
Standard Method of Test for

**Theoretical Maximum Specific
Gravity (G_{mm}) and Density of
Asphalt Mixtures**

AASHTO Designation: T 209-19

Technical Subcommittee: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (July)



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1. SCOPE

- 1.1. This test method covers the determination of the theoretical maximum specific gravity/gravity mix maximum (G_{mm}) and density of uncompacted asphalt mixture at 25°C (77°F).
Note 1—The precision of the method is best when the procedure is performed on samples that contain aggregates that are completely coated. In order to assure complete coating, it is desirable to perform the method on samples that are close to the optimum asphalt binder content.
- 1.2. The values stated in SI units are to be regarded as the standard.
- 1.3. *This standard may involve hazardous materials, operations, and equipment. 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.*
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2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 231, Weighing Devices Used in the Testing of Materials
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
 - R 47, Reducing Samples of Asphalt Mixtures to Testing Size
 - R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
 - R 97, Sampling Asphalt Mixtures
- 2.2. *ASTM Standard:*
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
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3. TERMINOLOGY

- 3.1. *Definitions:*
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- 3.1.1. *density, as determined by this test method*—the mass of a cubic meter of the material at 25°C (77°F) in SI units, or the mass of a cubic foot of the material at 25°C (77°F) 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 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. SIGNIFICANCE AND USE

- 4.1. The theoretical maximum specific gravity (G_{mm}) and density of asphalt mixture are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt materials.
 - 4.1.1. These properties are used to calculate percent air voids in compacted asphalt mixture.
 - 4.1.2. These properties provide target values for the compaction of asphalt mixture.
 - 4.1.3. These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in asphalt mixture.

5. APPARATUS

- 5.1. Follow the procedures for performing equipment calibrations, standardizations, and checks that conform to R 18 and R 61.
- 5.2. *Vacuum Container:*
 - 5.2.1. 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 0.075-mm (No. 200) wire mesh to minimize the loss of fine material.
 - 5.2.2. 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 6.3. Avoid using a small sample in a large container.
 - 5.2.3. *Bowl for Mass Determination in Water Only (Section 11.1)*—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.
 - 5.2.4. *Flask for Mass Determination in Air Only (Section 11.2)*—A thick-walled volumetric glass flask with a factory-inscribed line and a rubber stopper with a connection for the vacuum line.
 - 5.2.5. *Pycnometer for Mass Determination in Air Only (Section 11.2)*—A glass, metal, or plastic pycnometer with a volume defined by means of a glass capillary stopper, capillary lid, or glass plate.
- 5.3. *Balance*—A balance conforming to the requirements of M 231, Class G 2. The balance shall be standardized at least every 12 months.

- 5.3.1. For the mass determination-in-water method (Section 11.1), 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.
- 5.4. *Vacuum Pump or Water Aspirator*—Capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mmHg).
- 5.4.1. When an oil 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.
- 5.5. *Vacuum Measurement Device*—Residual pressure manometer¹ or vacuum gauge to be connected directly to the vacuum vessel and capable of measuring residual pressure down to 4.0 kPa (30 mmHg) or less (preferably to zero). The device shall be standardized at least annually and be accurate to 0.1 kPa (1 mmHg). It shall 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 a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer shall not be situated on top of the vessel.

Note 2—A residual pressure of 4.0 kPa (30 mmHg) absolute pressure is approximately equivalent to a 97 kPa (730 mmHg) reading on a vacuum gauge at sea level.

Note 3—Residual pressure in the vacuum container, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum container.

Note 4—An example of a suitable arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum container that otherwise would enter the oil in the vacuum pump and decrease the pump’s ability to provide adequate vacuum.

