Colorado Procedure 51-15

Standard Method of Test for

Determining the Maximum Specific Gravity of HMA

(This procedure is based upon AASHTO T 209-12. AASHTO T 209-12 or any subsequent revisions may not be used in place of this procedure.)

1. SCOPE

1.1   This method covers the determination of the maximum specific gravity of uncompacted bituminous paving mixtures.

2. REFERENCED DOCUMENT

2.1   *AASHTO Standards*:
  T 164   Quantitative Extraction of Bitumin from Bituminous Paving Materials

  T 168   Sampling Bituminous Paving Mixtures.

2.2   *ASTM Standards:*
  E1   Specification for ASTM Thermometers

2.3   *Colorado Procedures:*
  CP 41   Sampling Hot Mix Asphalt

  CP-L 5101 Verification of Laboratory Equipment used to Test Bituminous Mixtures
  CP-L 5115 Preparing & Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor
  CP-L 5120 Determination of the Asphalt Binder Content of Bituminous Mixtures by the Ignition Method

3. APPARATUS

3.1   *Balance* – A balance conforming to the requirements of AASHTO M 231, Class G 2. The balance shall be standardized at least every 12 months.

3.2   *Container* - Heavy walled volumetric flask, with the top sanded flat to provide a good seal with a cover plate, having a capacity of at least 2,000 ml. If containers other than heavy walled flasks are used, repeated weightings of the flask as specified in Subsection 4.1 must be within 0.2 grams of one another. Containers shall be sufficiently strong to withstand a partial vacuum and shall have covers as follows: for use with the flask, a rubber stopper with a hose connection. The hose opening shall be covered with a small piece of fine wire mesh to minimize the possibility of loss of fine material. The top surfaces of all containers shall be smooth and substantially plane.

3.3   *Thermometers* - Calibrated liquid-in-glass, total immersion type, of suitable range with gradations at least every 0.2°F (0.1°C) and a maximum scale error of 0.2°F (0.1°C) as prescribed in ASTM Specification E 1.

3.4   *Vacuum Pump or Water Aspirator* - Capable of developing a partial vacuum of 28 ± 2 mm of mercury (Hg) for evacuating air from the container.

3.5   *Water Bath* - Constant temperature water bath capable of maintaining a temperature of 77°F ± 1° (25°C ± 0.5°).

3.6   *Manometer or Vacuum Gauge* - Free of air bubbles, initially traceable to NIST, and be capable of measuring residual pressure down to 30 mm Hg or less.

3.7   *Needle Valve* - Capable of adjusting the partial vacuum applied to the specimen to 28 ± 2 mm of mercury.

3.8   *Oven* – If using Section 8, capable of maintaining a temperature of 230°F ± 9° (110°C ± 5°). If short-term aging is required, an oven capable of maintaining 200° F (94°C).

4. CALIBRATION OF FLASK

4.1 Approximately once per month, accurately determine the mass of the flask filled with water at 77.0°F ± 1.0° (25.0°C ± 0.5°) and covered by the cover plate to be used for testing. Average the last three determinations of the weight of the flask, water, and cover plate and record this number. Alternatively, generate a curve as described in Subsection 6.5 and verify at least one point on this curve approximately once per month.

5. TEST SAMPLES

5.1 Field samples shall be obtained, as required by the Schedule, in accordance with CP 41, Sampling Hot Mix Asphalt.

5.2 The size of the test specimens shall be governed by the nominal maximum aggregate size of the mixture and conform to the mass requirement of Table 51-1. Split or quarter the field sample in accordance with CP 55 until the mass of the material required for the test is obtained. Two separately taken identical test specimens shall be obtained. The two specimens shall not be recombined at any time after they have been taken.

5.3 If laboratory or field produced specimens are to be compacted for voids analysis using CP-L 5115, the specimens used to determine the theoretical maximum specific gravity should be short-term aged using the same heating procedure as used for the specimens being compacted. Specimens, which have been held at a temperature above 200°F (94°C) for 1 or more hours after mixing, do not require additional aging.

TABLE 51-1:
Sample Mass for Various Nominal Maximum Sizes of Aggregate.

