

THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT (HMA) PAVING MIXTURES FOP FOR AASHTO T 209 (09)

Scope

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

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

Apparatus

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

Standardization of Flask

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

Test Sample Preparation

1. Obtain samples in accordance with the FOP for AASHTO T 168 and reduce according to the FOP for AASHTO R 47.
2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.018 for the bowl method and 0.011 for the flask method, the test must be re-run.

**Table 1
Test Sample Size for G_{mm}**

Nominal Maximum Aggregate Size mm (in.)	Minimum Mass g
37.5 or greater (1 ½)	4000
19 to 25 (¾-1)	2500
12.5 or smaller (½)	1500

Procedure – General

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

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (¼ in.). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.
2. Cool the sample to room temperature.
3. Determine and record the mass of the dry bowl or flask, including the cover, to the nearest 0.1 g.
4. Place the sample in the bowl or flask.
5. Determine and record the mass of the dry bowl or flask, cover, and sample to the nearest 0.1 g.
6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A”.
7. Add sufficient water at approximately 25° ±1°C (77° ±1.8°F) to cover the sample by about 25 mm (1 in.).

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

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

9. Remove entrapped air by subjecting the contents to a partial vacuum of 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg) residual pressure for 15 ± 2 minutes.
10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2 minute intervals. This agitation facilitates the removal of air.
11. Turn off the vacuum pump, slowly open the release valve, and remove the lid. When performing the flask method, complete steps 12B through 16B within 10 ± 1 minutes.

Procedure – Bowl

- 12A. Suspend and immerse the bowl and contents in water at $25 \pm 1.0^\circ\text{C}$ ($77 \pm 1.8^\circ\text{F}$) for 10 ± 1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.
- 13A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.
- 14A. Empty and re-submerge the bowl following Step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.
- 15A. Determine and record the submerged weight of the sample the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 13A. Designate this submerged weight as “C”.

Procedure – Flask

- 12B. Immediately fill the flask with water without reintroducing air.
- 13B. Stabilize the temperature of the flask and contents in a water bath so that the final temperature is within $25 \pm 1^\circ\text{C}$ ($77 \pm 1.8^\circ\text{F}$).
Note 2: In lieu of placing the flask in the water bath, determine the temperature of the water in the flask and make the appropriate density correction using Table 2 when the temperature is outside $25 \pm 1^\circ\text{C}$ ($77 \pm 1.8^\circ\text{F}$).
- 14B. Finish filling the flask, place the cover or a glass plate on the flask, and eliminate all air from the flask.
Note 3: When using the metal flask and cover, place the cover on the flask and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling flask to avoid reintroducing air into the water.
- 15B. Towel dry the outside of the flask and cover.
- 16B. Determine and record the mass of the flask, cover, de-aired water, and sample to the nearest 0.1 g. within 10 ± 1 minutes of completion of Step 11. Designate this mass as “E”.

Procedure – Mixtures Containing Uncoated Porous Aggregate

If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the vacuuming procedure, resulting in an error in

maximum density. To determine if this has occurred, complete the general procedure and then:

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.
2. Spread sample before an electric fan to remove surface moisture.
3. Determine the mass of the sample when the surface moisture appears to be gone.
4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.
5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as “A_{SSD}”.
6. Calculate, as indicated below, G_{mm}, using “A” and “A_{SSD}”, and compare the two values.

Calculation

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

Bowl Procedure

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

where:

A = mass of dry sample in air, g

C = submerged weight of sample in water, g

Example:

A = 1432.7 g

C = 848.6 g

$$G_{mm} = \frac{1432.7 \text{ g}}{1432.7 \text{ g} - 848.6 \text{ g}} = 2.453$$

Flask Procedure

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

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

(for mixtures containing uncoated aggregate materials)

where:

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

Example (in which two increments are averaged):

Test 1	Test 2
A = 1200.3 g	A = 960.2 g
D = 7502.5 g	D = 7525.5 g
E = 8217.1 g	E = 8096.3 g
Temperature = 26.2°C	Temperature = 25.0°C

$$G_{mm1} = \frac{1200.3 \text{ g}}{1200.3 \text{ g} + 7502.5 \text{ g} - 8217.1 \text{ g}} \times 0.99968 = 2.470$$

$$G_{mm2} = \frac{960.2 \text{ g}}{960.2 \text{ g} + 7525.5 \text{ g} - 8096.3 \text{ g}} \times 1.00000 = 2.466$$

Allowable variation is: 0.011 for the Flask method and 0.018 for the Bowl method

2.470 - 2.466 = 0.004, which is < 0.011, so they can be averaged.