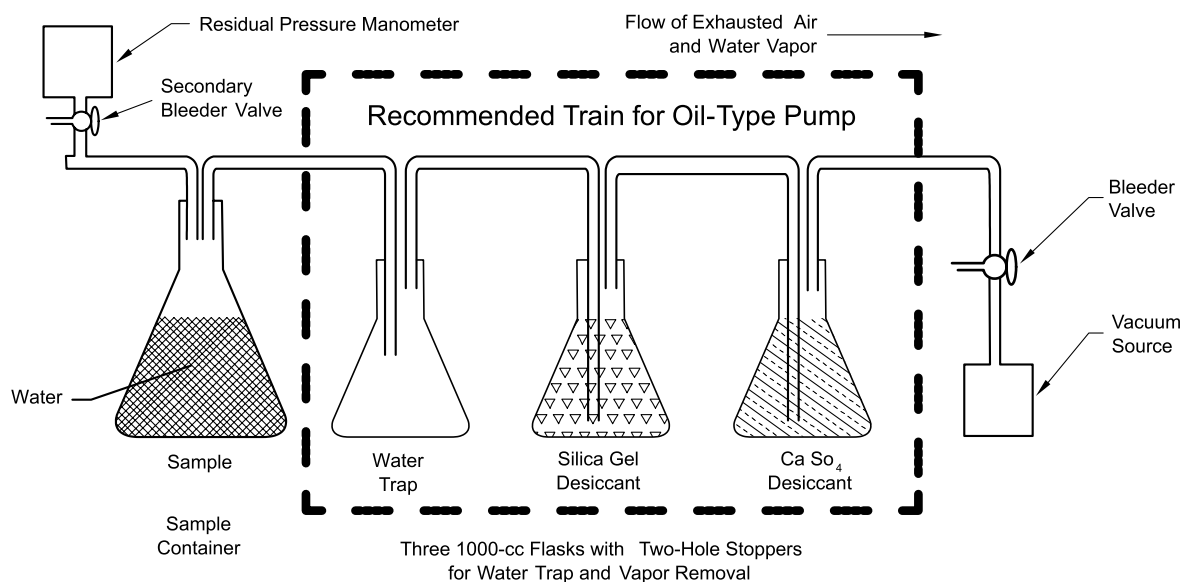


Figure 1—Example of Suitable Arrangement of Testing Apparatus

- 5.6. *Bleeder Valve*—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.

- 5.7. *Thermometer (Mass Determination in Air)*—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F), of suitable range with subdivisions of 0.5°C (1°F). The thermometer shall be standardized at the test temperature at least every 12 months.
- 5.8. *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 135 ± 5°C (275 ± 9°F) or 105 ± 5°C (221 ± 9°F).
- 5.8.1. *Thermometer*—A liquid-in-glass thermometer or other thermometric device accurate to 3°C (5°F) shall be used to measure the temperature of the oven. The thermometer shall be standardized at least every 12 months.
- 5.9. *Water Bath:*
- 5.9.1. For bowls, a water bath capable of maintaining a constant temperature between 20 and 30°C (68 and 86°F) is required.
- 5.9.2. *Thermometer (Mass Determination in Water)*—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F) shall be used to measure the temperature of the water bath. The thermometer shall be standardized at least every 12 months.
- 5.9.3. When using the mass determination-in-water technique (Section 13.1), the water bath must be suitable for immersion of the suspended container with its deaerated sample.
- 5.10. *Protective Gloves*—Used when handling glass equipment under vacuum.

6. SAMPLING

- 6.1. *Plant-Produced*
- 6.1.1. Obtain the sample in accordance with R 97.
- 6.1.2. Reduce the sample in accordance with R 47.
- 6.2. *Laboratory-Prepared*
- 6.2.1. When necessary, reduce samples prepared or produced in a laboratory in accordance with R 47.
- 6.3. The size of the sample shall conform to the following requirements. Samples larger than the capacity of the container may be tested a portion at a time.

