Asphalt
Mix Volumetrics

Mix Volumetrics

As was the case with portland cement concrete, the design of asphalt concrete mixes is based on having the right volume proportions of the ingredients even though the ingredients are batched by weight.

You need to have enough asphalt cement to coat all of the aggregate particles and you need to have enough air voids to prevent the asphalt cement from “bleeding” to the surface under wheel loads.

Mix Volumetrics

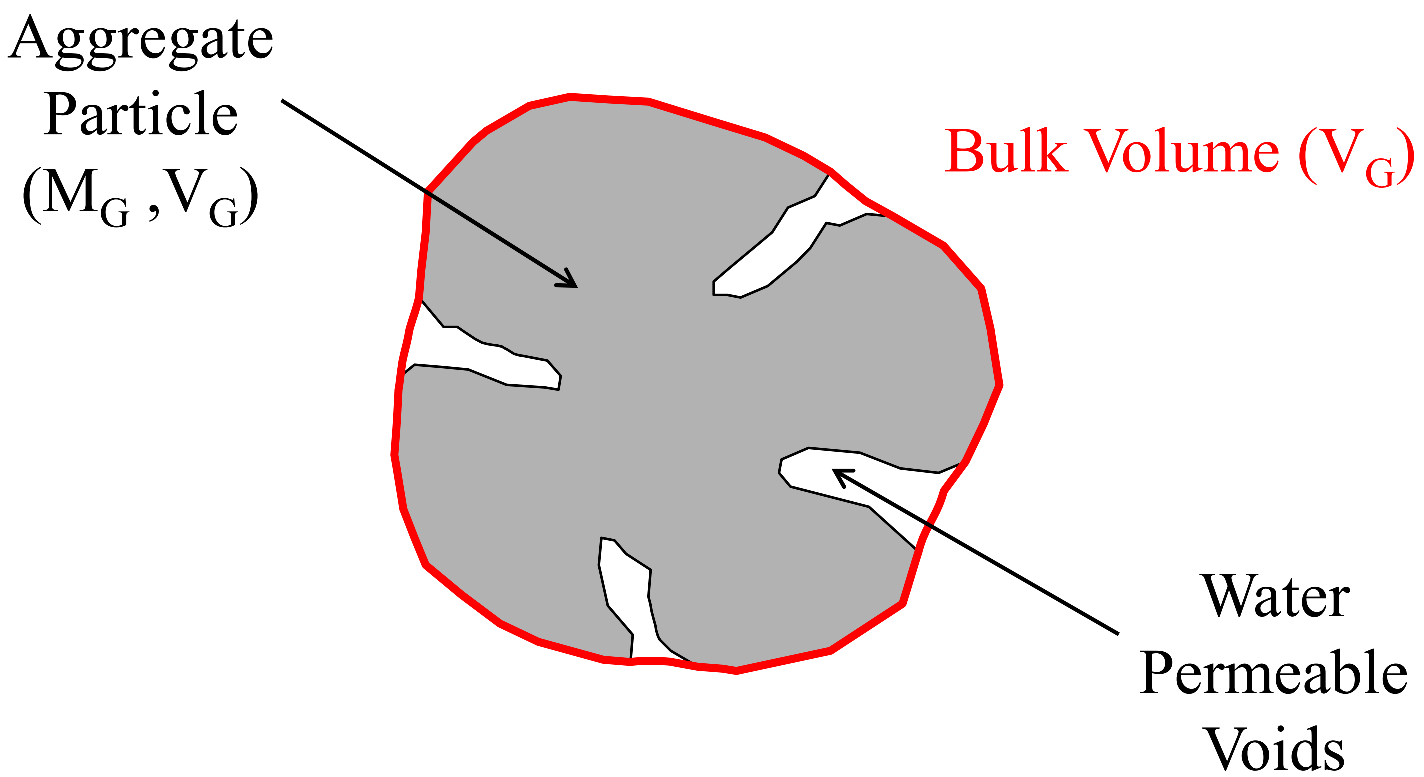
So we start our discussion of asphalt mix design with a look at the volumes of the various ingredients and a few volume ratios called voids in total mix (VTM), voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). Each of these must fall within a specified range in order to have a successful asphalt mix design.

