CHAPTER 7

TESTING OF ASPHALT CONCRETE MIXTURES

Asphalt Testing

This section will deal with the methods of determining asphalt concrete properties by laboratory testing. In a hot-mix asphalt (HMA) paving mixture, asphalt and aggregate are blended together in precise proportions. The relative proportions of these materials determine the physical properties of the mix, and ultimately, how the mix will perform as a finished pavement.

The Department (VDOT) establishes the mix design requirements. Once these are established it is the responsibility of the contractor/producer and his technician to develop the mix within the framework of the specifications. Through many years of laboratory testing and actual road application, the Department has established design ranges for asphalt concrete mixtures used in Virginia (Rd & Bridge Spec. Section 211 Table II-14). When a sample of HMA is tested in the laboratory, it can be analyzed to determine its probable performance in the pavement structure; as well as, conformance with VDOT specifications. The laboratory tests used are:

- **Ignition Method of Determining Asphalt Content**
- **Maximum Specific Gravity (Rice, MSG, or G_{mm})**
- **Bulk Specific Gravity of Mixture (G_{mb})**
- **Sieve Analysis**
- **Tensile Strength Ratio (TSR)**

These tests are used to determine the following characteristics of the mixture:

Asphalt Content, Voids in Total Mix (VTM), Voids Filled with Asphalt (VFA), Voids in the Mineral Aggregate (VMA), Fines to Asphalt Ratio (F/A), Aggregate Gradation, and Stripping Potential.

Other tests performed in the lab are:

- **Boil Test**
- **Moisture Content**
- **Particle Coating**
- **Aggregate Concensus Properties Tests**

Table II-14
Mix Design Criteria

Mix Type	VTM (%) Production (Note 1)	VFA (%) Design	VFA(%) Production (Note 2)	Min. VMA (%)	Fines/Asphalt Ratio (Note 3)	Number of Gyrations N Design	N Initial	N Max.	Density (%) at N Initial
SM-9.0A Notes1,2,3	2.0 – 5.0	75-80	75-85	16	0.6-1.3	65	7	100	≤ 90.5
SM-9.0D Notes1,2,3	2.0 – 5.0	75-80	75-85	16	0.6-1.3	65	7	100	≤ 89.0
SM-9.0E Notes 1,2,3	2.0 – 5.0	75-80	75-85	16	0.6-1.3	65	7	100	≤ 89.0
SM-9.5 A Notes 1,2,3	2.0 – 5.0	73-79	68-84	15	0.6-1.2	65	7	100	≤ 90.5
SM-9.5 D Notes 1,2,3	2.0 – 5.0	73-79	68-84	15	0.6-1.2	65	7	100	≤ 89.0
SM-9.5 E Notes 1,2,3	2.0 – 5.0	73-79	68-84	15	0.6-1.2	65	7	100	≤ 89.0
SM-12.5 A Notes 1,2,3	2.0 – 5.0	70-78	65-83	14	0.6-1.2	65	7	100	≤ 90.5
SM-12.5D Notes 1,2,3	2.0 – 5.0	70-78	65-83	14	0.6-1.2	65	7	100	≤ 89.0
SM-12.5 E Notes 1,2,3	2.0 – 5.0	70-78	65-83	14	0.6-1.2	65	7	100	≤ 89.0
IM-19.0 A Notes 1,2,3	2.0 – 5.0	69-76	64-81	13	0.6-1.2	65	7	100	≤ 90.5
IM-19.0 D Notes 1,2,3	2.0 – 5.0	69-76	64-81	13	0.6-1.2	65	7	100	≤ 89.0
IM-19.0E Notes 1,2,3		69-76	64-81	13	0.6-1.2	65	7	100	≤ 89.0
BM-25.0A Note 2,3,4	1.0 – 4.0	67-87	62-83	12	0.6-1.3	65	7	100	≤ 89.0
BM-25.0D Note 2,3,4	1.0 – 4.0	67-87	59-83	12	0.6-1.3	65	7	100	≤ 89.0

SM = Surface Mixture; Im = intermediate Mixture; BM= Base Mixture

Note 1: Asphalt content should be selected at 4.0 percent Air Voids.

Note 2: During production of an approved job mix, the VFA shall be controlled within these limits.
Note 3: Fines-Asphalt Ratio is based on effective asphalt content.
Note 4: Base mix shall be designed at 2.5 % air voids. BM-25.0A shall have have a minimum asphalt content of 4.4 percent, unless otherwise approved by the Engineer. BM-25.0D shall have a minimum asphalt content of 4.6%, unless otherwise approved by the Engineer.

Table II-14A
Recommended Performance Grade of Asphalt Cement

Mix Type	Percentage of Reclaimed Asphalt Pavement (RAP)in Mix %RAP ≤ 20%	20% < %RAP ≤ 30%	20% < %RAP ≤ 35%
SM-9.0 A, SM-9.5 A, SM-12.5 A	PG 64-22	PG 64-22	
SM-9.0 D, SM-9.5 D, SM-12.5 D	PG 70-22	PG 64-22	
IM-19.0A	PG 64-22	PG 64-22	
IM-19.0D	PG 70-22	PG 64-22	
BM-25.0A	PG 64-22		PG-64-22
BM-25.0D	PG 70-22		PG-64-22

Figure 7-1

Terminology / Definitions

Air Voids

Air voids are small airspaces or pockets of air (see fig. 7-2) that occur between the coated aggregate particles in the final compacted mix. A certain percentage of air voids is necessary in all dense-graded highway mixes to allow for some additional pavement compaction under traffic and to provide spaces into which small amounts of asphalt can flow during this subsequent compaction. The allowable percentage of air voids (in laboratory specimens) is between 2.0 percent and 4.0 percent for most surface course mixes.

