Washington State
Department of Transportation

WSDOT SOP 731

Method for Determining Volumetric Properties of Hot Mix Asphalt

1. Scope

This procedure covers the determination of volumetric properties of Hot Mix Asphalt, i.e., Air Voids (Va), Voids in Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA), and Dust to Binder Ratio ($P_{\#200}/P_{be}$).

2. References

T 329	WSDOT FOP for AASHTO Moisture Content of Hot Mix Asphalt (HMA) by Oven Method
T 27/11	WSDOT FOP for WAQTC/AASHTO Sieve Analysis of Fine and Coarse Aggregates
T 166	WSDOT FOP for AASHTO Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
T 168	WSDOT FOP for WAQTC/AASHTO Sampling of Hot Mix Asphalt Paving Mixtures
T 209	WSDOT FOP for AASHTO Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures
T 308	WSDOT FOP for AASHTO Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
T 312	WSDOT FOP for AASHTO Preparing Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
T 712	WSDOT Test Method Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

3. Calibration of Compactor

a. The gyratory compactor will be calibrated in accordance with WSDOT VP-58 and according to the manufacturer's established calibration procedure. Anytime the gyratory compactor is moved to a new testing site a new calibration is required in accordance with WSDOT VP-58.

4. Test Samples

a. All test samples shall be obtained per WSDOT FOP for WAQTC/AASHTO T 168, and reduced in accordance with WSDOT Test Method T 712. It is recommended that the gyratory test sample be the first sample acquired in order to minimize heat loss.

b. The size of the gyratory sample shall be such that it will produce a compacted specimen 115.0 ± 5.0 mm in height. Generally, the mix design verification report from the State Materials Laboratory initial starting mass is adequate.

c. Place the gyratory sample in an oven set no more than 25° F above the compaction temperature (Note 1) as soon as possible to reduce sample cooling. The gyratory test is temperature sensitive. The sample should be heated five degrees above the compaction temperature as shown on the mix design verification report.

Note 1: Any change in compaction temperature must be confirmed by the temperature viscosity chart provided by the asphalt supplier, which can be obtained from the Paving Contractor.

5. Procedure

a. Place a compaction mold, base plate, and top plate (if required), in an oven set at no more than 350°F for a minimum of 60 minutes prior to the estimated beginning of compaction. Subsequent uses of a conditioned mold will require 5 minutes of reheating.

b. Place a thermometer into the center of the mix, do not stir the mixture. (Note 3) Compact the sample immediately upon achieving compaction temperature in accordance with step 4 (c).

Note 2: While the gyratory test sample is heating it is beneficial to prepare and/or run the other tests as times permits.

c. Perform the sample compaction in accordance with WSDOT FOP for AASHTO T 312 Section 9.

d. Determine theoretical maximum density per WSDOT FOP for AASHTO T 209.

e. Determine asphalt content and gradation per WSDOT FOP for AASHTO T 308 and WSDOT FOP for WAQTC/AASHTO T 27/11.

f. Determine moisture content per WSDOT FOP for AASHTO T 329.

g. Allow the gyratory compacted specimen to cool at room temperature for 15 to 24 hours. Determine the Bulk Specific Gravity (Gmb) of the specimen in accordance with WSDOT FOP for AASHTO T 166 Method A.

Note 3: For repeatability between operators the retest sample should be cooled for the same amount of time at room temperature as the original specimen. When sending retest samples to the Region or State Laboratory, note the time the original sample was cooled at room temperature in the remarks section of the transmittal.

