AF2903 Road Construction and Maintenance

Volumetric Analysis of Asphalt Mixtures

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Volumetrics

All matter has mass and occupies space.

Volumetrics are the relationships between mass and volume

Specific Gravity, G

$$\frac{\text{Mass}}{\text{Volume}}$$

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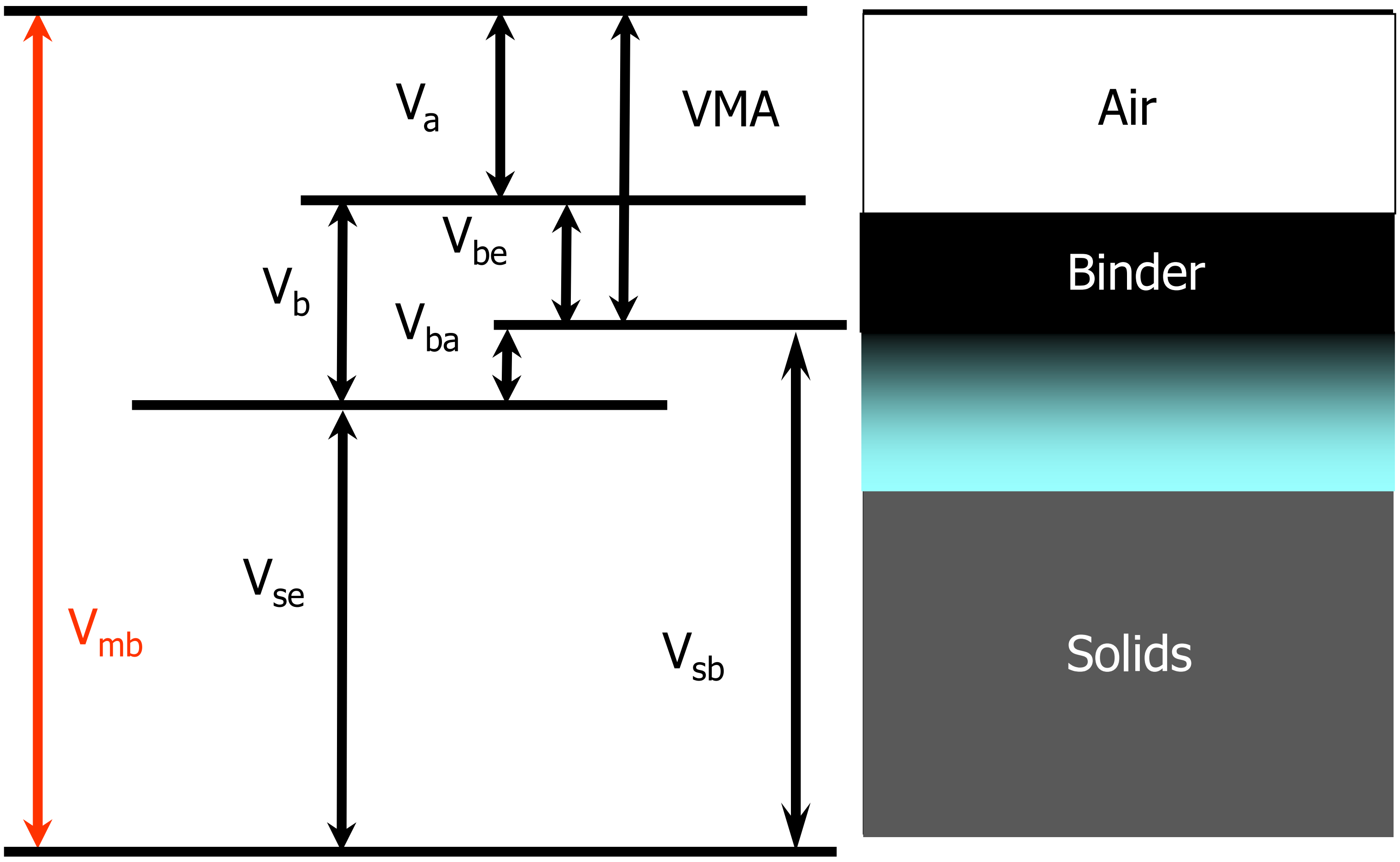
Volumetric Relationships



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Basic Terms

Specific Gravity (G): G_{xy}

x: b = binder
s = stone (i.e., aggregate)
m = mixture

y: b = bulk
e = effective
a = apparent
m = maximum

Example:

G_{mm} = gravity, mixture, maximum
(i.e., maximum gravity of the mixture)

Basic Terms (cont.)