The durability of an asphalt pavement is a function of the air-void content. This is because the lower the air-voids, the less permeable the mixture becomes. Too high an air-void content provides passageways through the mix for the entrance of damaging air and water. A low air-void content, on the other hand, can lead to flushing, a condition in which excess asphalt squeezes out of the mix to the surface. Density and void content are directly related. The higher the density, the lower the percentage of voids in the mix, and vice versa. Job specifications require pavement that allows as low an air void content as is practical, approximately 8.0 percent.

Percent Voids Total Mix (VTM)

The VTM is that part of the compacted mixture not occupied by aggregate or asphalt expressed as a percentage of the total volume. It is synonymous with air voids and is the complement of the percent density when based upon the maximum specific gravity (G_{mm}). The VTM obtained in the Superpave Mix Design gives an indication of whether the mix can be compacted adequately in the field. In view of the excellent stabilities achieved with most Virginia mixes, the VTM is probably the number one criterion for predicting field compaction and, ultimately, pavement life.

Percent Voids Filled with Asphalt (VFA)

The VFA is the percentage of voids in the compacted aggregate mass that are filled with asphalt cement. It is synonymous with the asphalt-void ratio. The VFA property is important not only as a measure of relative durability, but also because there is an excellent correlation between it and percent density. If the VFA is too low, there is not enough asphalt to provide durability and to over-densify under traffic and bleed. Thus, the VFA is a very important design property.

Voids in the Mineral Aggregate (VMA)

Voids in the mineral aggregate (VMA) are the air-void spaces that exist between the aggregate particles in a compacted paving mixture, including spaces filled with asphalt. VMA represents the space that is available to accommodate the asphalt and the volume of air voids necessary in the mixture. The more VMA in the dry aggregate, the more space is available for the film of asphalt.

Based on the fact that the thicker the asphalt film on the aggregate particles the more durable the mix, specific minimum requirements for VMA are specified in Section 211.03 of the specifications. Minimum VMA values should be adhered to so that a durable asphalt film thickness can be achieved. Increasing the density of gradation of the aggregate to a point where below minimum VMA values are obtained leads to thin films of asphalt and a dry looking, low durability mix. Therefore, economizing in asphalt content by lowering VMA is actually counter-productive and detrimental to pavement quality.

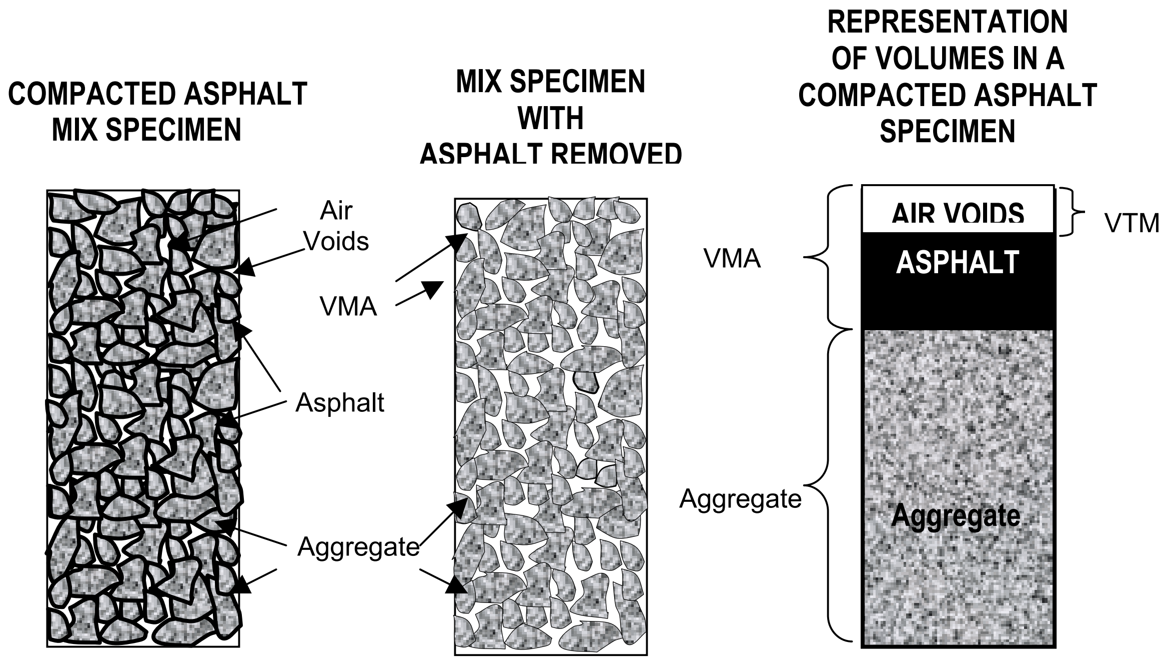

Figure 7-2
Illustration of VMA in a Compacted Mix Specimen

(Note: For simplification, the volume of absorbed asphalt is not shown.)

F/A Ratio

The Fines to Asphalt Ratio (F/A) is an indication of the film thickness of coated particles. The film thickness helps reduce premature aging and reduce moisture damage.

Asphalt Content

The proportion of asphalt in the mixture is critical and must be accurately determined in the laboratory and then precisely controlled on the job. The optimum asphalt content of a mix is highly dependent on aggregate characteristics such as gradation and absorptiveness. Aggregate gradation is directly related to optimum asphalt content. The finer the mix gradation, the larger the total surface area of the aggregate and the greater the amount of asphalt required to uniformly coat the particles. Conversely, because coarser mixes have less total aggregate surface area, they demand less asphalt.