Nominal Maximum Size of Aggregate		Number and Minimum Mass of Specimens
in.	mm	specimens x grams
1 ½	37.5	2 × 3000 g
1	25.0	2 × 1500 g
3/4	19.0	2 × 1000 g
1/2	12.5	2 × 750 g
3/8	9.5	2 × 500 g
No. 4	4.75	2 × 500 g

6. PROCEDURE

6.1 For each specimen, separate the particles of the specimen, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 1/4 in. (6.4 mm). 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 can be so handled.

6.2 Cool the specimen to room temperature, place in the tared flask and weigh. Designate the net mass of specimen as A. Add sufficient water at approximately 77°F (25°C) so that the specimen is covered to a minimum depth of 1 in. (25 mm) and remains covered while it is agitated.

NOTE 1: If the potential presence of lime in asphalt paving mixture needs to be determined, add 2-4 drops of phenolphthalein alcohol indicator into the flasks after adding sufficient water and prior to subjecting the contents to a partial vacuum. Let it rest for 10 seconds and look for the indicator to show the potential presence of lime.

6.3 Remove entrapped air by subjecting the contents to a partial vacuum of 28 ± 2 mm Hg for 15 ± 2 minutes. Agitate the container and contents manually by vigorous shaking for 15 ± 5 seconds at intervals of about 2 minutes. Alternatively, a mechanical device, shown to be at least as effective at removing entrapped air as the manual method and shown to not result in stripping of the asphalt binder from the aggregate, may be used to agitate the container.

NOTE 2: If there are multiple broken or sawed uncoated aggregate surfaces or if uncoated fine material separates from the specimen and settles to the bottom of the flask once the test is complete, use the supplemental procedure described in Section 8.

NOTE 3: 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 grams in 20 liters of water. This solution is then diluted to about 20:1 to make a wetting agent of which 5 to 10 ml may be added to each sample to give a final concentration of Aerosol OT of about 1 gram per 200,000 liters.

6.4   *Flask Determination* - Fill the flask with water, at a temperature of 77°F ± 1° (25°C ± 0.5°), being careful not to introduce air bubbles into the flask. Optionally, if air bubbles are seen in the flask, gently stir the specimen with a rod to dislodge any air bubbles that may still be trapped in the flask. Fill the flask to the top with water and cover the flask with the same cover plate used in the flask's calibration, making sure that there are no air bubbles beneath the flask's cover plate. Place the flask and contents into a 77°F ± 1° (25°C ± 0.5°) constant temperature water bath. Remove the flask from the water bath and dry the exterior of the flask completely. Check that no air bubbles have appeared beneath the flask's cover plate. Determine the weight of the flask, water, specimen, and cover plate 10 ± 1 minutes after completing Subsection 6.3.

6.5   In lieu of a constant temperature water bath, determine the temperature of the water within the flask immediately after weighing the flask, water, and specimen and make the appropriate density correction to 77°F (25°C) using the curve in Figure 51-1. In this case, the mass of the flask, water, and cover glass must be determined at the same temperature as the test temperature. This shall be done by plotting the mass of the flask, water, and cover plate for at least five approximately / equally spaced temperatures, which span the range of test temperatures to be used. Allow the flask and water to equilibrate at each temperature for at least one minute before measuring the water temperature and then weighing the flask, water, and cover plate. Alternatively, one point (using three trials) near the middle of the expected temperature range may be determined. The volume of the flask may then be calculated by subtracting the mass of the flask and cover glass, and then dividing the mass of the water by the density of the water at that temperature using the equation from FIGURE 51-1. A table may be constructed by multiplying the volume of the flask by the density of water and adding the mass of the flask and cover glass for each temperature desired. This method may be used for containers which have a minimal change in volume over the temperature range to be expected, such as annealed glass flasks. At least one point on the resulting plot of mass vs. temperature should be verified monthly.

7. CALCULATION

7.1   Calculate the specific gravity of the specimen as follows:

7.1.1   *Flask Determination*:

$$\text{Specific Gravity} = \frac{A}{(A + D - E)}$$

[Equation 1]

Where:

A = Mass of dry specimen in air, g,
D = Mass of flask filled with water at 77°F (25°C), g,
E = Mass of flask filled with water and specimen at 77°F (25°C), g.