Mix Volumetrics

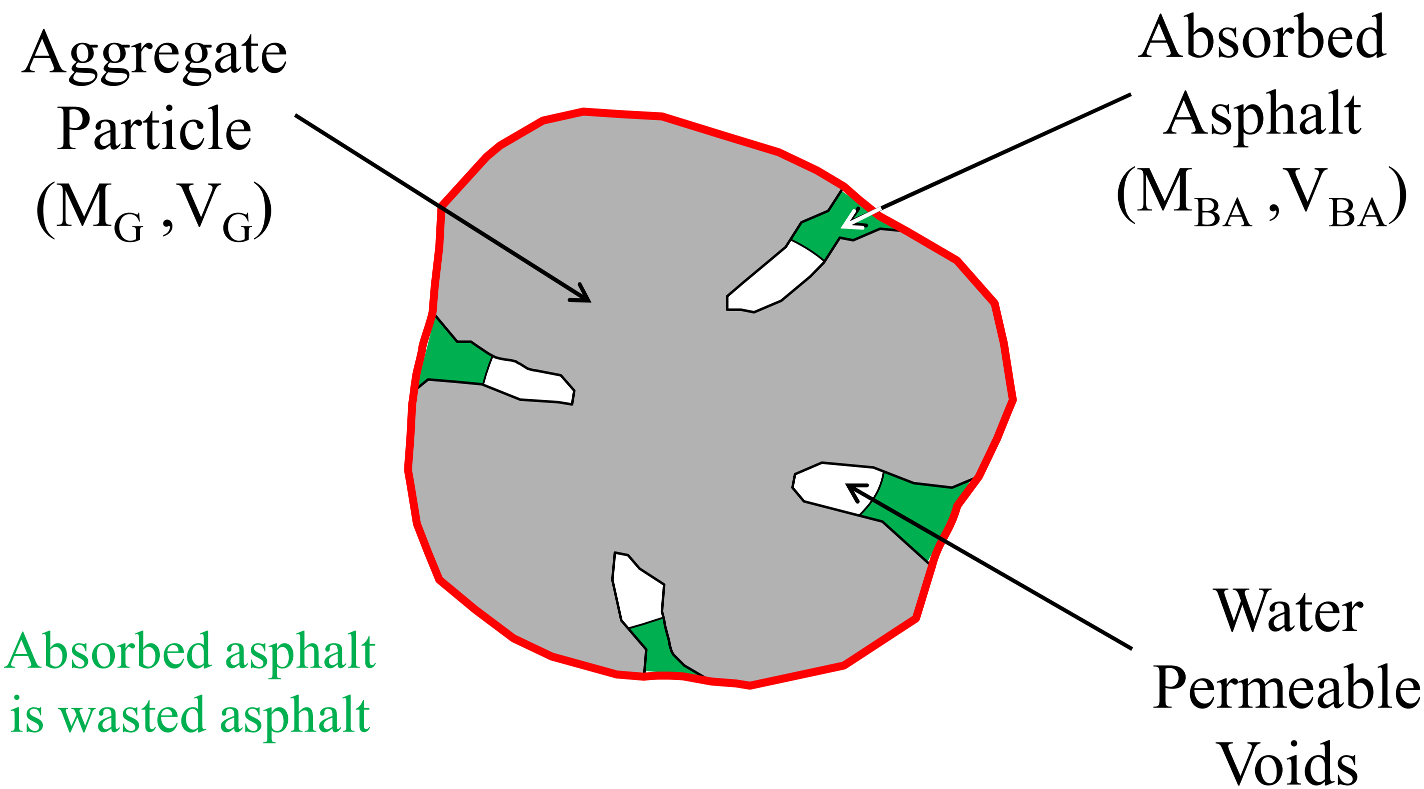
When aggregate is mixed with asphalt cement, the asphalt cement (a) coats the surface of the particles and (b) is partially absorbed into the pervious pores. The ***absorbed*** asphalt provides no benefit to the mix; only the asphalt cement on the surface is ***effective*** in binding the aggregate particles together.

The next several slides introduce the relevant masses and volumes of the aggregate, the absorbed asphalt cement, and the effective asphalt cement.

