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METHOD OF TEST FOR DETERMINING THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT

A. SCOPE

This test method describes the procedure for determining the theoretical maximum specific gravity (also known as Rice specific gravity) and density of uncompacted hot mix asphalt (HMA) at 77°F using the weighing in air method. A supplemental dry back procedure is provided for reclaimed asphalt pavement (RAP) and for HMA where combined virgin aggregate water absorption is 2.0 % or more determined by California Test 206 and 207.

The theoretical maximum specific gravities and densities of HMA 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. They are:

1. Used to calculate values for percent air voids in compacted HMA.

2. Used to establish target values for the compaction of HMA.

3. Essential when calculating the amount of binder absorbed by the internal porosity of the individual aggregate particles in HMA.

B. REFERENCES

California Test 125 – Sampling Highway Materials and Products Used in the Roadway Structural Sections
California Test 206 – Specific Gravity and Absorption of Coarse Aggregate
California Test 207 – Specific Gravity and Absorption of Fine Aggregate
California Test 304 – Preparation of Hot Mix Asphalt for Test Specimens
AASHTO T 209 – Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures
ASTM E 1 – Standard Specification for ASTM Liquid-in-Glass Thermometers

C. APPARATUS

1. Vacuum Container: the vacuum containers 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 must be covered by a piece of No. 200 wire mesh to minimize the loss of fine material.

   NOTE: An example of a correct arrangement of the testing apparatus is shown in Figure 1. The purpose of the filter flasks is to trap water vapor from the vacuum vessel that otherwise would enter the oil in the vacuum pump and decrease the pump's ability to provide high vacuum.

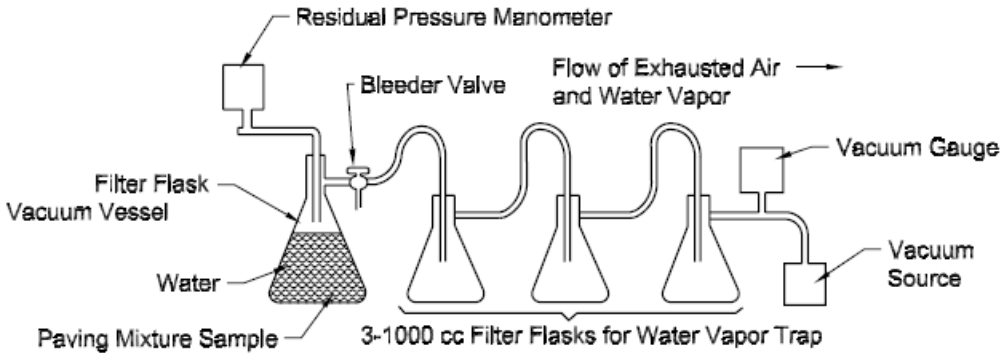

FIGURE 1. Example of Correct Arrangement of Testing Apparatus

a. Vacuum Flask: a thick-walled volumetric glass flask with a capacity of approximately 4000 mL and a rubber stopper with a connection for the vacuum line.

b. Vacuum Pycnometer: a glass or metal pycnometer with a capacity of approximately 4500 mL.

NOTE: A pycnometer will be required for HMA containing aggregate larger than 1 in. maximum size.

2. Cover Plate: a glass or metal cover plate of sufficient size to completely cover the vacuum container. The plate should be smooth and free of scratches.

3. Balance: a balance or scale having a capacity of 10 000 g, and capable of measuring the weight of the cover plate, sample, and vacuum container filled with water to an accuracy of 0.1 g.

4. Vacuum Pump: a vacuum pump capable of evacuating air from the vacuum container to a residual pressure of 3.7 kPa ± 0.3 kPa (28 mm ± 2 mm Hg). Residual pressure, as employed in this test method, is the pressure in a vacuum container when vacuum is applied.

