

## THEORETICAL MAXIMUM SPECIFIC GRAVITY ( $G_{mm}$ ) AND DENSITY OF ASPHALT MIXTURES FOP FOR AASHTO T 209

### Scope

This procedure covers the determination of the maximum specific gravity ( $G_{mm}$ ) of uncompacted asphalt mixtures in accordance with AASHTO T 209-~~1920~~. 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, meeting AASHTO M 231, Class G2
- 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~~full vacuum applied
- 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)
- Vacuum measurement device: 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 and accurate to 0.1 kPa (1 mm Hg)
- 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 for Pycnometer or Volumetric Flask Method)
- Thermometers: ~~Standardized liquid-in-glass, or electronic digital total immersion type,~~ Thermometric devices accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Automatic vacuum control unit (optional)
- Timer
- Towel

**Standardization of Pycnometer or Volumetric Flask**

Use a ~~pycnometer / volumetric flask~~ container that ~~is~~ has been standardized according to accurately determine the mass of water, at  $25 \pm 0.5^{\circ}\text{C}$  ( $77 \pm 1^{\circ}\text{F}$ ), in the ~~pycnometer / volumetric flask~~. Annex A. The ~~pycnometer / volumetric flask~~ container 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 R 97 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 by calculating the weighted average ( $G_{mm (avg)}$ )~~. If the increments have a specific gravity difference greater than 0.014, 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 (1½)	4000
19 to 25 (¾ to 1)	2500
12.5 or smaller (½)	1500

\*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  $25^{\circ}\text{C}$  ( $77^{\circ}\text{F}$ ) 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 contentssample to a partial vacuum of  $3.7 \pm 0.3$  kPa ( $27.5 \pm 2.5$  mm Hg) residual pressure for  $15 \pm 2$  minutes.
10. Agitate the container and contentssample, 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  $10 \pm 1$  minute.

### Procedure – Bowl

- 12A. Fill the water bath to overflow level with water at  $25 \pm 1^\circ\text{C}$  ( $77 \pm 2^\circ\text{F}$ ) 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 contentssample in water at  $25 \pm 1^\circ\text{C}$  ( $77 \pm 2^\circ\text{F}$ ) for  $10 \pm 1$  minute. The holder shall be immersed sufficiently to cover both it and the bowl.
- 15A. Determine and record the submerged weight of the bowl and contentssample to the nearest 0.1 g. Designate as 'C.'
- ~~1. 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 ~~content~~sample so that the final temperature is within  $25 \pm 1^\circ\text{C}$  ( $77 \pm 2^\circ\text{F}$ ).
- 14B. Finish filling the pycnometer / volumetric flask with water that is  $25 \pm 1^\circ\text{C}$  ( $77 \pm 2^\circ\text{F}$ ), 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  $10 \pm 1$  minute 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,  $G_{mm}$  using “A” and “Assd,” and compare the two values.

### Calculation

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

#### Bowl Procedure

$$G_{mm} = \frac{A}{A - C} \frac{A}{A + B - C} \quad \text{or} \quad G_{mm} = \frac{A}{A_{SSD} - C} \frac{A}{A_{SSD} + B - C}$$

(for mixes containing uncoated aggregate materials)

~~where~~ Where:

- A = mass of dry sample in air, g
- A<sub>SSD</sub> = ~~Mass~~ mass of saturated surface dry sample in air, g
- B = standardized submerged weight of the bowl, g, (see Annex A)
- C = submerged weight of sample ~~in water~~ and bowl, g

#### Example:

$$G_{mm} = \frac{1432.7 \text{ g}}{1432.7 \text{ g} + 286.3 \text{ g} - 1134.9 \text{ g}} = 2.453 \quad \text{or}$$

$$G_{mm} = \frac{1432.7 \text{ g}}{1434.2 \text{ g} + 286.3 \text{ g} - 1134.9 \text{ g}} = 2.447$$

Given:

- A = 1432.7 g
- A<sub>SSD</sub> = 1434.2 g
- B = 286.3 g
- C = ~~848.6~~ 1134.9 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 mixtures containing uncoated materials)

~~where~~ Where:

A = ~~Mass~~ Mass = mass of dry sample in air, g

ASDD = ~~Mass~~ Mass = mass of saturated surface-dry sample in air, g

D = ~~Mass~~ Mass = standardized mass of pycnometer / volumetric flask filled with water at 25°C (77°F), g, ~~determined during the Standardization of Pycnometer / Volumetric Flask procedure~~ (See Annex A)

E = ~~Mass~~ Mass = 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):**

<u>Increment 1</u>	<u>Increment 2</u>
A = 2200.3 g	A = 1960.2 g
D = 7502.5 g	D = 7525.5 g
E = 8812.0 g	E = 8690.8 g
Temperature = 26.2°C	Temperature = 25.0°C

$$G_{mm_1} = \frac{2200.3 \text{ g}}{2200.3 \text{ g} + 7502.5 \text{ g} - 8812.0 \text{ g}} = 2.470$$

$$G_{mm_2} = \frac{1960.2 \text{ g}}{1960.2 \text{ g} + 7525.5 \text{ g} - 8690.8 \text{ g}} \times 1.00000 = 2.466$$

Given:

<u>Increment 1</u>	<u>Increment 2</u>
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~~Allowable variation is: 0.014~~

<u>A<sub>1</sub> = 2200.3 g</u>	<u>A<sub>2</sub> = 1960.2 g</u>
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<u>D<sub>1</sub> = 7502.5 g</u>	<u>D<sub>2</sub> = 7525.5 g</u>
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<u>E<sub>1</sub> = 8812.0 g</u>	<u>E<sub>2</sub> = 8690.8 g</u>
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Variation = 2.470 - 2.466 = 0.004, which is < 0.014, so they can

Allowable variation is: 0.014. The values may be averaged used.