The relationship between aggregate surface area and optimum asphalt content is most pronounced where filler material (very fine aggregate fractions which pass through the No. 200 (0.075 mm) sieve is involved. Small increases in the amount of filler in a gradation can literally absorb much of the asphalt binder, resulting in a dry, unstable mix. Small decreases have the opposite effect: too little filler results in too rich (wet) a mixture. Variations in filler content will cause changes in mix properties, from dry to wet. If a mix contains too little or too much mineral filler, however, arbitrary adjustments to correct the situation are likely to worsen it. Instead, proper sampling and testing should be done to determine the cause of the variations and, if necessary to establish a new job-mix design.

The absorptiveness (ability to absorb asphalt) of the aggregate used in the mix is critical in determining optimum asphalt content. Enough asphalt must be added to the mix to allow for absorption and still coat the particles with an adequate film. When discussing absorbed and unabsorbed asphalt, technologists discuss two types of asphalt content: total asphalt content and effective asphalt content.

Total asphalt content is the amount of asphalt that must be added to the mixture to produce the desired mix qualities. Effective asphalt content is the volume of asphalt not absorbed by the aggregate; the amount of asphalt that effectively forms a bonding film on the aggregate surfaces. Effective asphalt content is calculated by subtracting the amount of absorbed asphalt from the total asphalt content. The absorptiveness of an aggregate is obviously an important consideration in determining the asphalt content of a mixture. It is generally known for established aggregate sources, but requires careful testing where new aggregate sources are being used.

Tensile Strength Ratio

This test measures the strength loss resulting from damage caused by “stripping” under laboratory controlled accelerated water conditioning. The results may be used to predict long-term susceptibility to stripping of an asphalt concrete. To combat the effects of water damage, an anti-stripping additive is used in all asphalt mixes.

The Contractor may use either 1.0 percent hydrated lime in accordance with Section 211.02 (i) of the Specifications, an approved chemical additive from the Department’s approved list found in the Materials Division’s Manual of Instructions at the manufacturer’s recommended dosage, or a combination of both. (This test is covered in the Asphalt Plant Mix Design class)

For production tests, the mixture shall produce a tensile strength ratio (TSR) value not less than 0.80 for Superpave mixes. The TSR value is determined in accordance with AASHTO T- 283 (including a freeze-thaw cycle).

Boil Test

This test method determines the effectiveness of an anti-stripping additive when used as an asphalt anti-stripping compound in asphalt mixtures. The Boil Test is performed in accordance with VTM-13. The results are reported as “Pass” or “Fail”.

Moisture Content

It is important that the Contractor maintains and monitors the moisture content of the aggregate blend and asphalt concrete mixture. Specifications require that the finished mixture have a moisture content not exceeding 1 percent.

Testing Procedures

When a plant has produced a mixture, the mixture must be tested to ensure that it meets VDOT specifications. In addition, the Contractor’s payment for the mixture produced will be based on the asphalt content and aggregate gradation determined by testing. The following will provide the necessary information for laboratory testing of plant produced mixtures.

Procedure for Compacting Specimen (AASHTO T-312)

The purpose of compacting specimens is to determine the bulk specific gravity of a mixture and ultimately use this number to determine the air voids of the mixture. In determining the **Bulk Specific Gravity** of a particular mix (G_{mb}), three test specimens must be prepared and compacted as follows:

Molding Specimens:

a. Cut the gyratory on and let it warm-up. Once the gyratory has cycled through the warm-up period, make sure the gyratory has the correct settings (i.e. the number of gyrations, ram pressure, etc.). The gyrations used for compacting specimens can be found in Section 211.03 Table II-14.

b. Heat the molds to the desired compaction temperature as specified in Section 211.03 (d) 6.

c. Place the mixture in an oven set at the desired compaction temperature. Place a thermometer into the mixture so temperature can be monitored. It is recommended that once the material has become workable, the desired amount of material for each of the three specimens be weighed out and placed in a small pan and heated to compaction temperature. Use a flat bottom scoop to scoop out the mixture. Once the specimen weight has been measured and placed into separate pans for each of the three specimens, place thermometers in each of the three pans to monitor temperature.

d. After the mixture has reached the compaction temperature, place a heated mold on a table and insert a piece of filter paper into the bottom of the mold. Place the material into the mold. Place a piece of filter paper onto the top of the material. If needed, place the top plate into the mold.

e. Place the mold into the gyratory compactor. Press the start button.

f. Once compaction is complete, check to make sure the specimen height is 115 ± 5 mm. Remove the mold from the gyratory. Extract the specimen and remove the filter paper from the top and bottom of the specimen. Place the specimen on a smooth, flat surface and allow to cool overnight at room temperature.

g. Repeat these steps as necessary for compacting additional specimens. Once the specimens have cooled, determine the bulk specific gravity of the specimens.

Bulk Specific Gravity Procedure (AASHTO T-166)

Determine the Bulk Specific Gravity of the compacted cores in accordance with AASHTO T-166 Method A as follows:

A. Dry the specimen to a constant mass

NOTE 2. Constant mass shall be defined as the mass at which further drying at 125 ± 5 °F (52 ±3 °C) does not alter the mass by more than 0.05 percent. Samples saturated with water shall initially be dried overnight at 125 ± 5 °F (52 ± 3°C) and then weighed at two-hour drying intervals. Recently molded laboratory samples which have not been exposed to moisture do not require drying.