5. Moisture Traps: a suitable moisture trap consisting of at least two 1000 mL filter flasks, or equivalent, must be installed between the vacuum container and vacuum source to reduce the amount of moisture entering the vacuum pump. A suitable desiccant may be used in conjunction with the moisture trap for better results.

6. Residual Pressure Manometer: a manometer traceable to National Institute of Standard Technologies (NIST) (mandatory) to be connected directly to the vacuum container and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less (preferably to zero). It is to be connected to the end of the vacuum line using an appropriate tube and either a "T" connector on top of the container or by using a separate opening from the vacuum line in the top of the container to attach the hose. To avoid damage, the manometer itself is not to be situated on top of the container but adjacent to it.

NOTE: A residual pressure of 4.0 kPa (30 mm Hg) absolute pressure is approximately equivalent to 97 kPa (730 mm Hg) reading on a vacuum gauge at sea level.

7. Vacuum Gauge: vacuum gauge suitable for measuring the vacuum being applied at the source of the vacuum. This device can be connected directly to the vacuum source or be in the vacuum line close (less than 2 ft) to the source. This is required to check the reading given by the residual pressure manometer attached directly to the vacuum container.

8. Thermometers: calibrated liquid-in-glass thermometers of suitable range with subdivisions and maximum scale error of 0.5°F, or any other thermometric device of equal accuracy, precision and sensitivity must be used. Thermometers must conform to the requirements of ASTM Specification E 1.

9. Mechanical Agitation Device: device capable of applying a gentle but consistent agitation of the sample. This device must be equipped with a means of firmly anchoring the container so that it does not move on the surface of the device. If stripping of asphalt is a problem, the device can be equipped with a speed control.

10. Bleeder Valve: valve attached to the vacuum pipeline to facilitate adjustment of the vacuum being applied to the vacuum container.

11. Distilled Water: water used in this procedure must be distilled.

D. CALIBRATION OF VACUUM CONTAINERS

1. Calibrate the vacuum containers (flasks and pycnometers) by determining the weight of the container filled with water at 77°F ± 1°F. Use a glass or metal cover plate to ensure accurate filling. Wipe the outside of the vacuum container dry, weigh the full container and cover plate, and measure and record the temperature of the water. Designate the weight of the container filled with water and cover plate as D.

   NOTE: When the specified temperature range cannot be maintained, calibrate the vacuum containers by determining the weight of the container filled with water over the range of water temperatures likely to be encountered in service (Figure 2).

2. While calibration of vacuum containers must be done only once a year, the calibration should be checked occasionally, particularly at 77°F ± 1°F.