Average:

$$\text{---} 2.470 + 2.466 = 4.936 \text{---} 4.936 \div 2 = \mathbf{2.468}$$

**Weighted average**

For large samples tested a portion at a time, calculate the  $G_{mm(avg)}$  by multiplying the dry mass of each increment by its  $G_{mm}$ , add the results together ( $\Sigma$ ) and divide by the sum ( $\Sigma$ ) of the dry masses.

$$G_{mm(avg)} = \frac{\Sigma(A_x \times G_{mm_x})}{\Sigma A_x}$$

or

$$G_{mm(avg)} = \frac{(A_1 \times G_{mm_1}) + (A_2 \times G_{mm_2})}{A_1 + A_2} \text{ etc.}$$

Where:

$A_x$  = mass of dry sample increment in air, g

$G_{mm_x}$  = theoretical maximum specific gravity of the increment

**Example:**

$$G_{mm(avg)} = \frac{(2200.3 \text{ g} \times 2.470) + (1960.2 \text{ g} \times 2.466)}{2200.3 \text{ g} + 1960.2 \text{ g}} = \frac{10,268.6}{4160.5 \text{ g}} = 2.468$$

**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.

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

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

or

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

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

### Report

- ~~Results on~~ On forms approved by the agency
- Sample ID
- $G_{mm}$  to the nearest 0.001
- Theoretical maximum density to the nearest  $1 \text{ kg/m}^3$  ( $0.1 \text{ lb/ft}^3$ )



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## **ANNEX A – STANDARDIZATION OF BOWL AND PYCNOMETER OR VOLUMETRIC FLASK**

(Mandatory Information)

### **Bowl – Standardization**

1. Fill the water bath to overflow level with  $25 \pm 1^{\circ}\text{C}$  ( $77 \pm 2^{\circ}\text{F}$ ) water and allow the water to stabilize.
2. 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.
3. Suspend and completely immerse the bowl for  $10 \pm 1$  minute.
4. Determine and record the submerged weight of the bowl to the nearest 0.1 g.
5. Refill the water bath to overflow level.
6. Repeat Steps 2 through 5 two more times for a total of three determinations.
7. If the three determinations are within 3 g., average the determinations. Designate as “B.”
8. If the variation of the three determinations is greater than 0.3 g., take corrective action and perform the standardization procedure again.

### **Bowl – Check**

1. Fill the water bath to overflow level  $25 \pm 1^{\circ}\text{C}$  ( $77 \pm 2^{\circ}\text{F}$ ) water and allow the water to stabilize.
2. 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.
3. Suspend and completely immerse the bowl for  $10 \pm 1$  minute.
4. Determine and record the submerged weight of the bowl to the nearest 0.1 g.
5. If this determination is within 0.3 g of the standardized value, use the standardized value for “B.”
6. If it is not within 0.3 g, take corrective action and perform the standardization procedure again.

### **Pycnometer or Volumetric Flask – Standardization**

1. Fill the pycnometer / volumetric flask with water at approximately  $25^{\circ}\text{C}$  ( $77^{\circ}\text{F}$ ).
2. Place the metal or plastic cover, or a glass plate on the pycnometer / volumetric flask and eliminate all air. (See Note 2.)
3. Stabilize the pycnometer / volumetric flask at  $25 \pm 1^{\circ}\text{C}$  ( $77 \pm 2^{\circ}\text{F}$ ) for  $10 \pm 1$  min.
4. Towel dry the outside of the pycnometer / volumetric flask and cover.
5. Determine and record the mass of the pycnometer / volumetric flask, water, and lid to the nearest 0.1 g.

6. Repeat Steps 2 through 5 two more times for a total of three determinations.
7. If the three determinations are within 0.3 g, average the three determinations. Designate as “D.”
8. If the variation of the determinations is greater than 0.3 g., take corrective action and perform the “Pycnometer or Volumetric Flask – Standardization” again.

### **Pycnometer or Volumetric Flask – Check**

1. Fill the pycnometer / volumetric flask with water at approximately 25°C (77°F).
2. Place the metal or plastic cover or a glass plate on the pycnometer / volumetric flask and eliminate all air. (See Note 2.)
3. Stabilize the pycnometer / volumetric flask at 25 ± 1°C (77 ± 2°F) for 10 ± 1 min.
4. Towel dry the outside of the pycnometer / volumetric flask and cover.
5. Determine and record the mass of the pycnometer / volumetric flask, water, and lid.
6. If this determination is within 0.3 g of the standardized value, use the standardized value for “D.”
7. If it is not within 0.3 g, perform the standardization procedure again.