B. Cool the specimen to room temperature at 77 ± 9 °F (25 ± 5 °C), and record the dry mass **A**.

C. Immerse each specimen in water at 77 ± 3 °F (25 ± 1 °C) for 4 ± 1 minutes and record the immersed mass, **C**.

D. Remove the specimen from the water, quickly damp dry the specimen by blotting with a damp towel as quickly as possible, and determine the surface-dry mass, **B**. (Any water that seeps from the specimen during weighing operation is considered part of the saturated specimen).

E. Calculate the Bulk Specific Gravity of each specimen using the following equation:

$$\text{Bulk Specific Gravity (BSG) of Core} = \frac{A}{B-C}$$

Where: A = Weight of Core in Air
B = SSD Weight of Core in Air
C = Weight of Core in Water

F. Calculate the average Bulk Specific Gravity of the mix (G_{mb}) using the following equation:

$$G_{mb} = \frac{\text{BSG specimen 1} + \text{BSG specimen 2} + \text{BSG specimen 3}}{3}$$

This value, G_{mb}, will be used to determine air voids (VTM) of the mixture.

Maximum Specific Gravity Procedure (AASHTO T-209)

The maximum specific gravity (G_{mm}) or RICE is determined by AASHTO T-209 (RICE METHOD) in which vacuuming is used to extract all the air from the mixture. This represents 100% density (no air voids) for a particular asphalt mixture. This value is used in conjunction with the bulk specific gravity to determine the density of the compacted specimens for that mixture.

Determining the maximum specific gravity (G_{mm}) is performed as follows:

After quartering or splitting a mixture to obtain the sample weight needed for the particular mixture, spread the mix out on a table to cool. Separate the mix particles so that there are no particles larger than 1/4 inch.

(1) Weigh the Rice bucket in air and record the weight. (A)

(2) Place the sample in the Rice bucket.

(3) Weigh the sample and the bucket together in air. (C)

(4) Add water to the sample in the bucket until the sample is completely covered with water. The temperature of the water must be 77°F (25°C). (If the temperature is not 77°F, the temperature correction factor must be used.)

(5) Place the top on the Rice bucket and pull the vacuum to 27.75 $\pm$ 2.25 mm HG. Maintain the vacuum for 15 ± 2 minutes, shaking the bucket at 2 minute intervals or place the bucket on a slow continuous shaker. The vacuum is removing the air voids in the mix.

(6) After the 15 minutes are up, release the vacuum, remove the top and place the bucket suspended in the bath for 10 ±1 minute.(The water in this bath must also be 77°F (25°C). After 10 minutes are up, record the weight of the sample and bucket in water (D). After recording this weight, gently pour water from bucket back into water bath, dispose of sample in bucket (you no longer need the sample). Then place empty bucket back into water bath, leaving it immersed for 10 ± 1 minute. Record this weight (B) (this will be the weight in water of the empty bucket).

Calculate the Maximum Specific Gravity (G_{mm}) using the following equation:

$$G_{mm} = \frac{(C - A)}{(C-A) - (D-B)}$$

A = Weight of Container in air
B = Weight of Container in water
C = Weight of Container and Sample in air
D = Weight of Container and Sample in water

Procedure for Determining Asphalt Content (VTM-102)

The Virginia Test Method for determining the asphalt content in asphalt mixtures is the Ignition Method, Virginia Test Method (VTM) 102. This test method uses an ignition oven to burn off the asphalt in the mixture, leaving the aggregate behind.

The asphalt content of the mix will be used to determine the VMA and F/A ratio of the mixture. When preparing a sample for testing by the Ignition Method, the quartering method as specified in AASHTO T-248 may be used.

The complete VTM-102 is in Appendix C of this manual.

Boil Test Procedure (VTM-13)

1. When necessary for the test to be run at the plant, allow the sample to cool to 230±9°F (110 ± 5°C).

2. Use approximately 400 grams of the mixture passing the 1/2 inch (12.5 mm) sieve. **NOTE: Remove plus 1/2 inch (12.5 mm) material from mixture prior to attaining specified temperature.**

3. Place approximately 200 grams on a paper towel before boiling. Place the remainder (approximately 200 grams) of the mixture in boiling water and continue boiling for 10 minutes. Drain the water from the mixture and place the sample on a paper towel. Allow to cool at room temperature.

4. The next morning compare the boiled and unboiled portions on the paper towels. If the boiled portion shows more signs of stripping than the unboiled portion, the test fails. The producer will take a second sample and test as stated herein. If the second sample fails, production shall be halted until corrective action is taken to the satisfaction of the Engineer. On the resumption of production, samples will be taken immediately and tested as stated herein above.

5. Report as passing or failing.

Calculation of Volumetric Properties

To determine the volumetric properties (VTM, VMA, VMA, F/A) of the mixture, the Bulk Specific Gravity of the mixture (G_{mb}), Maximum Specific Gravity (G_{mm}), Asphalt Content and Aggregate Gradation must be determined. In addition, the effective specific gravity of the aggregate and the bulk specific gravity of the aggregate must be calculated.

Effective Specific Gravity of Aggregate (G_{se}):

$$G_{se} = \frac{P_s}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

where,

G_{se} = effective specific gravity of aggregate
P_s = percent stone (100 – P_b from Ignition Method)
G_{mm} = maximum specific gravity of mixture (Rice)
P_b = asphalt content (from Ignition Method)
G_b = binder specific gravity (1.030)

Bulk Specific Gravity of Aggregate (G_{sb}):

$$G_{sb} = G_{se} - CF$$

where,

G_{sb} = bulk specific gravity of aggregate
G_{se} = effective specific gravity of aggregate
CF = field correction factor supplied with job-mix formula

Once these properties have been determined, the volumetric properties (VTM, VMA, VFA, and F/A) can be calculated as follows.