6. Volumetric Calculations

Calculations

a. Calculate $\%G_{mm}$ @ N_{design} as follows:

$$\%G_{mm}@N_{design} = \frac{G_{mb}}{G_{mm}} \times 100$$

Example:

$$\%G_{mm}@N_{design} = \frac{2.383}{2.493} \times 100 = 95.6\%$$

Where:

$\%G_{mm}@N_{design}$ = % theoretical maximum specific gravity @ N_{design}
G_{mb} = Bulk specific gravity of the compacted specimen
G_{mm} = Maximum specific gravity of the paving mixture
N_{design} = Number of design gyrations

b. Calculate $\%G_{mm}@N_{ini}$ as follows:

$$\%G_{mm}@N_{ini} = 100 \times \left(\frac{G_{mb} \times h_d}{G_{mm} \times h_i}\right)$$

Example:

$$\%G_{mm}@N_{ini} = 100 \times \left(\frac{2.383 \times 110.0}{2.493 \times 123.1}\right) = 85.4\%$$

Where:

$\%G_{mm}@N_{ini}$ = Percent theoretical maximum specific gravity @ $N_{initial}$
h_d = Height of specimen at design gyration level
h_i = Height of specimen at initial design gyration level
$N_{initial}$ = Number of initial gyrations

c. Calculate Air Voids (V_a) as follow:

$$V_a = 100 \times \left(1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right)$$

Example:

$$V_a = 100 \times \left(1 - \left(\frac{2.383}{2.493}\right)\right) = 4.4\%$$

Where:

V_a = Percent air voids

d. Calculate Voids in Mineral Aggregate (VMA) as follows:

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

Example:

$$VMA = 100 - \left(\frac{(2.383 \times 94.8)}{2.630}\right) = 14.1\%$$

Where:

P_s = Percent of aggregate in the mixture (100-P_b)

Example:
100% mix – 5.2% asphalt = 94.8% aggregate

Where:

G_{sb} = Bulk specific gravity of the combined aggregate
VMA = Voids in Mineral Aggregate, percent

e. Calculate Voids Filled with Asphalt (VFA) as follows:

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

Example:

$$VFA = 100 \times \left(\frac{14.1 - 4.4}{14.1}\right) = 68.8\%$$

Where:

VFA = Voids Filled with Asphalt, percent

f. Calculate Gravity Stone Effective (G_{se}) as follows:

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

Example:

$$G_{se} = \frac{100 - 5.2}{\left(\frac{100}{2.493} - \frac{5.2}{1.025}\right)} = 2.706$$

Where:

G_{se} = Gravity Stone Effective (specific gravity of aggregates, excluding voids permeable to asphalt)
P_b = Percent of binder
G_b = Gravity binder

Note 4: G_b is the specific gravity of the asphalt binder. It is imperative that current G_b is used in the volumetric calculations. Any changes in the binder specific gravity must be confirmed by the temperature viscosity curve provided by the asphalt supplier, which can be obtained from the paving Contractor.

g. Calculate Percent Binder Effective (P_{be}) as follows:

$$P_{be} = P_b - \left(\frac{(P_s \times G_b)(G_{se} - G_{sb})}{(G_{se} \times G_{sb})}\right)$$

Example:

$$P_{be} = 5.2 - \left(\frac{(94.8 \times 1.025)(2.706 - 2.630)}{(2.706 \times 2.630)}\right) = 4.2$$

Where:

P_{be} = Percent binder effective, the percent by mass of effective asphalt content minus the quantity of binder lost by absorption into the aggregate particles.
P_s = Percent of aggregate in the mixture
G_b = Gravity binder
G_{se} = Effective specific gravity of the aggregate
G_{sb} = Bulk specific gravity of the combined aggregate
P_b = Percent of binder

h. Calculate dust-to-binder ratio (P_{200}/P_{be}) as follows:

$$P_{200}/P_{be} = P_{200} \div P_{be}$$

Example:

$5.0 \div 3.6 = 1.4$

Where:

P_{200}/P_{be} = Dust-to-binder ratio
P_{200} = Percent of aggregate passing the No. 200 sieve

7. Report

Report the results using one or more of the following of the following:

- Materials Testing System (MATS)
- WSDOT Form 350-560 for asphalt content, gradation, and moisture content
- WSDOT Form 350-162 for volumetric properties
- Form approved in writing by the State Materials Engineer