

WSDOT FOP for AASHTO T 209¹

Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures

1. Scope

- 1.1 This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted hot-mix asphalt paving mixtures at 77°F (25°C).
- 1.2 The values stated in English units are to be regarded as the standard.
- 1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 AASHTO Standards

M 231 – Weighing Devices Used in the Testing of Materials

R 61 – Establishing Requirements for and Performing Equipment Standardizations and Checks

2.2 ASTM Standards

D 4311 – Practice for Determining Asphalt Volume Correction to a Base Temperature

C 670 – Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3 Other Standards

T 168 – WAQTC FOP for AASHTO for Sampling Bituminous Paving Mixtures

T 712 – WSDOT Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

3. Terminology

3.1 Definitions

- 3.1.1 Density, as determined by this test method. The mass of a cubic meter of the material at 77°F (25°C) in English units, or the mass of a cubic foot of the material at 77°F (25°C) in inch-pound units.
- 3.1.2 Residual pressure, as employed by this test method. The pressure in a vacuum vessel when vacuum is applied.
- 3.1.3 Specific gravity, as determined by this test method. The ratio of a given mass of material at 77°F (25°C) to the mass of an equal volume of water at the same temperature.

¹This FOP is based on AASHTO T 209 (2011) and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.

4. Summary of Test Method

4.1 A weighed sample of HMA paving mixture in the loose condition is placed in a tared vacuum vessel. Sufficient water is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum vessel. At the end of the vacuum period, the vacuum is gradually released. The volume of the sample of paving mixture is obtained by filling the vacuum container level full of water and weighing in air. At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 77°F (25°C) is calculated. If the temperature employed is different from 77°F (25°C), an appropriate correction is applied.

5. Significance and Use

5.1 The theoretical maximum specific gravities and densities of hot-mix asphalt paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt binder materials.

5.1.1 These properties are used to calculate percent air voids in compacted HMA.

5.1.2 These properties provide target values for the compaction of HMA.

5.1.3 These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in HMA.

6. Apparatus

6.1 Follow the procedures for performing equipment standardizations, standardization, and checks found in [R 61](#).

6.2 Vacuum Container

6.2.1 The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of No. 200 (75- μ m) mesh to minimize the loss of fine material.

6.2.2 The capacity of the vacuum container should be between 2000 and 10,000-mL and depends on the minimum sample size requirements given in [Section 7.2](#). Avoid using a small sample in a large container.

6.2.3 Vacuum Bowl – Either a metal or plastic bowl with a diameter of approximately 7.1 to 10.2 in (180 to 260 mm) and a bowl height of at least 6.3 in (160 mm) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4 Vacuum Flask for Weighing in Air Only – A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.2.5 Pycnometer for Weighing in Air Only – A glass, metal, or plastic pycnometer.

- 6.3 Balance, conforming to the requirements of AASHTO M 231, Class G 2. The balance shall be standardized at least every 12 months.
- 6.3.1 For the mass determination-in-water method, the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.
- 6.4 Vacuum pump or water aspirator, capable of evacuating air from the vacuum container to a residual pressure of 30 mm Hg (4.0 kPa) or less.
- 6.4.1 When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.
- 6.5 Absolute pressure gauge or vacuum gauge, used for annual standardization and traceable to NIST (mandatory) to be connected directly to the vacuum vessel and to be capable of measuring residual pressure down to 30 mm Hg (4.0 kPa), or less (preferably to zero). It is to be connected at the end of the vacuum line using an appropriate tube and either a “T” connector on the top of the vessel or by using a separate opening (from the vacuum line) in the top of the vessel to attach the hose.
- Note 2:** A residual pressure of 30 mm Hg (4.0 kPa) absolute pressure is approximately equivalent to 730 mm Hg (97 kPa) reading on vacuum gauge at sea level.
- 6.6 Bleeder valve, attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel.
- 6.7 Thermometric device (mass determination in air), liquid-in-glass thermometers, or other suitable thermometric device, accurate to 1°F (0.5°C). The thermometric device shall be standardized at the test temperature at least every 12 months.
- 6.8 Water bath that can be maintained at a constant temperature between 73 and 82.9°F (22.8 and 28.3°C).
- 6.9 Protective gloves, used when handling glass equipment under vacuum.
- 6.10 Mallet, with a rubber or rawhide head.

7. Sampling

- 7.1 Obtain the sample in accordance with WAQTC FOP for AASHTO T 168 and WSDOT T 712.
- 7.2 The size of the sample shall conform to the requirements in [Table 1](#). Samples larger than the capacity of the container may be tested a portion at a time.