7.2   Whenever water temperatures other than 77°F are used, use the following equation:

$$\text{Specific Gravity} = \frac{A}{(A + F) - (G + H)} \times \frac{dw}{0.9970}$$

[Equation 2]

Where:

A = Mass of dry specimen in air, g,
F = Mass of flask filled with water at test temperature, g, as read from the plot generated in Subsection 6.5,
G = Mass of flask filled with water and specimen at test temperature, g,
H = Correction for thermal expansion of bitumen, g. from Figure 51-2. **Note:** H may be assumed to be zero for test temperatures between 70°F and 90°F (21.1°C and 32.3°C),
dw = Density of water at test temperature. Curve D in Figure 51-1, Mg/m^3,
0.9970 = Density of water at 77°F (25°C). Mg/m^3.

The ratio (dw/0.9970) is Curve R in Figure 51-1.

NOTE 4: This general procedure for correcting for thermal effects should also be applicable to corresponding measurements made with other suitable containers.

7.3 *Repeatability* - If the specific gravities of the two specimens are not within 0.011 of each other, the results should be discarded, a new specimen obtained, and the specific gravity of the material retested.

8. SUPPLEMENTAL PROCEDURES FOR MIXTURES CONTAINING POROUS AGGREGATE NOT COMPLETELY COATED

METHOD A – DRY-BACK

8.1 Proceed as follows after completing Section 6.

8.1.1 Oven dry a filter paper and record its weight. Place the filter paper into a filter paper cone holder.

8.1.2 Drain the water from the specimen through the filter paper cone being careful not to lose any of the specimen. Allow the specimen to drain completely.

8.1.3 Weigh an empty pan sufficient in size to hold the test specimen while it dries in Subsection 8.2.

8.1.4 Empty the specimen from the filter paper into the pan from Subsection 8.1.3 and place the pan before an electric fan.

8.1.5 Oven dry the filter paper and any specimen which may still remain on the paper's surface at a temperature of 230°F ± 9° (110°C ± 5°) for more than 30 minutes. Subtract the weight of the filter paper used in Subsection 8.1.1 and record this weight.

8.2 Spread specimen before an electric fan to remove surface moisture. Weigh at 15-minute intervals and when the loss in mass is less than 0.5g for this interval, the specimen may be considered to be surface dry. This procedure requires about 2 hours and should be accompanied by intermittent stirring of the specimen. Conglomerations of mixture should be broken by hand. Care must be taken to prevent loss of particles of mixture.

8.3 To calculate the specific gravity of the specimen, the sum of the final surface-dry mass and the mass of any specimen remaining on the filter paper from Subsection 8.1.5 is substituted for A in the denominator of Equation 1 or 2.

METHOD B – ASPHALT CEMENT ADD-IN FOR CALCULATING THE EFFECTIVE SPECIFIC GRAVITY FOR RAP (Reclaimed Asphalt Pavement)

8.4.1 Before Subsection 6.1, add in 2% to 3% virgin asphalt cement per CP-L 5120 Subsection 9.1, to the specimen. Use the binder mixing temperature stated in CP-L 5115 Table 2.

8.4.2 After specimen has properly cooled proceed with Subsection 6.1.

8.5 For calculating effective specific gravity of the aggregates, the percent binder is the virgin binder added per this procedure and any binder that is already on the aggregate that is determined by CP-L 5120 or AASHTO T 164.

METHOD C – CALCULATING THE EFFECTIVE SPECIFIC GRAVITY FOR RAS (Reclaimed Asphalt Shingles)

8.6 Determine the maximum specific gravity according to AASHTO T 209.

8.7 For calculating effective specific gravity of the aggregates, the percent binder is any binder that is already on the aggregate that is determined by CP-L 5120 or AASHTO T 164.

9. PRECISION

9.1 Criteria for judging the acceptability of specific gravity test results obtained by this method are given in Table 51-2 entitled "Specific Gravity Test Results." The figures given in column 2 are the standard deviations that have been found to be appropriate for the conditions of 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

10. Report

10.1   *Report the following information:*

10.1.1 The specific gravity of each specimen to the nearest 0.001. The average specific gravity of two specimens to the nearest 0.001.

TABLE 51-2: Specific Gravity Test Results

Test and Type Index	Acceptable Standard Deviation (1S)	Range of Two Results (D2S)
Test results obtained without use of Section 8[a]:		
Single-operator precision	**0.0040**	**0.011**
Multi laboratory precision	**0.0064**	**0.019**

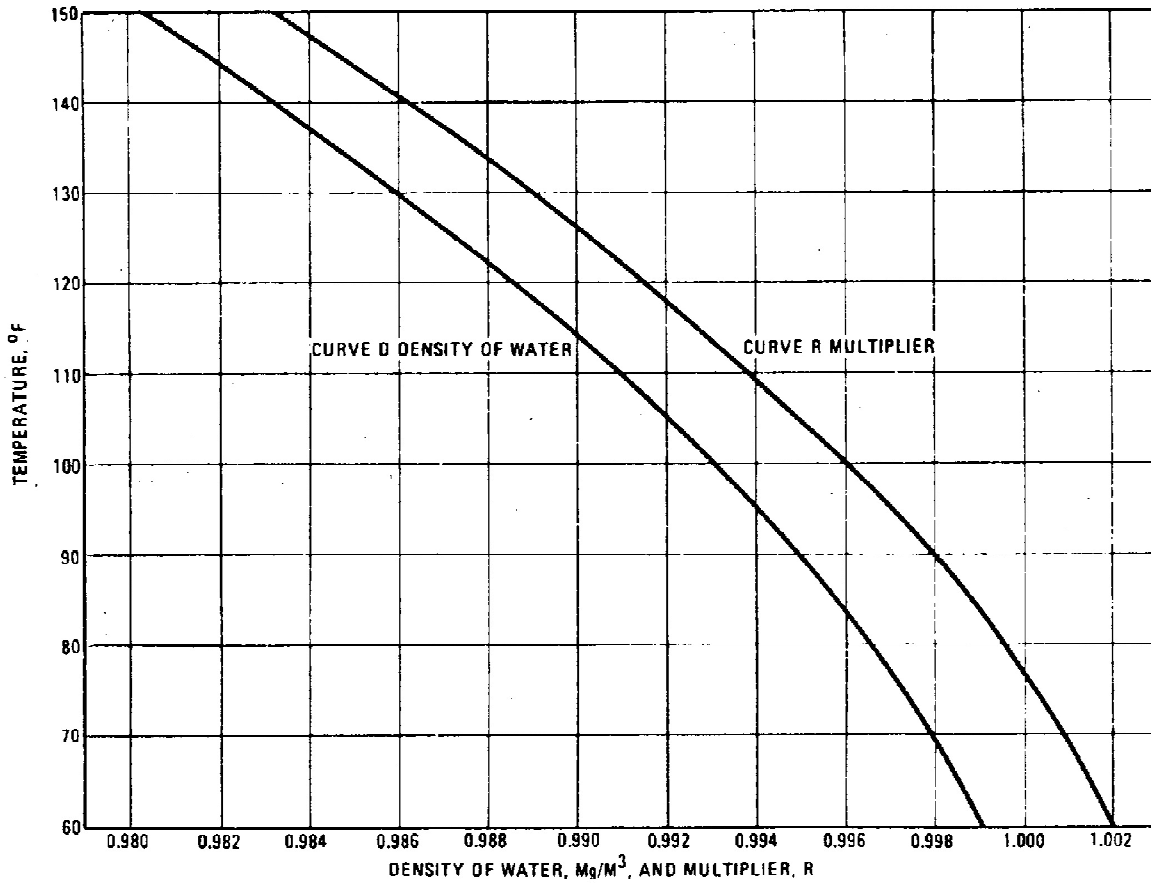[a] **Basis of estimate**: 3 replicates, 5 materials, 5 laboratories.

FIGURE 51-1: Curves D and R for Equation 2

The equation of curve D, the density of water from 60°F to 150°F is:
  $D = (1.001\ 402) + (0.000\ 029\ 42) \times T - (0.000\ 001\ 133) \times T^2$
Where: T = Temperature in degrees Fahrenheit.

The equation for the multiplier R from 60°F to 150°F is:
  $R = (1.004\ 385) + (0.000\ 028\ 68) \times T - (0.000\ 001\ 129) \times T^2$
Where: T = Temperature in degrees Fahrenheit.

(Please check all results against the graph for correctness.)
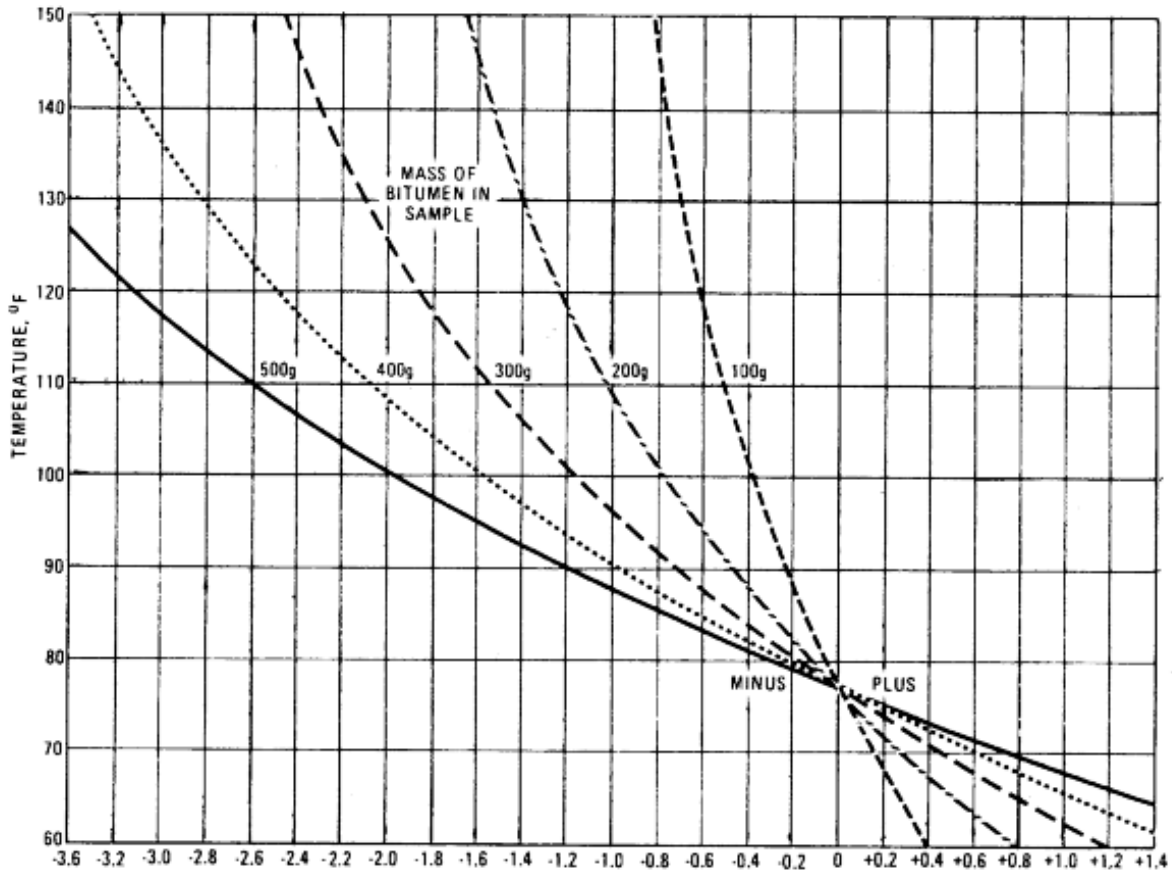
Curve R is the Ratio (dw / 0.9970)

FIGURE 51-2: Correction Curves for Thermal Expansion of Bitumen, H, in Equation 3

The equation for the correction for the thermal expansion of bitumen, H, from 60°F to 150°F is:

$$H = [\text{grams bitumen}] \times [(0.022\ 71) - (0.000\ 386) \times T + (0.000\ 001\ 201) \times T^2]$$

Where: T = Temperature in degrees Fahrenheit.

(Please check all results against the graph for correctness.)

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