Asphalt Concrete Properties
Mix Volumetrics

Aggregate Particle ($M_G, V_G$)

Absorbed Asphalt ($M_{BA}, V_{BA}$)

Effective Asphalt ($M_{BE}, V_{BE}$)

Water Permeable Pores
Mix Volumetrics

Air Voids
$(V_A)$
Figure 6-9  Mass/volume relationships in asphalt mixes.

- \( M \): Total mass (\( = M_G + M_B \))
- \( M_G \): Mass of aggregate
- \( M_B \): Mass of asphalt (binder) (\( = M_{BE} + M_{BA} \))
- \( M_{BE} \): Mass of effective asphalt, the asphalt binder between particles
- \( M_{BA} \): Mass of absorbed asphalt, absorbed into the pores of the aggregate particles
- \( V \): Total volume of the compacted mix
- \( V_G \): Volume of aggregate, the bulk volume including the aggregate pores
- \( V_{BE} \): Volume of effective asphalt
- \( V_{BA} \): Volume of absorbed asphalt
- \( V_B \): Volume of asphalt (\( = V_{BE} + V_{BA} \))
- \( V_A \): Volume of air between the coated aggregate particles in the mix
- \( V_{GE} \): Effective volume of aggregate (\( = V_G - V_{BA} \))
- \( V_{MM} \): Volume of voidless mix (minimum mix volume)
Bulk Volume

Aggregate Particle

Water Permeable Pores
Net Volume

Aggregate Particle

Water Permeable Pores
Effective Volume

Aggregate Particle

Absorbed Asphalt

Water Permeable Pores
Mix Volumetrics

\[ \rho = \rho_{MB} = \text{bulk density of compacted mix} = \frac{M}{V} \]

\[ \rho_{MM} = \text{maximum density of mix} = \frac{M}{V_{MM}} \]

\[ P_B = \text{binder (asphalt) content} = \frac{M_B}{M} \times 100\% \]

\[ AV = VTM = \text{voids in total mix} = \frac{V_A}{V} \times 100\% \]

\[ \text{VMA} = \text{voids in mineral aggregate} = \frac{V_{BE} + V_A}{V} \times 100\% \]

\[ \text{VFA} = \text{voids filled with asphalt} = \frac{V_{BE}}{V_{BE} + V_A} \times 100\% \]
Voids in Total Mix (Air Voids)

\[ AV = VTM = \left( 1 - \frac{\rho_{mb}}{\rho_{mm}} \right) \times 100\% \]

\( \rho_{mb} = \text{bulk density of compacted mixture} \)

D 2726 - Bulk Specific Gravity and Density of Compacted Bituminous Mixtures

\( \rho_{mm} = \text{maximum density of the mixture} \)

D 2041 - Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
Voids in Total Mix (Air Voids)

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

- \( G_{mb} = \text{bulk specific gravity of compacted mixture} \)
- \( G_{mm} = \text{maximum specific gravity of the mixture} \)

D 2726 - Bulk Specific Gravity and Density of Compacted Bituminous Mixtures

D 2041 - Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
Example

A compacted asphalt concrete specimen has a mass in air of 1200 g and an apparent mass in water of 650 g. If the maximum specific gravity of the mix is 2.35, what is the VTM (air void content) of the specimen?
Voids in Mineral Aggregate

VTM
(Voids in Total Mix)

VMA
(Voids in Mineral Aggregate)

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Voids in Mineral Aggregate

\[
VMA = \left[ 1 - \frac{\rho_{mb} (1 - P_b)}{\rho_{sb}} \right] \times 100\%
\]

\(\rho_{mb}\) = bulk density of compacted mixture
\(\rho_{sb}\) = bulk density of the aggregate blend
\(P_b\) = asphalt binder content of mixture
Voids in Mineral Aggregate

\[
VMA = \left[ 1 - \frac{G_{mb} \left( 1 - P_b \right)}{G_{sb}} \right] \times 100\%
\]

\( G_{mb} \) = bulk relative density of compacted mixture
\( G_{sb} \) = bulk relative density of the aggregate blend
\( P_b \) = asphalt binder content (to the nearest 0.1%)
Bulk Density of Aggregate Blend

\[ \rho_{sb} = G_{sb} \times \rho_w \]

\[ \frac{1}{G_{sb}} = \frac{f_1}{G_1} + \frac{f_2}{G_2} + \cdots + \frac{f_n}{G_n} \]

- \( G_i \) = bulk relative density of aggregate \( i \)
- \( f_i \) = fraction of blend from aggregate \( i \)
Example

The compacted asphalt specimen from the previous example has a 6% asphalt content. If the aggregate blend contains 40% screenings ($G_s = 2.65$), 40% sand ($G_s = 2.69$) and 20% gravel ($G_s = 2.61$), what is the VMA of the specimen?
Voids Filled with Asphalt

\[ VFA = \left( 1 - \frac{VTM}{VMA} \right) \times 100\% \]

VFA is the percentage of the available space between the aggregate particles (the VMA) that is occupied by effective asphalt binder rather than by air voids.
Example

What is the VFA of the compacted specimen from the previous examples?