Average

$$2.470 - 2.466 = 0.004 \quad 0.004 \div 2 = 0.002 \quad 0.002 + 2.466 = \mathbf{2.468}$$

$$\text{Or } 2.470 + 2.466 = 4.936 \quad 4.936 \div 2 = 2.468$$

**Table 2
Temperature Correction Factor**

°C	°F	“R”		°C	°F	“R”
20.0	68.0	1.00117		23.3	74.9	1.00042
20.1	68.2	1.00114		23.4	74.1	1.00040
20.2	68.4	1.00112		23.5	74.3	1.00037
20.3	68.5	1.00110		23.6	74.5	1.00035
20.4	68.7	1.00108		23.7	74.7	1.00033
20.5	68.9	1.00106		23.8	74.8	1.00030
20.6	69.1	1.00104		23.9	75.0	1.00028
20.7	69.3	1.00102		24.0	75.2	1.00025
20.8	69.4	1.00100		24.1	75.4	1.00023
20.9	69.6	1.00097		24.2	75.6	1.00020
21.0	69.8	1.00095		24.3	75.7	1.00018
21.1	70.0	1.00093		24.4	75.9	1.00015
21.2	70.2	1.00091		24.5	76.1	1.00013
21.3	70.3	1.00089		24.6	76.3	1.00010
21.4	70.5	1.00086		24.7	76.5	1.00007
21.5	70.7	1.00084		24.8	76.6	1.00005
21.6	70.9	1.00082		24.9	76.8	1.00002
21.7	71.1	1.00080		25.0	77.0	1.00000
21.8	71.2	1.00077		25.1	77.2	0.99997
21.9	71.4	1.00075		25.2	77.4	0.99995
22.0	71.6	1.00073		25.3	77.5	0.99992
22.1	71.8	1.00030		25.4	77.7	0.99989
22.2	72.0	1.00068		25.5	77.9	0.99987
22.3	72.1	1.00066		25.6	78.1	0.99984
22.4	72.3	1.00064		25.7	78.3	0.99981
22.5	72.5	1.00061		25.8	78.4	0.99979
22.6	72.7	1.00059		25.9	78.6	0.99976
22.7	72.9	1.00057		26.0	78.8	0.99973
22.8	73.0	1.00054		26.1	79.0	0.99971
22.9	73.2	1.00052		26.2	79.2	0.99968
23.0	73.4	1.00050		26.3	79.3	0.99965
23.1	73.6	1.00047		26.4	79.5	0.99963
23.2	73.8	1.00045		26.5	79.7	0.99960

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.

$$\text{Theoretical maximum density kg/m}^3 = G_{\text{mm}} \times 997.1 \text{ kg/ m}^3$$

$$2.468 \times 997.1 \text{ kg/ m}^3 = 2461 \text{ kg/ m}^3$$

or

$$\text{Theoretical maximum density lb/ft}^3 = G_{\text{mm}} \times 62.245 \text{ lb/ft}^3$$

$$2.468 \times 62.245 \text{ lb/ft}^3 = 153.6 \text{ lb/ft}^3$$

Report

Results shall be reported on standard forms approved for use by the agency. Report G_{mm} to three decimal places. Report the theoretical maximum density to 1 kg/m³ (0.1 lb/ft³).

PERFORMANCE EXAM CHECKLIST

**THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT (HMA) PAVING MIXTURES
FOP FOR AASHTO T 209**

Participant Name _____ Exam Date _____

Record the symbols “P” for passing or “F” for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Sample reduced to correct size?	_____	_____
2. Particles carefully separated insuring that aggregate is not fractured?	_____	_____
3. After separation, fine aggregate particles not larger than 6.3 mm (1/4in)?	_____	_____
4. Sample at room temperature?	_____	_____
5. Mass of bowl or flask & cover determined to 0.1 g?	_____	_____
6. Mass of sample and bowl or flask & cover determined to 0.1 g?	_____	_____
7. Mass of sample calculated and conforms to required size?	_____	_____
8. Water at approximately 25°C (77°F) added to cover sample?	_____	_____
9. Entrapped air removed using partial vacuum for 15 ±2 min?	_____	_____
10. Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes?	_____	_____
11. Bowl determination:		
a. Bowl and contents suspended in water at 25 ±1°C (77 ±1.8°F) for 10 ±1 minutes?	_____	_____
b. Submerged weight of bowl and contents determined to 0.1 g?	_____	_____
c. Submerged weight of empty bowl determined to 0.1 g?	_____	_____
d. Net submerged weight of contents calculated?	_____	_____
12. Flask determination:		
a. Flask filled with water without reintroducing air into the sample?	_____	_____
b. Flask then placed in constant temperature water bath (optional)?	_____	_____
c. Contents at 25 ±1°C (77 ±1.8°F) or temperature taken and Table 2 in FOP used?	_____	_____
d. Mass of filled flask determined to 0.1 g, 10 ±1 minutes after removal of entrapped air completed?	_____	_____

OVER

Procedure Element

Trial 1 Trial 2

e. Mass of flask and water obtained from the Standardization of Flask procedure?

13. G_{mm} calculated correctly and to 0.001?

14. Density calculated correctly and to 1 kg/m^3 (0.1 lb/ft^3)?

Comments: First attempt: Pass Fail Second attempt: Pass Fail

Examiner Signature _____ WAQTC #: _____