VTM:

$$VTM = 100 \times \left[1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right]$$

where,

G_{mb} = bulk specific gravity of mix
G_{mm} = maximum specific gravity of mix (Rice)

This VTM value will used to determine density and VFA.

Density:

The percent density of each test specimen can be determined by the following formula:

$$\% \text{ density} = 100 - VTM$$

VMA:

Determine the voids in the mineral aggregate (VMA) using the following formula:

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}} \right]$$

where,

G_{mb} = bulk specific gravity of mix
P_s = Percent stone (100 – P_b from Ignition Method)
G_{sb} = bulk specific gravity of aggregate

VFA:

Determine the voids filled with asphalt (VFA) using the following formula:

$$VFA = \left[\frac{(VMA - VTM)}{VMA} \right] \times 100$$

F/A Ratio:

Determine the F/A ratio as follows:

1. Determine the percent passing the No. 200 (75μm) sieve from sieve analysis of mixture.

2. Calculate the effective specific gravity of aggregate (G_{se}) and bulk specific gravity of aggregate (G_{sb}).

3. Calculate the effective asphalt content (P_{be}) of the mixture.

$$P_{be} = P_b - (P_s \times G_b) \times \left[\frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} \right]$$

where;

P_{be} = Effective Asphalt Content

P_b = Asphalt Content from Ignition Method

P_s = Percent stone (100 – P_b)

G_b = Binder specific gravity (1.030)

G_{se} = Effective Specific Gravity of Aggregate

G_{sb} = Bulk Specific Gravity of Aggregate

4. Calculate F/A ratio.

$$\text{F/A ratio} = \frac{\text{\% passing 200}}{P_{be}}$$

Example Calculations

The results of laboratory testing are as follows:

The Asphalt Content of the mixture after performing the Ignition Method is 4.60.
The field correction factor submitted with the job-mix formula is 0.021.
The percent passing the No. 200 sieve is 5.0.

Maximum Specific Gravity (G_{mm}) Procedure

Specimen		(Grams)
Wt. Bucket in Air	**A**	2089.5
Wt. of Bucket in Water	**B**	1343.7
Wt. of Bucket and Sample in Air	**C**	3432.7
Wt. of Bucket and Sample in Water	**D**	2137.5

Maximum Specific Gravity (G_{mm}):

$$G_{mm} = \frac{C - A}{(C-A) - (D-B)}$$

$$G_{mm} = \frac{3432.7 - 2089.5}{(3432.7 - 2089.5) - (2137.5 - 1343.7)}$$

$$G_{mm} = \frac{1343.2}{1343.2 - 793.8} = \frac{1343.2}{549.4} = \mathbf{2.445}$$

Bulk Specific Gravity (G_{mb}) Procedure

Specimen		1	2	3
Wt. of Core in Air	**A**	1188.7	1183.1	1184.6
SSD Wt. of Core	**B**	1196.2	1191.0	1192.1
Wt. of Core in Water	**C**	677.4	672.8	672.8

Bulk Specific Gravity of Mixture (G_{mb}):

$$\text{Bulk Specific Gravity } (B_{SG}) \text{ of Core} = \frac{A}{B-C}$$

Where:
A = Weight of Core in Air
B = SSD Weight of Core in Air
C = Weight of Core in Water

$$G_{mb} \text{ Core 1} = \frac{1188.7}{1196.2 - 677.4} = \frac{1188.7}{518.8} = \mathbf{2.291}$$

$$G_{mb} \text{ Core 2} = \frac{1183.1}{1191.0 - 672.8} = \frac{1183.1}{518.2} = \mathbf{2.283}$$

$$G_{mb} \text{ Core 3} = \frac{1184.6}{1192.1 - 672.8} = \frac{1184.6}{519.3} = \mathbf{2.281}$$

The Average Bulk Sp. Gr. of the cores is the Bulk Specific Gravity of the mixture (G_{mb}):

$$\text{Avg.}G_{mb} = \frac{G_{mb}\text{ specimen1} + G_{mb}\text{ specimen2} + G_{mb}\text{ specimen3}}{3}$$

$$\text{Avg.}G_{mb} = \frac{2.291 + 2.283 + 2.281}{3}$$

$$\text{Avg.}G_{mb} = \frac{6.855}{3}$$

$$\text{Avg.}G_{mb} = \mathbf{2.285}$$

Effective Specific Gravity of Aggregate (G_{se}):

$$G_{se} = \frac{P_s}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

$$G_{se} = \frac{100 - 4.6}{\frac{100}{2.445} - \frac{4.6}{1.03}}$$

$$G_{se} = \frac{95.4}{40.9 - 4.5}$$

$$G_{se} = \frac{95.4}{36.4}$$

$$G_{se} = \mathbf{2.621}$$

Bulk Specific Gravity of Aggregate (G_{sb}):

$$G_{sb} = G_{se} - CF$$

$$G_{sb} = 2.621 - 0.021$$

$$G_{sb} = \mathbf{2.600}$$

Voids in Total Mix:

$$VTM = 100 \times \left[1 - \left(\frac{\text{Avg. } G_{mb}}{G_{mm}}\right)\right]$$

$$VTM = 100 \times \left[1 - \left(\frac{\text{Avg.}G_{mb}}{G_{mm}}\right)\right]$$

$$VTM = 100 \times \left[1 - \left(\frac{2.285}{2.445}\right)\right]$$

$$VTM = 100 \times \left[1 - 0.935\right]$$

VTM = 100 x 0.065 = **6.5%**

Voids in Mineral Aggregate:

$$VMA = 100 - \left(\frac{(\text{Avg. } G_{mb} \times P_s)}{G_{sb}}\right)$$

$$VMA = 100 - \left(\frac{2.285 \times 95.4}{2.600}\right)$$

$$VMA = 100 - \left(\frac{217.989}{2.600}\right)$$

$$VMA = 100 - 83.84$$

VMA = **16.2**

Voids Filled with Asphalt:

$$VFA = \frac{VMA - VTM}{VMA} \times 100$$

$$VFA = \frac{16.2 - 6.5}{16.2} \times 100 = \mathbf{60}$$

$$VFA = \frac{9.7}{16.2} \times 100$$

$$VFA = 0.599 \times 100$$

VFA = **60**

F/A Ratio:

$$\text{F/A ratio} = \frac{\text{\% passing 200}}{P_{be}}$$

$$P_{be} = P_b - \left\{ (P_s \times G_b) \times \left(\frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})}\right) \right\}$$

$$P_{be} = 4.6 - \left\{ ((100\text{-}4.6) \times 1.03) \times \left(\frac{(2.621 - 2.600)}{(2.621 \times 2.600)}\right) \right\}$$

$$P_{be} = 4.6 - \left\{ (95.4 \times 1.03) \times \left(\frac{.021}{6.815}\right) \right\}$$

$$P_{be} = 4.6 - \{ 98.262 \times .003 \}$$

$$P_{be} = 4.6 - 0.29$$

P_{be} = **4.31**

$$\text{F/A ratio} = \frac{5.0}{4.31}$$

F/A ratio = **1.2**

Voumetric Properties Worksheets

Determine the Maximum Specific Gravity of the Mixture (G_{mm})

Maximum Specific Gravity of the Mixture (G_{mm}) = $\frac{(C - A)}{(C - A) - (D - B)}$

A = Wt. of the Container in Air
B = Wt. of the Container in Water
C = Wt. of the Container & Sample in Air
D = Wt. of the Container & Sample in Water

Given:

A = 875.5
B = 458.8
C = 2161.8
D = 1236.3

G_{mm} = $\frac{(\quad - \quad)}{(\quad - \quad) - (\quad - \quad)}$

G_{mm} = $\frac{\qquad}{\quad - \quad}$

G_{mm} = $\frac{\qquad}{\qquad}$

G_{mm} =

Volumetric Properties Worksheets (continued)

Determine the Bulk Specific Gravity of the Mixture (Gmb) AASHTO T-166 Method A

Bulk Specific Gravity of the Mixture (G_{mb}) = $\frac{A}{(B - C)}$

A = Wt. of Core in Air
B = SSD Wt. of Core in Air
C = Wt. of Core in Water

Given:

Specimen #1	Specimen # 2	Specimen # 3
A = 4653.5	A = 4662.5	A = 4622.5
B = 4662.8	B = 4672.7	B = 4631.7
C = 2745.4	C = 2749.6	C = 2730.2

G_{mb} = $\frac{\qquad\qquad}{(\qquad - \qquad)}$

G_{mb} = ______________________

G_{mb} =

(Repeat for Specimens #2 & #3)

Calculate Average Bulk Specific Gravity (Avg. $_{Gmb}$)

Avg. $_{Gmb}$ = $\frac{G_{mb} \text{ Spec. \#1} + G_{mb} \text{ Spec. \#2} + G_{mb} \text{ Spec. \#3}}{3}$

Avg. G_{mb} = $\frac{\qquad + \qquad + \qquad}{3}$

Avg. G_{mb} =

Volumetric Properties Worksheets (continued)

Determine the % Voids in the Total Mixture (VTM)

$$VTM = 100 \times \left[1 - \left(\frac{Avg.\ G_{mb}}{G_{mm}} \right) \right]$$

Where:
Avg. G_{mb} (Average Bulk Sp. Gr. of the Mix) = 2.427
G_{mm} (Maximum Sp. Gr. of the Mix) = 2.528

$$VTM = 100 \times \left[1 - \left(\frac{\qquad}{\qquad} \right) \right]$$

$$VTM = 100 \times \left[1 - \qquad \right]$$

VTM = 100 x

VTM =

Volumetric Properties Worksheets (continued)

Determine the Effective Specific Gravity of the Aggregate (G_{se})

$$G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$$

Where:

P_b (Percent Binder) = 5.65%
G_{mm} = 2.528
G_b (Binder Sp. Gr.) = 1.030
P_s (Percent Stone) = 100 – Pb

$$G_{se} = \frac{}{\left(\frac{100}{}\right) - \left(\frac{}{}\right)}$$

$$G_{se} = \frac{}{ - }$$

$$G_{se} = \frac{}{}$$

G_{se} =

Determine the Bulk Specific Gravity of the Aggregate (G_{sb})

$G_{sb} = G_{se}$ – CF (Correction Factor from JMF)

Where:
CF (Correction Factor) = 0.026 (From Job Mix Formula)
G_{se} (Effective Sp.Gr.Agg.) = 2.769

G_{sb} = –

G_{sb} =

Volumetric Properties Worksheets (continued)

Determine the Voids in the Mineral Aggregate (VMA)

VMA uses the Average G_{mb} (Bulk Sp.Gr. of Mixture) for the three test specimen

$$VMA = 100 - \left[\frac{(\text{Avg. } G_{mb} \times P_s)}{G_{sb}} \right]$$

Where:

Avg.G_{mb} (Average Bulk Sp. Gr. of Mix) = 2.427
G_{sb} (Bulk Sp. Gr. of the Agg.) = 2.743
P_s (Percent Stone) = 94.35

$$VMA = 100 - \left[\frac{(\_\_\_\_ \times \_\_\_\_)}{} \right]$$

$$VMA = 100 - \left[\frac{\_\_\_\_\_\_\_\_}{} \right]$$

VMA = 100 –

VMA =

Volumetric Properties Worksheets (continued)

Determine the Voids Filled with Asphalt (VFA)

VFA uses the average VTM for the three specimens.

$$VFA = \left[\frac{(VMA - VTM)}{VMA} \right] \times 100$$

Where:

VMA = 16.5
VTM = 4.0

$$VFA = \left[\frac{(\qquad - \qquad)}{\qquad} \right] \times 100$$

$$VFA = \left[\frac{\qquad}{\qquad} \right] \times 100$$

VFA = x 100

VFA =

Volumetric Properties Worksheets (continued)

1. **Determine the % passing the #200 sieve from sieve analysis of the mixture.**
2. **Calculate the P_{be} (Effective Binder Content) of the mixture.**

$$P_{be} = P_b - \left[(P_s \times G_b) \times \left(\frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} \right) \right]$$

Where:

P_{be} = Effective Binder (asphalt) Content
P_b = Binder (asphalt) Content from Ignition Method (5.65%)
P_s = Percent Stone (100 – Pb)
G_b = Binder (asphalt) Specific Gravity (1.030)
G_{se} = Effective Specific Gravity of Aggregate (2.769)
G_{sb} = Bulk Specific Gravity of Aggregate (2.743)

$$P_{be} = \quad - \left[(\quad \times \quad) \times \left(\frac{(\quad - \quad)}{(\quad \times \quad)} \right) \right]$$

$$P_{be} = \quad - \left[\quad \times \left(\frac{\quad}{\quad} \right) \right]$$

$$P_{be} = \quad - \left[\quad \times \quad \right]$$

$$P_{be} = \quad - $$

$$P_{be} = $$

Volumetric Properties Worksheets (continued)

Calculate the F/A Ratio

$$\text{F/A Ratio} = \frac{\%\text{ passing \#200 sieve}}{P_{be}}$$

Where:

% passing the #200 sieve = 5.9%

P_{be} = 5.36%

F/A Ratio = ―――――

F/A Ratio =

Asphalt Mixture Volumetric Properties Formulas

Max. Specific Gravity (G_{mm})

A = Weight of Bucket in Air
B = Weight of Bucket in Water
C = Weight of Bucket and Sample in Air
D = Weight of Bucket and Sample in Water

$$G_{mm} = \frac{(C - A)}{(C - A) - (D - B)}$$

Bulk Specific Gravity of Core (G_{mb})

A = Weight of Core in Air
B = SSD Weight of Core in Air
C = Weight of Core in Water

$$G_{mb} = \frac{A}{(B - C)}$$

Average Bulk Sp. Gr. of Cores (Avg. G_{mb}) = Sum of G_{mb} Cores / Number of Cores

---

VTM (% Voids in Total Mix.)

$$\textbf{VTM} = 100 \times \left[1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right] \qquad \textbf{Avg. VTM} = 100 \times \left[1 - \left(\frac{\text{Avg. } G_{mb}}{G_{mm}}\right)\right]$$

Density

Density = 100 – VTM **Avg. Density** = 100 – Avg. VTM

Effective Specific Gravity of Aggregate (G_{se})

$$G_{se} = \frac{P_s \text{ (Percent Stone)}}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b \text{ (\% Binder Content)}}{G_b}\right)}$$

Bulk Specific Gravity of Aggregate (G_{sb})

$$G_{sb} = G_{se} - \text{CF (Correction Factor)}$$

VMA (% Voids in the Mineral Aggregate)

$$\textbf{VMA} = 100 - \frac{(\text{Avg. } G_{mb} \times P_s)}{G_{sb}}$$

VFA (% Voids Filled with Asphalt)

$$\textbf{VFA} = \frac{(\text{VMA} - \text{Avg. VTM})}{\text{VMA}} \times 100$$

Asphalt Mixture Volumetric Properties Formulas (continued)

F/A Ratio (Fines to Effective Asphalt Ratio)

$$P_{be} = P_b - \left[(P_s \times G_b) \times \left(\frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} \right) \right]$$

F/A Ratio (Fines to Effective Asphalt Ratio)

$$\textbf{F/A Ratio} = \frac{\%\ \text{passing}\ \#200}{P_{be}}$$

Definitions:

G_{mm} = Maximum Specific Gravity of the Mixture (Rice)
G_{mb} = Bulk Specific Gravity of the Mixture (Cores)
G_{se} = Effective Specific Gravity of the Aggregate
G_b = Binder (Asphalt) Specific Gravity
G_{sb} = Bulk Specific Gravity of the Aggregate (BSGA)
P_b = Percent Binder (Asphalt) Content
P_{be} = Effective Binder (Asphalt) Content
P_s = Percent Stone (100 – P_b)

CHAPTER 7
TESTING OF ASPHALT CONCRETE MIXTURES
Study Questions

1. The Ignition Method test utilizes a sample of Asphalt Concrete taken from the truck.

   A. True
   B. False

2. The Ignition Oven is the method used to determine the asphalt content in asphalt mixtures.

   A. True
   B. False

3. The Virginia test method for determining the asphalt content in asphalt mixtures is the centrifuge method.

   A. True
   B. False

4. The actual test sample of an asphalt mixture used in the Ignition Oven shall be a minimum of 1500 grams for an SM-12.5A mix.