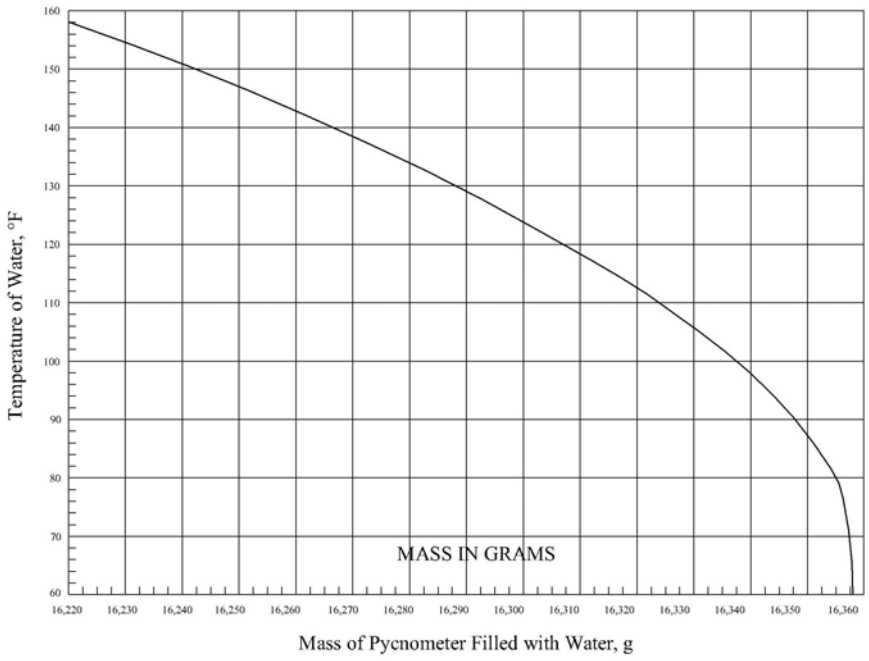

FIGURE 2. Example Calibration Curve for Pycnometer (D)

E. SAMPLING

1. Obtain HMA samples in accordance with California Test 125.

2. The size of the sample must conform to the following requirements.

Size of Largest Particle of Aggregate in HMA	Minimum HMA Sample Size, g
2 in.	6000
1½ in.	4000
1 in.	2500
¾ in.	2000
½ in. and smaller	1500

3. Samples larger than about $^2/_3$ of the volume of the container may be tested in portions. No portion of the sample being tested can be less than 1250 g.

F. PROCEDURE

1. Prepare laboratory-mixed and field-mixed HMA samples in accordance with California Test 304.

2. Separate the particles of the 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. If a sample of HMA 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.

3. Cool the sample to room temperature (77°F ± 9°F) and place it in a tared vacuum container. A container within a container is not to be used. Weigh and designate the net weight of the sample as A. Add sufficient water at a temperature of approximately 77°F to completely submerge the sample with a minimum of 1 in. of water over the sample.

4. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 kPa ± 0.3 kPa (28 ± 2 mm Hg). The vacuum should be achieved within 2 min. Maintain this residual pressure for 15 min ± 2 min. Agitate the container and contents during the vacuum period continuously using a mechanical device.

   NOTE: 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 % 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.

5. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa per second and proceed with the following:

   a. Weighing in Air – Fill the vacuum container with water and adjust the contents to a temperature of 77°F ± 2°F. Determine the weight of the cover plate, sample and container completely filled with water in accordance with Section D.1 within 10 min ± 1 min after completing Section F.4. The cover plate used in the procedure must be the same cover plate used during calibration. Designate this weight as E.

   b. See Section G.1.b for correcting the theoretical maximum specific gravity when measurements are made at temperatures other than 77°F ± 2°F.

G. CALCULATION

1. Calculate the theoretical maximum specific gravity of the sample at 77°F as follows:

   a. Weighing in Air:

$$\text{Theoretical Maximum Specific Gravity (to the nearest } 0.001) = \frac{A}{A + D - E} \qquad (1)$$

   Where: A = weight of oven dry sample in air, g
   D = weight of container filled with water and cover plate at 77°F, g
   E = weight of cover plate, sample, and container completely filled with water at 77°F, g

   b. If the test temperature is within 77°F ± 2°F, Equation 1 may be used to calculate specific gravity.

c. If the test temperature is less than 75°F or greater than 79°F, correct for thermal effects as follows:

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{(A+F)-(G+H)} \times \frac{dw}{62.245} \quad (2)$$

Where: A = weight of oven dry sample in air, g
F = weight of container filled with water and cover plate at test temperature, g
G = weight of cover plate, sample, and container completely filled with water at test temperature, g
H = correction for thermal expansion of asphalt binder (Figure 3), g
F = weight of container filled with water and cover plate at test temperature, g
dw = density of water at test temperature. Curve D in Figure 4, lb/ft^3
62.245 = density of water at 77°F, lb/ft^3
The ratio $\frac{dw}{62.245}$ is Curve R in Figure 4

d. When it is necessary to test a sample a portion at a time, the differences between the maximum specific gravities for each portion should be within the precision statements of this test. If the values are within the precision statements, average the specific gravities for each portion. If the values are outside the precision statements, run the test again.