Nominal Maximum Aggregate Size, in (mm)	Minimum Sample Size, lb (g)
1½ (37.5) or greater	8 (4000)
¾ (19) to 1 (25)	5 (2500)
½ (12.5) or smaller	3 (1500)

Minimum Sample Sizes

Table 1

8. Standardization of Flasks, Bowls, and Pycnometers

This section has been deleted by WSDOT and replaced with the following:

The volumetric flask or metal vacuum pycnometer will be standardized periodically in conformance with established verification procedures or per AASHTO T 209. Standardization shall be done at 77°F.

9. Sample Preparation

9.1 Separate the particles of the HMA sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than ¼ in (6.3 mm). If an HMA sample is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

9.2 WSDOT has deleted this section.

9.3 Cool the sample to room temperature and place it in a tared and standardized flask, bowl, or pycnometer. Weigh and designate the net mass of the sample as A. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

Test Method A – Mechanical Agitation

10. Apparatus

10.1 In addition to the apparatus listed in [Section 6](#), the following apparatus is required for Method A.

10.1.1 Mechanical shaker-shaker for removing air from asphalt mix.

11. Procedure

11.1 Remove air trapped in the sample by applying gradually increased vacuum until the absolute pressure gauge or vacuum gauge reads 30 mm HG or less (4.0 kPa or less). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents using the mechanical device during the vacuum period. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum. To aid in releasing the trapped air from the metal vacuum pycnometer, tap the sides of the metal vacuum pycnometer 3 to 5 times with the mallet at approximately two-minute intervals.

Note: The release of entrapped air may be facilitated by the addition of a few drops of suitable wetting agent.

- 11.2 At the end of the vacuum period, release the vacuum within 10 to 15 seconds. Start the 9 to 11 minute time, as described in [Section 13.2](#), immediately upon starting the release of vacuum. Proceed to [Section 13.2](#).

Test Method B – Manual Agitation

12. Procedure

- 12.1 Remove air trapped in the sample by applying gradually increased vacuum until the absolute pressure gauge or vacuum gauge reads 30 mm HG or less (4.0 kPa or less). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period by vigorous shaking at intervals of about 2 minutes. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.
- 12.2 At the end of the vacuum period, release the vacuum within 10 to 15 seconds. Start the 9 to 11 minute time, as described in [Section 13.2](#) immediately upon starting the release of vacuum. Proceed to [Section 13.2](#).

13. Mass Determination

- 13.1 WSDOT has deleted this section.
- 13.2 Mass Determination in Air – Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of $77 \pm 2^\circ\text{F}$ ($25 \pm 1^\circ\text{C}$) in a constant temperature water bath. Determine the mass of the container (and contents), completely filled, 9 to 11 minutes after starting [Section 11.2](#) or [12.1](#). Designate this mass as E. Accurate filling may be ensured by the use of a glass cover plate.

In lieu of a constant temperature water bath described above, determine the temperature of the water within the flask or metal vacuum pycnometer and determine the appropriate density correction factor “R” using [Table 2](#).

14. Calculation

- 14.1 Calculate the theoretical maximum specific gravity of the sample at 77°F (25°C) as follows:
- 14.1.1 WSDOT has deleted this section.
- 14.1.2 Weighing Mass Determination in Air

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{A + D - E}$$

Where:

- A = Mass of oven-dry sample in air, g
 D = Mass of container filled with water at 77°F (25°C), g
 E = Mass of container filled with sample and water at 77°F (25°C), g

- 14.1.3 If the test temperature differs significantly from 77°F (25°C), correct for thermal effects as follows:

WSDOT has removed the AASHTO calculation and replaced it with the following calculations:

- a. Determination using temperature correction:

$$\text{Theoretical Maximum Gravity} = \frac{A}{A + D - E} \times R$$

Where:

- A = Mass of oven-dry sample in air, g;
- D = Mass of container filled with water at 77°F (25°C), g; and
- E = Mass of container filled with sample and water at 77°F (25°C), g.
- R = Factor from Table 2 to correct density of water from the test temperature to 77°F (25°C).

Note: The flask standardization is done at 77 ± 0.4°F (25 ± 0.2°C).