Mass (P) or Volume (V) Concentration: P_{xy} or V_{xy}

x: b = binder
s = stone (i.e., aggregate)
a = air

y: e = effective
a = absorbed

Example:

P_b = percent binder

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HMA Volumetric Terms

Bulk specific gravity (BSG) of compacted HMA

Maximum specific gravity (Gmm)

Air voids or voids total mix (Va)

Effective specific gravity of aggregate (Gse)

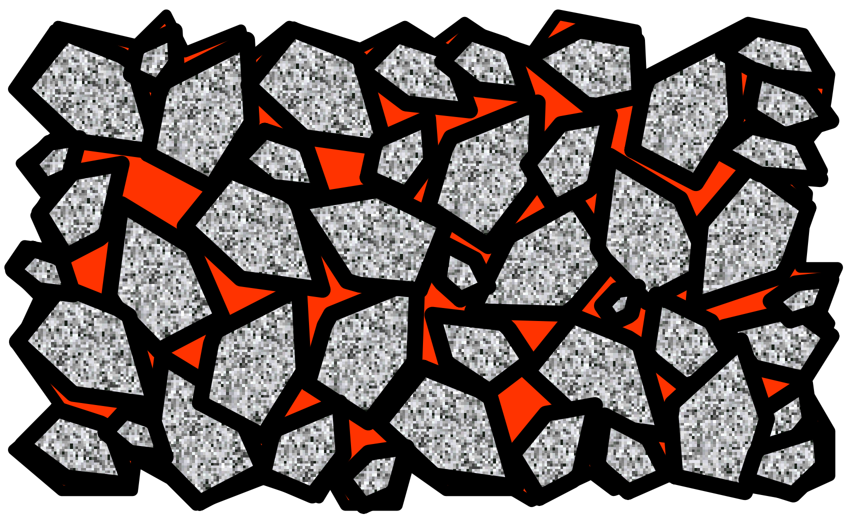
Voids in mineral aggregate, VMA

Voids filled with asphalt, VFA

Bulk Specific Gravity

AC mixed with agg. and compacted into sample

$$G_{mb} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg., AC, air voids}}$$



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Gmb Procedure

Mixing of asphalt and aggregate

Compaction of sample

Mass of dry sample

Mass under water

Mass saturated surface dry (SSD)

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Gmb Procedure

Obtain mass of dry compacted sample

Then, measure mass of specimen at SSD condition

Gmb Calculation

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

Where:

A = mass of dry sample

B = mass of SSD sample

C = mass of sample under water

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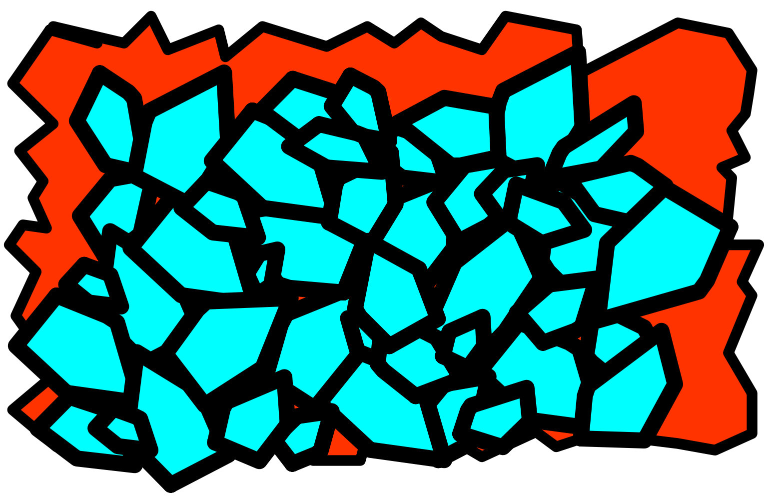
Maximum Specific Gravity (Gmm)

