(P_{be}\) = effective asphalt binder content (report to 0.01), percent by total weight
- \(P_s\) = aggregate content, percent by total weight = 100 – \(P_b\)
- \(P_b\) = asphalt binder content (AASHTO T 308) percent by total weight
- \(P_{ba}\) = absorbed asphalt binder

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

\[
DP = \frac{P_{-200}}{P_{be}}
\]

Where:
- \(DP\) = Dust Proportion, (dust-to-binder ratio) (report to 0.01)
- \(P_{-200}\) = aggregate passing the -#200 (75 µm) sieve, percent by mass of aggregate (AASHTO T 30)
- \(P_{be}\) = effective asphalt binder content, percent by total weight
TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATE BY DRYING FOP FOR AASHTO T 255

Scope

This procedure covers the determination of moisture content of aggregate in accordance with AASHTO T 255-00. It may also be used for other construction materials.

Overview

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

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

Apparatus

- Balance or scale: Capacity sufficient for the principle sample mass, accurate to 0.1 percent of sample mass or readable to 0.1 g, meeting the requirements of AASHTO M 231.
- Containers, clean, dry and capable of being sealed
- Suitable drying containers
- Microwave safe container with ventilated lids
- Heat source, controlled
  - Forced draft oven
  - Ventilated oven
  - Convection oven
- Heat source, uncontrolled
  - Infrared heater, hot plate, fry pan, or any other device/method that will dry the sample without altering the material being dried
  - Microwave oven (900 watts minimum)
• Hot pads or gloves

• Utensils such as spoons

Sample Preparation

In accordance with the FOP for AASHTO R 90 obtain a representative sample in its existing condition. The representative sample size is based on Table 1 or other information that may be specified by the agency.

### TABLE 1
Sample Sizes for Moisture Content of Aggregate

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

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

### Procedure

Determine all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.

When determining the mass of hot samples or containers or both, place and tare a buffer between the sample container and the balance. This will eliminate damage to or interference with the operation of the balance or scale.
1. Determine and record the mass of the container (and lid for microwave drying).

2. Place the wet sample in the container.
   
   a. For oven(s), hot plates, infrared heaters, etc.: Spread the sample in the container.
   
   b. For microwave oven: Heap sample in the container; cover with ventilated lid.

3. Determine and record the total mass of the container and wet sample.

4. Determine and record the wet mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 3.

5. Place the sample in one of the following drying apparatus:
   
   
   b. Uncontrolled heat source (Hot plate, infrared heater, etc.): Stir frequently to avoid localized overheating.

6. Dry until sample appears moisture free.

7. Determine mass of sample and container.

8. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 7.

9. Return sample and container to the heat source for additional drying.
   
   a. Controlled (oven): 30 minutes
   
   b. Uncontrolled (Hot plate, infrared heater, etc.): 10 minutes
   
   c. Uncontrolled (Microwave oven): 2 minutes

**Caution:** Some minerals in the sample may cause the aggregate to overheat, altering the aggregate gradation.

10. Determine mass of sample and container.

11. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 10.

12. Determine percent change by subtracting the new mass determination ($M_n$) from the previous mass determination ($M_p$) divide by the previous mass determination ($M_p$) multiply by 100.
13. Continue drying, performing steps 9 through 12, until there is less than a 0.10 percent change after additional drying time.

14. Constant mass has been achieved, sample is defined as dry.

15. Allow the sample to cool. Determine and record the total mass of the container and dry sample.

16. Determine and record the dry mass of the sample by subtracting the mass of the container determined in Step 1 from the mass of the container and sample determined in Step 15.

17. Determine and record percent moisture by subtracting the final dry mass determination ($M_D$) from the initial wet mass determination ($M_W$) divide by the final dry mass determination ($M_D$) multiply by 100.

<table>
<thead>
<tr>
<th>Heat Source</th>
<th>Specific Instructions</th>
<th>Drying intervals to achieve constant mass (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced Draft Oven (preferred),</td>
<td>110 ±5°C (230 ±9°F)</td>
<td>30</td>
</tr>
<tr>
<td>Ventilated Oven, or Convection Oven</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncontrolled:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot plate, Infrared heater, etc.</td>
<td>Stir frequently</td>
<td>10</td>
</tr>
<tr>
<td>Microwave</td>
<td>Heap sample and cover with ventilated lid</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 2
Methods of Drying

**Calculation**

**Constant Mass:**

Calculate constant mass using the following formula:

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

Where:

$M_p$ = previous mass measurement

$M_n$ = new mass measurement
Example:

Mass of container: 1232.1 g

Mass of container after first drying cycle: 2637.2 g

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

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

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

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

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

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

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

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

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

**Moisture Content:**

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

$$\frac{M_W - M_D}{M_D} \times 100 = \% \text{ Moisture Content}$$

where:

$M_W = \text{wet mass}$

$M_D = \text{dry mass}$
Example:

Mass of container: 1232.1 g

Mass of container and wet sample: 2764.7 g

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

Mass of container and dry sample (COOLED): 2633.0 g

Mass, M_D, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

\[ w = \left( \frac{1532.6 \text{ g} - 1400.9 \text{ g}}{1400.9 \text{ g}} \right) \times 100 = \frac{131.7 \text{ g}}{1400.9 \text{ g}} = 9.40\% \text{ rounded to 9.4%} \]

Report

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