C°	F°	"R"	C°	F°	"R"
22.8	73.0	1.00054	25.2	77.4	0.99995
23.0	73.4	1.00050	25.4	77.7	0.99990
23.2	73.8	1.00045	25.6	78.1	0.99984
23.3	73.9	1.00042	25.8	78.4	0.99979
23.4	74.1	1.00040	26.0	78.8	0.99974
23.6	74.5	1.00035	26.1	79.0	0.99971
23.8	74.8	1.00030	26.2	79.2	0.99968
23.9	75.0	1.00028	26.4	79.5	0.99963
24.0	75.2	1.00025	26.6	79.9	0.99958
24.2	75.6	1.00020	26.7	80.1	0.99955
24.4	75.9	1.00015	27.2	81.0	0.99941
24.6	76.3	1.00010	27.3	81.1	0.99938
24.8	76.6	1.00005	27.8	82.0	0.99924
25.0	77.0	1.00000	28.3	82.9	0.99910

Density Correction Factor "R"

Table 2

- b. Determination using weighted average:

$$\text{Weighted Average Maximum Specific Gravity} = \frac{(\text{Sp.G}_1 \times A_1) + (\text{Sp.G}_2 \times A_2)}{(A_1 + A_2)}$$

Where:

- Sp.G₁ = Specific gravity of first test segment
- Sp.G₂ = Specific gravity of second test segment
- A₁ and A₂ = Mass of dry sample in air of respective test segments

14.2 Theoretical Maximum Density (Rice) at 77°F (25°C)

- 14.2.1 Calculate the corresponding theoretical maximum density at 77°F (25°C) as follows:

Theoretical maximum density at 77°F (25°C) = theoretical maximum specific gravity \times 62.245 lb/ft³ in inch-pound units (or 997.1 kg/m³ in SI units).

Where:

The specific gravity of water at 77°F (25°C) = 62.245 in inch-pound units (or 997.1 in SI units).

15. Supplemental Procedure for Mixtures Containing Porous Aggregate

WSDOT has removed this section.

16. Report

- 16.1 Report the results using one of the following:

- Materials Testing System (MATS)
- DOT Form 350-092 and 350-157
- Form approved in writing by the State Materials Engineer

- 16.2 Report the Theoretical Maximum Specific Gravity (G_{mm}) to three decimal places.
Report the Theoretical Maximum Density to 0.1 lb/ft³.

17. Precision

See AASHTO T 209 for Precision.

Appendix

(Nonmandatory Information)

A1. Theoretical Maximum Specific Gravity for a Loose-Paving Mixture

WSDOT has removed this section.

Performance Exam Checklist

Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures FOP for AASHTO T 209

Participant Name _____ Exam Date _____

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	<input type="checkbox"/>	<input type="checkbox"/>
2. All equipment is functioning according to the test procedure, and if required, has the current standardization/verification tags present?	<input type="checkbox"/>	<input type="checkbox"/>
3. Particles of sample separated?	<input type="checkbox"/>	<input type="checkbox"/>
4. Care used not to fracture mineral fragments?	<input type="checkbox"/>	<input type="checkbox"/>
5. After separation, fine HMA particles not larger than ¼ inch?	<input type="checkbox"/>	<input type="checkbox"/>
6. Sample at room temperature?	<input type="checkbox"/>	<input type="checkbox"/>
7. Mass of bowl or flask determined?	<input type="checkbox"/>	<input type="checkbox"/>
8. Mass of sample and bowl or flask determined?	<input type="checkbox"/>	<input type="checkbox"/>
9. Mass of sample determined?	<input type="checkbox"/>	<input type="checkbox"/>
10. Water at approximately 77°F (25°C) added to cover sample?	<input type="checkbox"/>	<input type="checkbox"/>
11. Entrapped air removed using partial vacuum for 15 ± 2 min?	<input type="checkbox"/>	<input type="checkbox"/>
12. Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes?	<input type="checkbox"/>	<input type="checkbox"/>
13. For metal pycnometer, strike 3 to 5 times with a mallet?	<input type="checkbox"/>	<input type="checkbox"/>
14. Release of entrapped air facilitated by addition of suitable wetting agent (optional)?	<input type="checkbox"/>	<input type="checkbox"/>
15. Vacuum released within 10 to 15 seconds.	<input type="checkbox"/>	<input type="checkbox"/>
16. Flask determination:		
a. Flask filled with water?	<input type="checkbox"/>	<input type="checkbox"/>
1. Flask then placed in constant temperature water bath (optional) or?	<input type="checkbox"/>	<input type="checkbox"/>
2. Temperature of water in flask determined upon completion of 16b?	<input type="checkbox"/>	<input type="checkbox"/>
b. Contents at 77 ± 2°F or density of water corrected using Table 2 in FOP?	<input type="checkbox"/>	<input type="checkbox"/>
c. Mass of filled flask determined 9 to 11 minutes after removal of entrapped air completed?	<input type="checkbox"/>	<input type="checkbox"/>
17. All calculations performed correctly?	<input type="checkbox"/>	<input type="checkbox"/>

First Attempt: Pass Fail

Second Attempt: Pass Fail

Signature of Examiner _____

Comments: