Volumetrics in Asphalt Mixtures

The question often arises about controlling asphalt mixtures during the mixture design process and during production. Many people who are reviewing these numbers have a complete understanding of how the numbers effect the mixture, while some have little or no experience with these numbers. This will try to explain the numbers and how they affect the mixture.

The following are terminology /definitions which are used in the analysis of asphalt paving mixtures:

Air Voids (Va)

Air voids are small airspaces or pockets of air 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 or as required by the owner. 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.

Air Voids in Compacted Mixture, Pa

= Va / VmbX 100%
= (Vmb - (Vs + Vbe)) / Vmb X 100%
= (1 - (100/Gmm) / (100/Gmb)) X 100%
= (1 - Gmb/ Gmm) X 100%
= ((Gmm - Gmb)/ Gmm) X 100%

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. Most DOT specifications require 70-80 during the design phase; this requirement is intended for the mix during the design phase only and is typically not a production requirement.

HMA designed for moderate to heavy traffic may not pass the VFA requirement with a relatively low percent of air voids in the field even though the amount of air voids is within the acceptable range. Because low air void contents may be very critical in terms of resisting permanent deformation, the VFA requirement helps to avoid those mixes that are susceptible to rutting in heavy traffic situations.

VFA also restricts the allowable air void content for HMA that are near the minimum VMA criteria. HMA designed for lower traffic volumes may not pass the VFA requirement with a relatively high percent air voids in the field even though the air void requirement range is met. The purpose for the VFA is to avoid less durable HMA resulting from thin films of binder on the aggregate particles in light traffic situations.

VFA (Voids Filled with Asphalt)

= (Vol. of eff. asphalt) / (Vol. of eff. asphalt + air)
= V_{be} / (V_a+ V_{be}) X 100%
= (VMA - Pa) / VMA X 100%
where V_{be} = volume of effective asphalt
= V_b- V_{ba} - VFA is related to VMA and Air Voids (Pa) , as can be seen from the above equation.
- A low VFA may result in a high air voids, and a high VFA may result in a low air voids

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 most

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.

VMA (Voids in Mineral Aggregate)

= (Vol. of air + effective asphalt)
(Bulk vol. of compacted mix)
= (Va + Vb - Vba) / Vmb X 100%
= (Va + Vbe) / Vmb X 100%

- Adequate VMA is needed to ensure that adequate amount of asphalt could be added to the mixture without overfilling the voids and resulting in asphalt bleeding.

- When VMA is not adequate, two possible problems are: (A) When enough asphalt to coat the aggregate is added, low air voids and bleeding will result. (B) When not enough asphalt is added, low durability will result

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, in most cases is required to use 1.0 percent hydrated lime in the mixture.

Aggregate gradation and asphalt content tolerances for acceptance of plant produced mixtures

The table show is a typical example of the tolerances and required elements for Mixture acceptance during production

Property	Maximum Tolerances for any one sample	Average of samples for given mixtures for 4 or more samples
3/4" (19mm)	± 7.0	± 4.0
½" (12/5mm)	± 7.0	± 4.0
#4 (4.75mm)	± 6.0	± 3.5
#8 (2.36mm)	± 6.0	± 3.5
#50 (0.3mm)	± 4.0	± 2.3
#200 (0.07mm)	± 2.0	± 1.2
Asphalt Content	± 0.4	± 0.3
Air Voids	± 2.0	± 1.2
VMA	>Min	>Min