Loose (uncompacted) mixture.

$$G_{mm} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg. and AC}}$$



Gmm Procedure

Mixing asphalt and aggregates

Mass in air

Mass under water

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Gmm Calculation

$$G_{mm} = A / (A - C)$$

Where:

A = mass of dry sample

C = mass of sample under water

Air voids

$$\text{Air voids (Va)} = 100 * \left[\frac{Gmm - Gmb}{Gmm}\right]$$

Example:

$G_{mb} = 2.401$
$G_{mm} = 2.519$

$$\text{Air voids (Va)} = 100 * \left[\frac{2.519 - 2.401}{2.519}\right]$$

Air voids (Va) = 4.7 %

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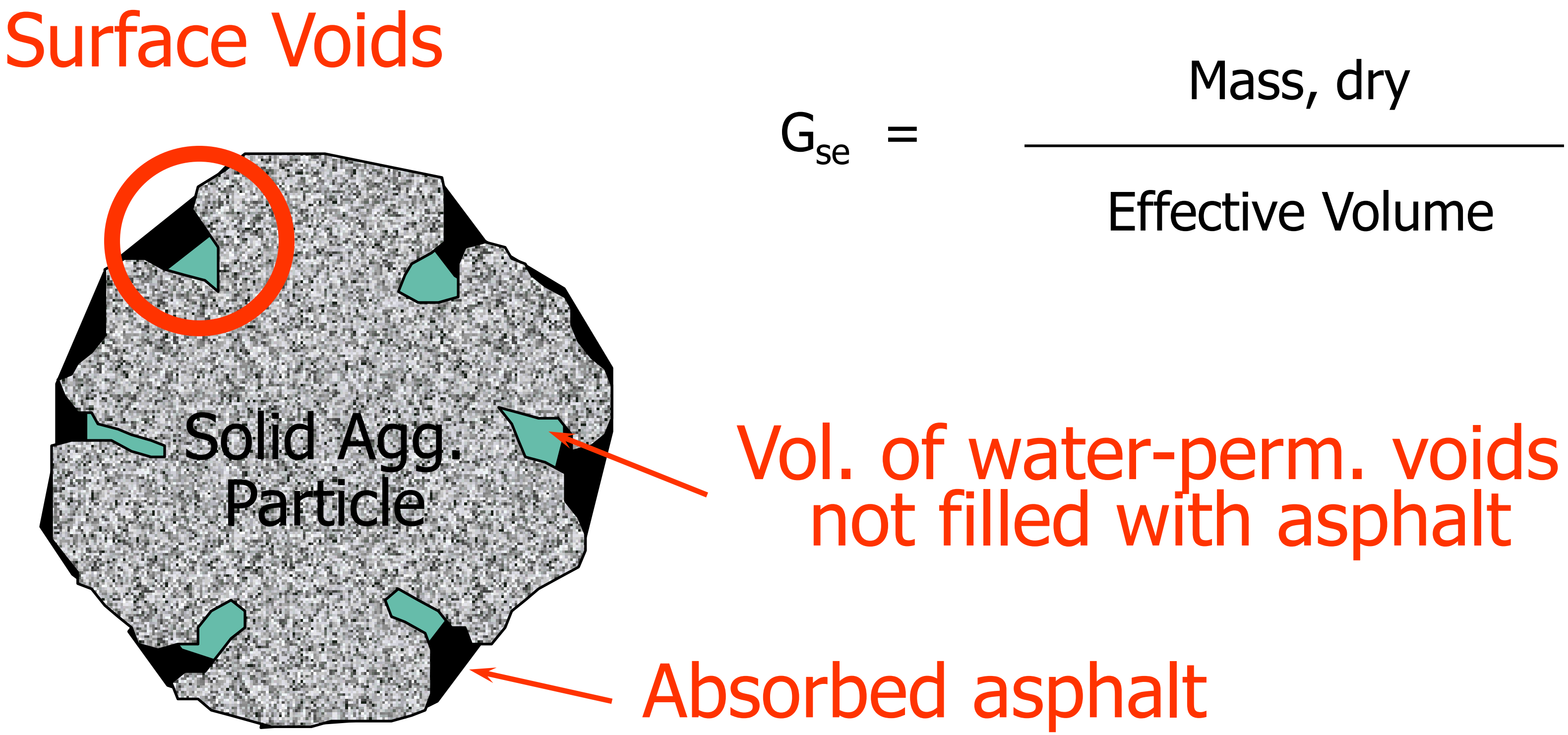
Effective Specific Gravity



$$G_{se} = \frac{\text{Mass, dry}}{\text{Effective Volume}}$$

Effective volume = volume of solid aggregate particle + volume of surface voids not filled with asphalt