Mix Volumetrics

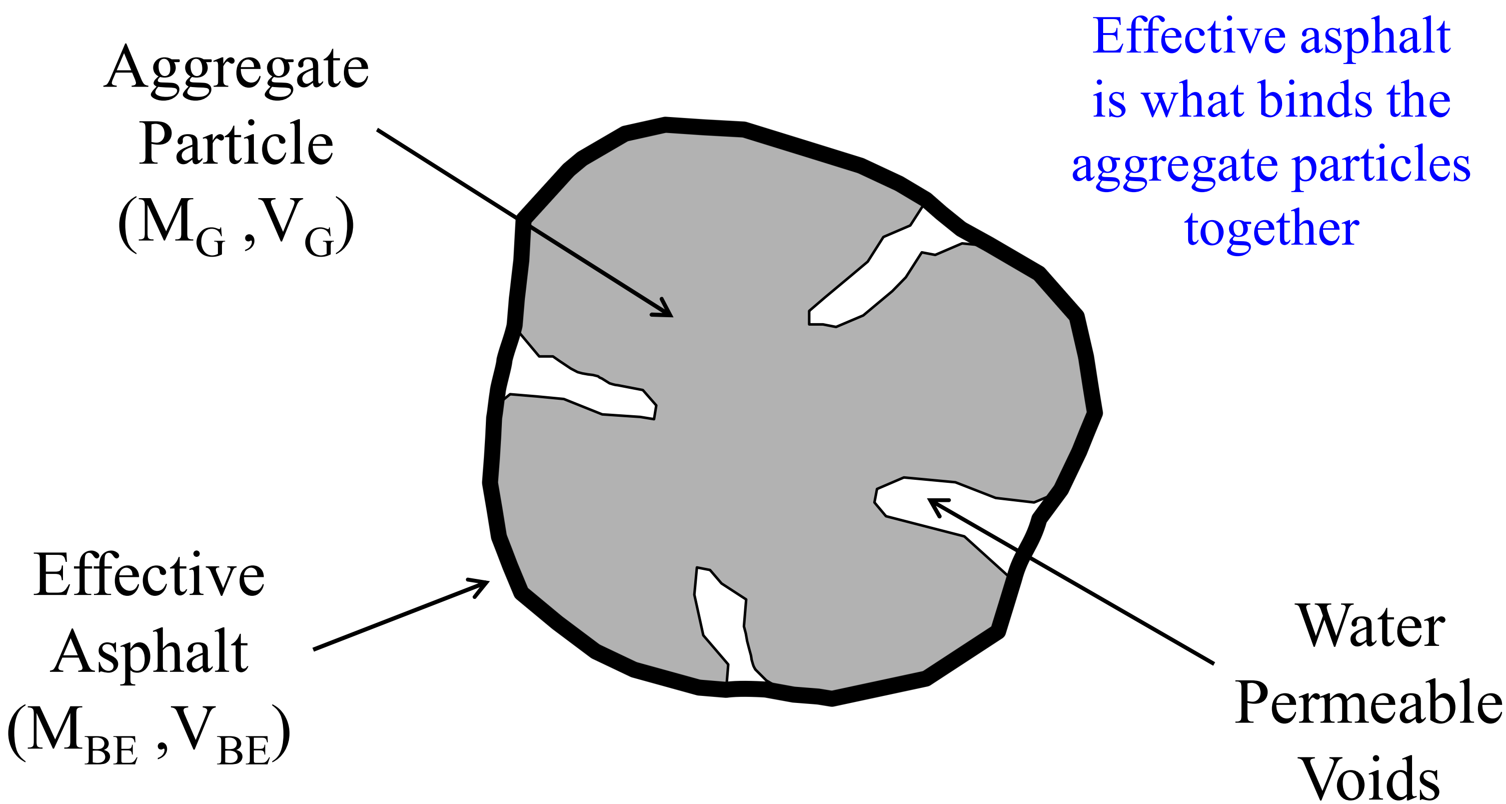


Mix Volumetrics

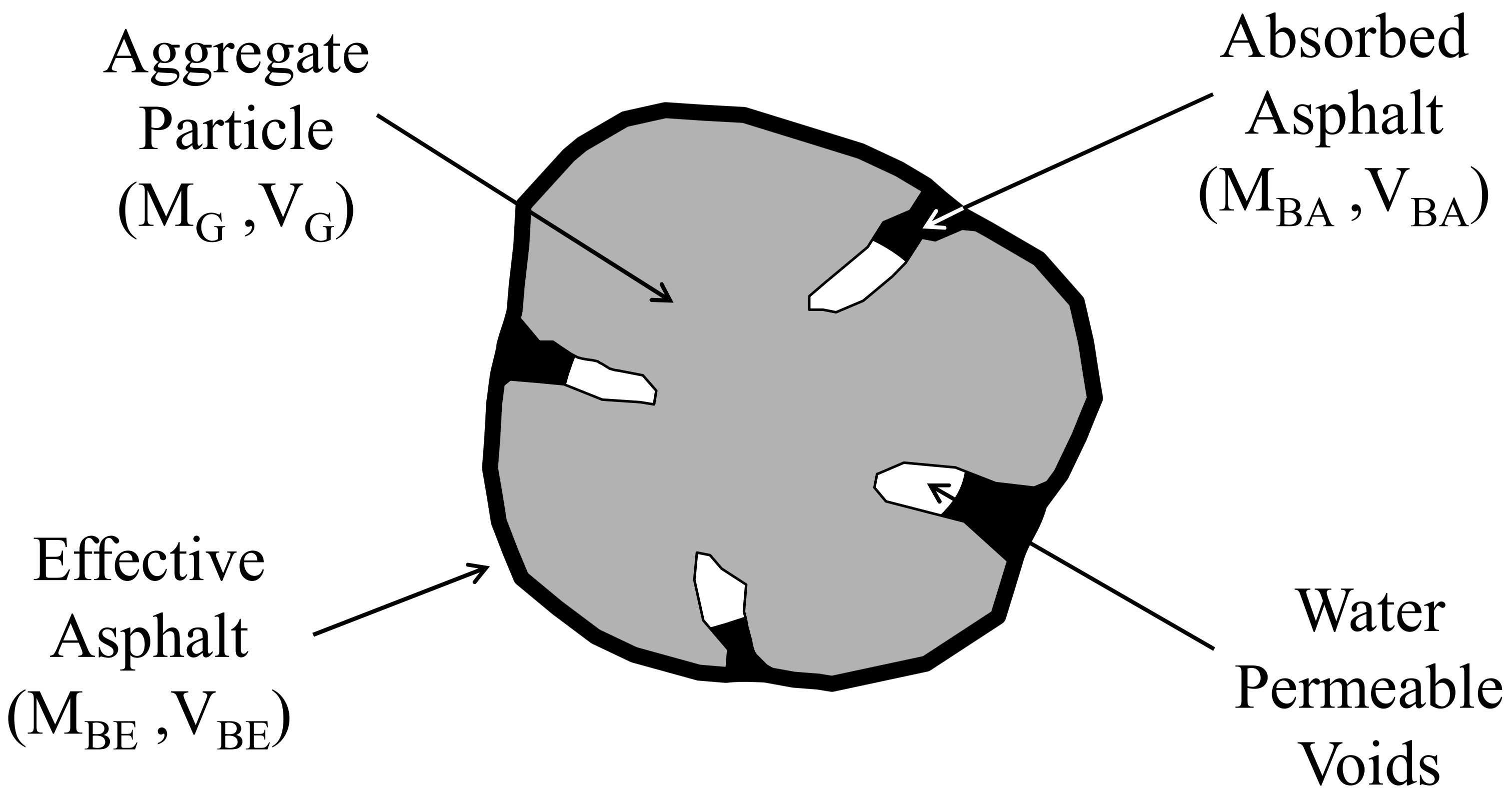


Absorbed asphalt
is wasted asphalt

Mix Volumetrics



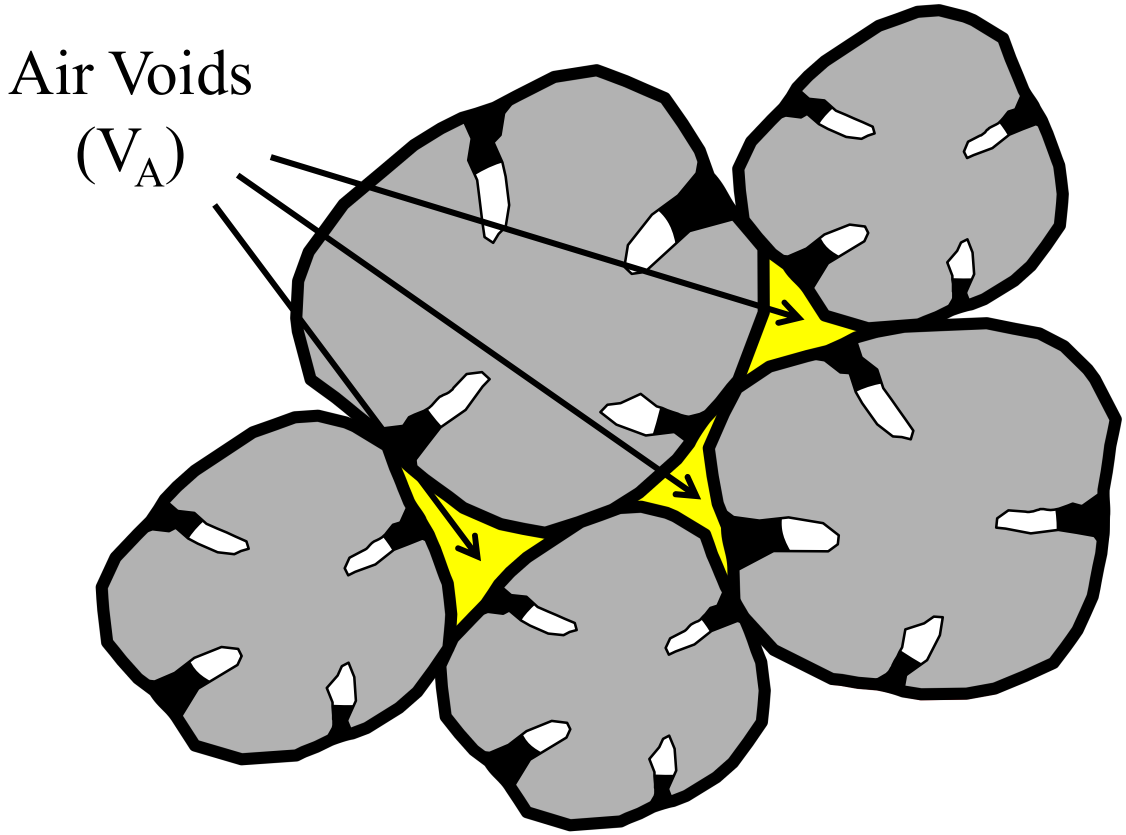
Mix Volumetrics



Voids in Total Mix

When you mix asphalt cement with aggregate, there will inevitably be some air voids in between the asphalt-coated aggregate particles. The ***voids in total mix*** (*VTM*) is the ratio of the air void volume to the total volume of the asphalt concrete. You can think of the VTM as the void content of the asphalt-coated aggregate particles inside the specimen.

Voids in Total Mix



Voids in Total Mix

We found the gravimetric air content of a portland cement concrete mix by comparing the actual density of the mix to the theoretical air-free density. We do the same sort of thing with asphalt concrete, but instead of *calculating* the air-free concrete density, we *measure* it using the "Rice" test.

Voids in Total Mix