Table 1—Minimum Sample Sizes

Nominal Maximum Aggregate Size, mm	Minimum Sample Size, g
37.5 or greater	4000
19 to 25	2500
12.5 or smaller	1500

7. SAMPLE PREPARATION

- 7.1. *Laboratory-Prepared Samples*

- 7.1.1. Samples prepared in a laboratory shall be short-term conditioned according to R 30. This conditioning shall be combined with any warming described in Section 7.3.
- 7.2. *Plant-Produced Samples*
- 7.2.1. Dry the sample to a constant mass at a temperature of $105 \pm 5^\circ\text{C}$ ($221 \pm 9^\circ\text{F}$) until further drying does not alter the mass by more than 0.1 percent. Drying shall be combined with any warming described in Section 7.3.
- Note 5**—Short-term conditioning at the specified temperature is especially important when absorptive aggregates are used. This short-term conditioning will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced asphalt mixtures should be evaluated to make sure short-term conditioning has taken place during production and delivery.
- 7.3. Separate the particles of the asphalt mixture sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm ($1/4$ in.). If an asphalt mixture sample is not sufficiently soft to be separated manually, place it in a pan and warm it in an oven until it can be separated as described.
- 7.4. Determine and record the mass of the empty vacuum container.
- 7.5. Cool the sample to room temperature, and place the sample in the vacuum container. A container within a container is not to be used. Determine and record the mass of the sample and container. Subtract the mass of the container from the mass of the sample and the container. Record the net mass of the sample as *A*.
- 7.6. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.
- Note 6**—The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001 percent or 0.2 g in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.

TEST METHOD A—MECHANICAL AGITATION

8. APPARATUS

- 8.1. In addition to the apparatus listed in Section 5, the following apparatus is required for Method A:
- 8.1.1. *Mechanical Shaker*—Shaker for removing air from asphalt mixture.

9. PROCEDURE

- 9.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). 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.
- 9.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mmHg) per second and proceed with one of the mass determination methods in Section 11.

TEST METHOD B—MANUAL AGITATION

10. PROCEDURE

- 10.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mmHg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period by vigorously shaking at intervals of about 2 min. 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.
- 10.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mmHg) per second and proceed with one of the mass determination methods in Section 11.

11. MASS DETERMINATION

- 11.1. *Mass Determination in Water*—Suspend the container and contents in a water bath at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$). Determine and record the mass after a 10 ± 1 min immersion. Designate the mass of the sample and container in water as *C*.
- 11.2. *Mass Determination in Air*—Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$). Determine and record the mass of the container and contents, completely filled, in accordance with Section A1.2.1 within 10 ± 1 min after the vacuum has been released. Designate this mass as *E*.

12. CALCULATION

- 12.1. *Theoretical maximum specific gravity (G_{mm})*
- 12.1.1. Calculate the theoretical maximum specific gravity (G_{mm}) of the sample at 25°C (77°F) as follows:

- 12.1.2. *Mass Determination in Water:*

$$G_{mm} = \frac{A}{A + B - C} \quad (1)$$

where:

- A* = mass of the oven-dry sample in air, g;
B = mass of the container submerged in water, g, determined in accordance with Section A1.1; and
C = mass of the sample and container in water, g.

- 12.1.3. *Mass Determination in Air:*

$$G_{mm} = \frac{A}{A + D - E} \quad (2)$$

where:

- A* = mass of the oven-dry sample in air, g;
D = mass of the container filled with water, g; determined in accordance with Section A1.2; and
E = mass of the container filled with the sample and water, g.

- 12.2. *Theoretical maximum density (G_{mm}) at 25°C (77°F):*
- 12.2.1. Calculate the corresponding theoretical maximum density (G_{mm}) at 25°C (77°F) as follows:
Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 997.1 kg/m³ in SI units.
or
Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 62.245 lb/ft³ in inch-pound units.
where:
The density of water at 25°C (77°F) = 997.1 kg/m³ in SI units or 62.245 lb/ft³ in inch-pound units.

13. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE

Note 7—Experiments indicate that this supplemental procedure has an insignificant effect on the test results if the asphalt mixture contains individual aggregate with a water absorption below 1.5 percent.