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Effective Specific Gravity

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

G_{se} is an aggregate property

Example:

Mix with 5.5 % asphalt cement

$G_{mm} = 2.519$
$G_b = 1.03$

$$G_{se} = \frac{100 - 5.5}{\dfrac{100}{2.519} - \dfrac{5.5}{1.03}} = 2.750$$

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Voids in Mineral Aggregate

VMA is an indication of film thickness on the surface of the aggregate

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

Given that $G_{mb} = 2.401$, $P_s = 94.5\%$, and $G_{sb} = 2.657$

$$VMA = 100 - \frac{(2.401)\,(94.5)}{2.657} = 14.6$$

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Voids Filled with Asphalt

VFA is the percent of VMA that is filled with asphalt cement

$$VFA = 100 \text{ x } \frac{VMA - V_a}{VMA}$$

Given that Va = 4.7 , VMA = 14.6

$$VFA = 100 \text{ X } \frac{14.6 - 4.7}{14.6} = 68 \%$$

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Percent Binder Absorbed

P_{ba} is the percent of absorbed asphalt by wt. of aggregate

$$P_{ba} = 100 \left(\frac{G_{se} - G_{sb}}{G_{sb}\, G_{se}} \right) G_b$$

$$P_{ba} = 100 \left(\frac{2.750 - 2.657}{2.750 * 2.657} \right) 1.03$$

$$P_{ba} = 1.32\ \%$$

Effective Asphalt Content

The effective asphalt content is the total asphalt content minus the percent lost to absorption.

$$P_{be} = P_b - \frac{P_{ba}}{100} \quad P_s$$

$$P_{be} = 5.5 - \frac{1.32}{100} \quad x \quad 95$$

$$P_{be} = 5.5 - 1.24 = 4.26\ \%$$

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Factors That affect Volumetrics of HMA

Asphalt viscosity

Mix temperature

Time held at elevated temperature

When V_{mm} decreases, G_{mm} increases

Affects calculations:

- G_{se}
- Percent binder absorbed
- Calculated maximum specific gravity
- Air voids

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Important Considerations

Consistent laboratory procedures

- Equiviscous mixing temperatures
- Mixing times

Curing time to simulate field conditions

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Example Problem

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Example Problem

Let's assume we have a compacted HMA mixture with the following properties.

Bulk Specific Gravity of the Mixture - G_{mb} = 2.421

Theoretical Maximum Specific Gravity - G_{mm} = 2.521

Asphalt Binder Specific Gravity - G_b = 1.03

Asphalt Content - P_b = 5.0 % (by mass of total mix)

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Example Problem

Let's also assume that three stockpiled aggregates were used to manufacture this HMA mixture. The percent of each aggregate and the Bulk Specific Gravity (G_{sb}) for each is as follows:

Aggregate	% of Total Aggregate	G sb
A	50 %	2.695
B	25 %	2.611
C	25 %	2.655

Example Problem

Based on the information given for this problem, the following parameters should be calculated:

Bulk Specific Gravity of the combined aggregate

Effective Specific Gravity of the aggregate

Percent Absorbed Asphalt for the Mixture

Percent Effective Asphalt For the Mixture

Percent Voids in Total Mix for the Mixture

Percent Voids in Mineral Aggregate for the Mixture

Percent Voids Filled with Asphalt for the Mixture

Example Problem - Answers

Bulk Specific Gravity of the Combined Aggregate - G_{sb}

$$G_{sb} = \frac{(P_A + P_B + P_C)}{\left[\frac{P_A}{G_A} + \frac{P_B}{G_B} + \frac{P_C}{G_C}\right]}$$

Where:

P_A, P_B & P_C = percent by mass of each aggregate in blend

G_A, G_B & G_C = Bulk Specific Gravity of each aggregate

Based on the information given:

$P_A = 50\%$ $G_A = 2.695$
$P_B = 25\%$ $G_B = 2.611$
$P_C = 25\%$ $G_C = 2.655$

$$G_{sb} = \frac{(50 + 25 + 25)}{\left[\frac{50}{2.695} + \frac{25}{2.611} + \frac{25}{2.655}\right]} = 2.663$$

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Example Problem - Answers

Effective Specific Gravity of Aggregate - G_{se}

$$G_{se} = \frac{100 - P_b}{\left[\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right]}$$

Where:

P_b = Percent asphalt binder by total mass of mixture

G_{mm} = Theoretical Maximum Specific Gravity of mixture

G_b = Specific Gravity of asphalt binder

Based on the information given:

$P_b = 5.0\ \%$

$G_{mm} = 2.521$

$G_b = 1.03$

$$G_{se} = \frac{100 - 5.0}{\left[\frac{100}{2.521} - \frac{5.0}{1.03}\right]} = 2.729$$

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Example Problem - Answers

<u>Percent Absorbed Asphalt Binder</u> - P_{ba}

$$P_{ba} = \frac{(100 * G_b)(G_{se} - G_{sb})}{Gsb * Gse}$$

Where:

G_b = Specific Gravity of asphalt binder

G_{se} = Effective Specific Gravity of aggregate

G_{sb} = Bulk Specific Gravity of aggregate

Based on the information known:

$G_b = 1.015$

$G_{se} = 2.735$

$G_{sb} = 2.705$

$$P_{ba} = \frac{(100 * 1.03)(2.729 - 2.663)}{(2.729 * 2.633)} = 0.95\ \%$$

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Example Problem - Answers

<u>Percent Effective Asphalt Binder</u> - P_{be}

$$P_{be} = P_b - \left[\frac{(P_{ba} * P_s)}{100}\right]$$

Where:

P_b = Percent asphalt binder in total mix

P_{ba} = Percent Absorbed Asphalt Binder in total mix

P_s = Percent aggregate in total mix

Based on the information known:

P_b = 5.0 %

P_{ba} = 0.4 %

P_s = 95.0 %

$$P_{be} = 5.0 - \left[\frac{(0.93 * 95.0)}{100}\right] = 4.1\ \%$$

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Example Problem - Answers

Percent Voids in Total Mix - Va

$$Va, \% = 100 * \left[\frac{(G_{mm} - G_{mb})}{G_{mm}} \right]$$

Where:

G_{mm} = Theoretical Maximum Specific Gravity of mix

G_{mb} = Bulk Specific Gravity of mix

Based on the information known:

$G_{mm} = 2.521$

$G_{mb} = 2.421$

$$Va = 100 * \left[\frac{(2.521 - 2.421)}{2.521} \right] = 4.0 \%$$

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Example Problem - Answers

Percent Voids in Mineral Aggregate - VMA

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

Where:

G_{mb} = Bulk Specific Gravity of mix

P_s = percent aggregate in total mix

G_{sb} = Bulk Specific Gravity of aggregate

Based on the information known:

G_{mb} = 2.421

P_s = 95.0 %

G_{sb} = 2.655

$$VMA = 100 - \left[\frac{(2.421 * 95.0)}{2.655} \right] = 13.4$$

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Example Problem - Answers

<u>Percent Voids Filled with Asphalt</u> - VFA

$$VFA, \% = 100 * \left[\frac{(VMA - Va)}{VMA} \right]$$

Where:

VMA = percent Voids in Mineral Aggregate

Va = percent Voids in Total Mix

Based on the information known:

VMA = 14.8 %

Va = 3.8 %

$$VFA = 100 * \left[\frac{(13.7 - 4.0)}{13.7} \right] = 71 \%$$

Example Problem - Summary

Summary:

G_{sb}	=	2.663
G_{se}	=	2.729
P_{ba} , %	=	0.93 %
P_{be} , %	=	4.2 %
Va, %	=	4.0 %
VMA , %	=	13.7 %
VFA, %	=	71 %

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Questions

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