In the Rice test, we heat the asphalt concrete mix to 140°F, disaggregate it into individual asphalt-coated particles, then determine the relative density of those particles. The relative density is found in much the same way as for fine aggregate. A *pycnometer* is filled with clean water and weighed, then the cooled asphalt-coated aggregate is added, displacing some of the water, and the pycnometer is weighed again.

ASTM D 2041 "Rice" Test

Disaggregate the asphalt concrete into individual asphalt coated rocks and small clusters of sand and asphalt …

… then determine the bulk specific gravity of the material

Voids in Total Mix

The relative density of the asphalt-coated particles is the theoretical maximum relative density of the mix.

Next, we compact the asphalt concrete to the desired density in a metal mold, extrude it from the mold, then weigh it in air and weigh it suspended in water to obtain its actual relative density.

Comparing the actual density to the air-free density gives us the voids in total mix.

ASTM D 2726

Compact the asphalt concrete to the same density as it will have in the pavement then weigh it in air and weigh it suspended in water.

$$G_{mb} = \frac{M_{\text{in air}}}{M_{\text{in air}} - M_{\text{in water}}}$$

Voids in Total Mix

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

G_{mb} = bulk specific gravity of compacted mixture

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

G_{mm} = maximum specific gravity of the mixture

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 suspended in water of 650 g. If the maximum specific gravity of the mix is 2.354, what is the air void content (voids in total mix) of the specimen?

Example

$$G_{mb} = \frac{m_{\text{in air}}}{m_{\text{in air}} - m_{\text{in water}}} = \frac{1200}{1200 - 650} = 2.182$$

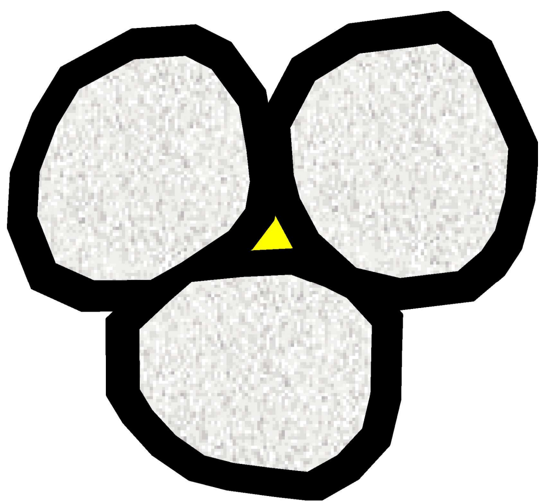
$$\text{VTM} = \left(1 - \frac{2.182}{2.354}\right) \times 100\% = 7.3\%$$