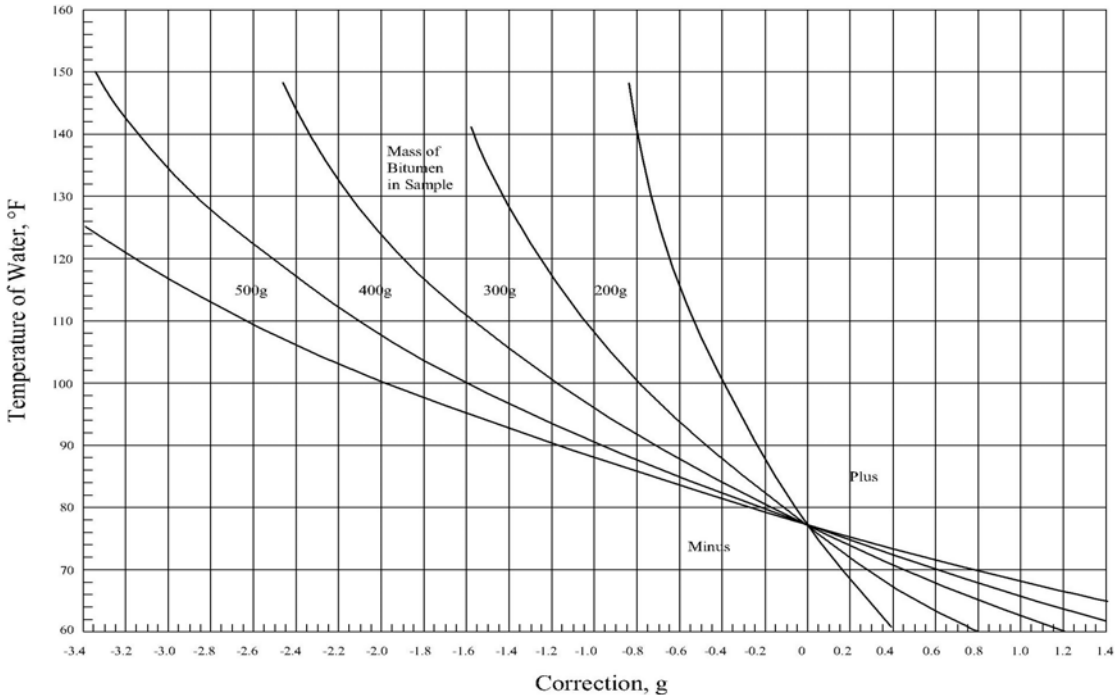

FIGURE 3. Correction Curves for Expansion of Asphalt Binder, H, in Equation 2

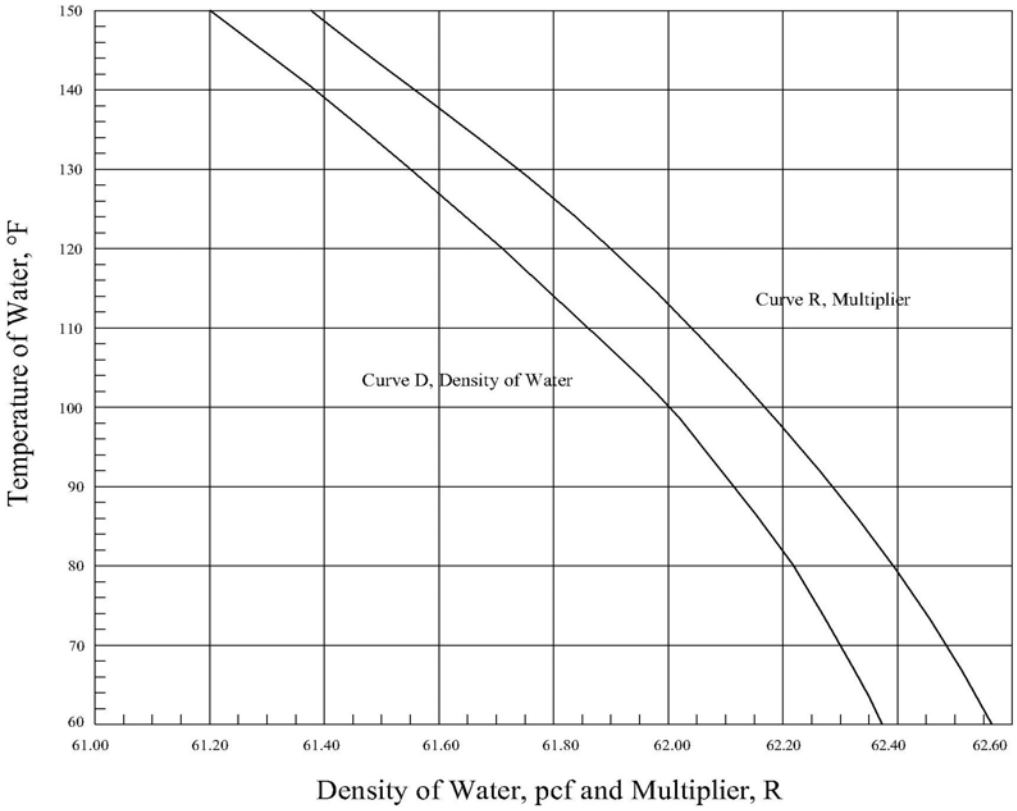

FIGURE 4. Curves D and R for Equation 2

2. Calculate the corresponding theoretical maximum density at 77°F as follows:

   Theoretical maximum density =

   Theoretical maximum specific gravity × 62.245 lb/ft^3

   Where: Density of water at 77°F = 62.245 lb/ft^3

H. SUPPLEMENTAL DRY BACK PROCEDURE

This supplemental dry back procedure is used for RAP and for HMA where combined virgin aggregate water absorption is 2.0 % or more measured in accordance with California Test 206 and 207.

1. Completing the procedure in accordance with Section F.5.a., drain water from the sample. To prevent loss of fine particles, decant water through a towel held over the top of the container.

2. After determining the initial weight, spread the sample before an electric fan to remove surface moisture. Weigh at 15 min intervals, and when the loss in weight is less than 0.05 % for this interval, the sample may be considered to be surface dry. This procedure requires about 2 hr and may be accompanied by

intermittent stirring of the sample. Break conglomerations of mixture by hand. Take care to prevent loss of particles of mixture.

3. To calculate the specific gravity of the sample, substitute the final surface-dry weight for A in the denominator of Equation 1 or Equation 2 (Section G).

I. REPORTING OF RESULTS

Report the following information:

- Asphalt binder content by total weight of mix.
- HMA specific gravity at 77°F to the nearest 0.001 (include temperature correction factor used to calculate maximum specific gravity).
- HMA density at 77°F to the nearest 0.1 lb/ft^3 (include temperature correction factor used to calculate maximum specific gravity).
- Type of mixture.
- Size of sample.
- Number of samples.
- Type of container.

J. PRECISION

Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table [based on AASHTO T-209]:

Test and Type	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)
Single-operator precision	0.0040	0.011
Multi-laboratory precision	0.0064	0.019

Note: Basis of estimate is 3 replicates, 5 materials, 5 laboratories.

The precision of the method is maximized when the procedure is run on samples that contain aggregates that are completely coated. In order to assure complete coating, it is desirable to run the method on samples that are close to the optimum asphalt binder content.

K. PRECAUTIONS

1. The equipment must be kept clean and free from any accumulation that would change the weight, in order to keep the volume calibration constant.

2. Care should be taken to use only neutral solvents.

3. Glass containers should not be subjected to high vacuum if they are scratched or damaged.

L. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

End of Text
(California Test 309 contains 9 pages)