- 13.1. If the pores of the aggregates are not thoroughly sealed by an asphalt film, they may become saturated with water during the application of vacuum. To determine if this condition has occurred, proceed as follows after completing Section 11.1 or 11.2. Drain the water from the sample. To prevent the loss of fine particles, decant the water through a towel held over the top of the container. Break several large pieces of aggregate and examine the broken surfaces for wetness.
- 13.2. If the aggregate has absorbed water, spread the sample before an electric fan to remove the surface moisture. Determine and record the mass at 15-min intervals, and when the loss in mass is less than 0.05 percent for this interval, the sample may be considered to be “surface dry.” This procedure requires about 2 h and shall be accompanied by intermittent stirring of the sample. Break conglomerations of the asphalt mixture by hand. Take care to prevent the loss of asphalt mixture particles.
- 13.3. To calculate the specific gravity of the sample, substitute the final surface-dry mass determined in Section 13.2 for A in the denominator of Equation 2 or 3 as appropriate.

14. REPORT

- 14.1. *Report the following information:*
- 14.1.1. G_{mm} and density of the asphalt mixture to the nearest 0.001 for specific gravity or nearest 1 kg/m³ (0.1 lb/ft³) for density as follows: sp gr 25/25°C (77/77°F) or density at 25°C (77°F);
- 14.1.2. Type of asphalt mixture;
- 14.1.3. Size of the sample;
- 14.1.4. Number of samples;
- 14.1.5. Type of container; and
- 14.1.6. Type of procedure.

15. PRECISION

- 15.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table:

Table 2—Precision Estimates

Test and Type Index	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)
Test results obtained without use of Section 15		
Method A ^a		
Single-operator precision	0.0051	0.014
Multilaboratory precision	0.0084	0.024
Method B ^b		
Single-operator precision	0.0064	0.018
Multilaboratory precision	0.0103	0.029

^a Basis of estimate: 1 replicate, 1 material, 344 laboratories.

^b Basis of estimate: 1 replicate, 1 material, 134 laboratories.

- 15.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. Multilaboratory precision has not been verified for 4500-mL or larger pycnometers.
- 15.3. The values in Column 3 are the acceptable range for two tests. When more than two results are being evaluated, the range given in Column 3 must be increased. Multiply the standard deviation(s) in Column 2 by the multiplier given in Table 1 of ASTM C670 for the number of actual tests.
- Example for three tests: $0.004 \times 3.3 = 0.013$.
- Additional guidance and background is given in ASTM C670.

16. KEYWORDS

- 16.1. Agitation; asphalt mixture; maximum density; maximum specific gravity; pycnometer; vacuum.

ANNEX

(Mandatory Information)

A1. STANDARDIZATION OF BOWLS, FLASKS, AND PYCNOMETERS

A1.1. *Standardization and Check of Bowl for Mass Determination in Water*

- A1.1.1 *Standardization*—Immerse an empty bowl in water at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$) for 10 ± 1 min. Determine and record the mass of bowl. Repeat this process three times. If the three masses are within 0.3 g, use the average as B in Equation 2. If the variation of the masses is greater than 0.3 g take corrective action and perform standardization procedure again.

- A1.1.2. *Check*—Perform the mass determination of the bowl as described in A1.2.1. If this determination is within 0.3 g of the standardized value, use the standardized value for C. If it is not within 0.3 g, perform the standardization procedure again.
- A1.2. *Standardization and Check of Flask and Pycnometer for Mass Determination in Air*
- A1.2.1 *Standardization*—Fill the flask or pycnometer with water at approximately 25 °C (77°F). Use a glass capillary stopper, capillary lid, or glass plate to ensure all entrapped air is removed. Stabilize the flask or pycnometer at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$) for 10 ± 1 min. Determine and record the mass of the flask or pycnometer, water, and lid. Repeat this process three times. If the three masses are within 0.3 g, use the average of the three masses as D in Equation 3. If the variation of the masses is greater than 0.3 g, take corrective action and perform the standardization procedure again.

¹ Sargent Welch, 39745 Gauge-Vacuum, Mercury Prefilled (or equivalent).