You really only need to know the VTM to the nearest 0.1%

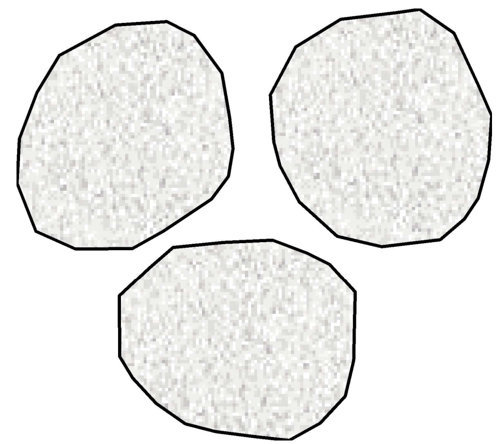
Voids in Mineral Aggregate

Imagine if you took a compacted asphalt concrete specimen and magically made all the asphalt cement disappear, leaving the aggregate particles hanging in mid-air. The ratio of the volume of the space around the aggregate particles to the total volume of the asphalt concrete is the ***voids in mineral aggregate*** (VMA). It measures how much room is available in the mix for the requisite amounts of asphalt cement and air.

Voids in Mineral Aggregate



VTM
(Voids in Total Mix)



VMA
(Voids in Mineral Aggregate)

Voids in Mineral Aggregate

If the VMA of an asphalt mix is too low, there's not enough room within the "aggregate skeleton" for the asphalt cement and air needed for a successful mix design. The resulting asphalt pavement would suffer from performance issues over time.

Voids in Mineral Aggregate

We calculate the VMA in a way similar to the VTM but this time the bulk density (specific gravity) of the aggregate itself is the theoretical maximum density. Imagine a block of solid aggregate and compare the density of that block to the density of the aggregate particles (that are now suspended in mid-air).

Voids in Mineral Aggregate

To calculate the density of the suspended aggregate particles, we need to know the ***asphalt content*** (P_b), which is the ratio of the mass of asphalt cement to the total mass of the asphalt concrete (not the mass of the aggregate as in the moisture content of aggregate).

$$P_b = \frac{m_{binder}}{m_{binder} + m_{aggregate}} \times 100\%$$

Voids in Mineral Aggregate

If we know that each cubic foot of asphalt concrete has a mass of X and we know that (let's say) 6% of that mass is asphalt cement, then the mass of all the aggregate in that cubic foot of asphalt concrete is 100% − 6% = 94% of the total mass. That's how we obtain the density of the suspended aggregate in the mix.

Voids in Mineral Aggregate

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

ρ_{mb} = bulk density of compacted mixture

ρ_{sb} = bulk density of the aggregate blend

P_b = asphalt binder content of mixture

Voids in Mineral Aggregate

If we divide top and bottom by the mass density of water (ρ_w) we convert the mass densities into relative densities (i.e., specific gravities).

Voids in Mineral Aggregate

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

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%)

Example

The compacted asphalt concrete specimen from the previous example has a 6.2% 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?

Example

$$\frac{1}{G_{sb}} = \frac{0.4}{2.65} + \frac{0.4}{2.69} + \frac{0.2}{2.61} = 0.3763$$

$$G_{sb} = \frac{1}{0.3763} = 2.658$$

$$VMA = \left[1 - \frac{2.182\left(1 - 0.062\right)}{2.658}\right] \times 100\% = 23.0\%$$

Voids Filled with Asphalt

The ***voids filled with asphalt*** (VFA) is simply the percentage of the void space between the "suspended" aggregate particles that is filled with asphalt cement. Everything else must be air.

Voids Filled with Asphalt

The VTM tells us what percentage of the total volume is air voids between the asphalt-coated aggregate and the VMA tells us what percentage of the total volume is the space available around the suspended aggregate after we've made the asphalt cement "disappear".

If you subtract the ratio of the two from 100%, you get the percentage of the available space that's <u>not</u> air, which is the percentage of the available space that is occupied by asphalt cement.

Voids Filled with Asphalt

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

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?

$$\text{VFA} = \left(1 - \frac{7.3\%}{23.0\%}\right) \times 100\% = 68.3\%$$