   A. True
   B. False

5. What is the purpose of the Ignition Method?

6. Specifications allow what percent voids in the total mix for an SM-12.5A?

7. VFA are voids in a filler aggregate in asphalt mixtures.

   A. True
   B. False

8. VMA are voids in a mineral aggregate.

   A. True
   B. False

9. Aspahlt test procedures can be found in the appropriate AASHTO procedure or Virginia Test Method (VTM).

   A. True
   B. False

10. ___________ is added to asphalt as an anti-stripping agent.

11. The __________ Test checks the effectiveness of an anti-stripping additive.

CHAPTER 7
Practice Problem No. 1
Volumetric Calculations

The results of laboratory testing of a SM-9.5A yielded the following results:

Asphalt Content = 5.05
Correction Factor = .017

Asphalt Binder Specific Gravity = 1.030
Percent minus 200 = 4.5

1. Complete the following tables:

Maximum Specific Gravity of Mix (G_{mm}):

		grams
Wt. Container in Air	**A**	741.2
Wt. Container in Water	**B**	647.2
Wt. Container and Sample in Air	**C**	2724.6
Wt. Container and Sample in Water	**D**	1852.8
Maximum Specific Gravity (G_{mm}) =		

Bulk Specific Gravity of Mix (G_{mb}):

		Specimen 1	Specimen 2	Specimen3
Wt. of Specimen in Air	**A**	4797.7	4790.8	4791.1
SSD wt. of Specimen	**B**	4799.5	4792.6	4792.9
Wt. of Specimen in Water	**C**	2830.7	2828.5	2828.0
Specimen Bulk Specific Gravity				
Average G_{mb} =				

2A. Calculate the Effective Specific Gravity of the Aggregate (G_{se}) = ____________

2B. Calculate the Bulk Specific Gravity of the Aggregate (G_{sb}) = ____________

3. Calculate the VTM, VMA, VFA, and F/A ratio for this mix.

4. Do all the volumetric properties meet the mix design criteria for this mix during production?

Design Range Criteria	Specification Criteria	Calculated Results	Meet Spec.?
VTM	____________	____________	____________
VMA	____________	____________	____________
VFA	____________	____________	____________
F/A	____________	____________	____________

CHAPTER 7
Practice Problem No. 1
Work Sheet

CHAPTER 7
Practice Problem No. 2
Volumetric Calculations

The results of laboratory testing of a SM-12.5D yielded the following results:

Asphalt Content = 5.01
Correction Factor = .018
Asphalt Binder Specific Gravity = 1.030
Percent minus 200 = 6.2

1. Complete the following tables:

Maximum Specific Gravity of Mix (G_{mm}):

		grams
Wt. Container in Air	**A**	745.9
Wt. Container in Water	**B**	651.2
Wt. Container and Sample in Air	**C**	2779.4
Wt. Container and Sample in Water	**D**	1875.0
Maximum Specific Gravity (G_{mm}) =		

Bulk Specific Gravity of Mix (G_{mb}):

		Specimen 1	Specimen 2	Specimen 3
Wt. of Specimen in Air	**A**	4793.7	4792.9	4789.0
SSD wt. of Specimen	**B**	4799.2	4796.1	4791.9
Wt. of Specimen in Water	**C**	2845.5	2846.5	2844.2
Specimen Bulk Specific Gravity				
Avg. G_{mb} =				

2A. Calculate the Effective Specific Gravity of the Aggregate (G_{se}) = ____________

2B. Calculate the Bulk Specific Gravity of the Aggregate (G_{sb}) = ____________

3. Calculate the VTM, VMA, VFA, and F/A ratio for this mix.

4. Do all the volumetric properties meet the mix design criteria for this particular mix during production?

Design Range Criteria	Specification Criteria	Calculated Results	Meet Spec.?
VTM	____________	____________	____________
VMA	____________	____________	____________
VFA	____________	____________	____________
F/A	____________	____________	____________

Chapter 7
Practice Problem No. 2
Work sheet

CHAPTER 7
Practice Problem No. 3
Volumetric Calculations

The results of laboratory testing of a IM-19.0A yielded the following results:

Asphalt Content = 5.40
Correction Factor = .023
Asphalt Binder Specific Gravity = 1.030
Percent minus 200 = 6.0

1. Complete the following tables:

Maximum Specific Gravity of Mix (G_{mm}):

		grams
Wt. Container in Air	A	746.8
Wt. Container in Water	B	651.2
Wt. Container and Sample in Air	C	2923.9
Wt. Container and Sample in Water	D	1956.7
Maximum Specific Gravity (G_{mm})		

Bulk Specific Gravity of Mix:

		Specimen 1	Specimen 2	Specimen 3
Wt. of Specimen in Air	A	4790.5	4791.4	4789.1
SSD wt. of Specimen	B	4795.0	4794.9	4792.4
Wt. of Specimen in Water	C	2810.0	2813.3	2809.2
Specimen Bulk Specific Gravity (G_{mb})				
Avg. G_{mb} =				

2A. Calculate the Effective Specific Gravity of the Aggregate (G_{se}) = ____________

2B. Calculate the Bulk Specific Gravity of the Aggregate (G_{sb}) = ____________

3. Calculate the VTM, VMA, VFA, and F/A ratio for this mix.

4. Do all the volumetric properties meet the mix design criteria for this particular mix during production?

Design Range Criteria	Specification Criteria	Calculated Results	Meet Spec.?
VTM	____________	____________	____________
VMA	____________	____________	____________
VFA	____________	____________	____________
F/A	____________	____________	____________

CHAPTER 7
Practice Problem No. 3
Worksheet