Bailey Method
Offers Technicians
Volumetric Control

by Mark Blow, P.E.

I f you have trouble controlling the volumetrics and compaction of asphalt mixes, you need the Bailey Method. The Bailey Method enables the quality control technician to measure the impact of changing gradation on the ability of your mixes to meet the specifications. The Bailey Method analyzes aggregate packing characteristics to predict the VMA movement caused by changes in gradation. The factors calculated while conducting a Bailey analysis will also provide significant insight into the compactability of mixes.

The system was first developed by Robert D. Bailey, who worked with the Illinois District 5 Materials Bureau. Bill Pine of the Heritage Research Group, Indianapolis, Ind., developed further refinements.

In the 1980s, Bailey developed a procedure to assure that coarse, dense-graded mixes developed a strong, stone-on-stone skeletal structure. The method operates around the principle that when compacted, the coarsest particles in the mix establish void spaces that must accommodate asphalt, air and the smaller particles in the mix. The larger sand-sized particles which fit into these voids create void spaces that smaller sized particles will fit within. The volume of these voids and the distribution of different aggregate sizes govern the resulting VMA, air voids and the stability of the mix with regard to compaction.

This thought process eventually led to a system of four basic "Bailey Principles" which, when combined, make up the Bailey Method as it is known today.

Bill Pine of the Heritage Group teaches the Bailey Method course at Asphalt Institute headquarters.

PRINCIPLE 1—THE PRIMARY CONTROL SIEVE

The Primary Control Sieve (PCS) is the aggregate size which determines what is coarse and what is fine for any aggregate or aggregate combination. The volume of coarse aggregate (retained on the PCS) determines if a mix is a coarse-graded mix, fine- graded mix or stone matrix asphalt (SMA) mix.

A coarse-graded mix has a volume of coarse aggregate large enough to develop stone-on-stone contact. The voids created by the coarse

aggregate then determine the amount of fine aggregate that can be accommodated in the mix. The volume of voids in the coarse aggregate is determined when the aggregate is in a "Loose Unit Weight" condition as determined by AASHTO T-19.

An SMA mix is also a coarse-graded mix, but the volume of fine aggregate is significantly less than the volume of voids created by the coarse aggregate. A fine-graded mix contains a volume of fine aggregate that significantly exceeds the volume of the voids determined by T-19. This creates a situation where the particles larger than the PCS are simply floating in the fine aggregate.

The Bailey analysis can calculate the amount and direction of change in VMA caused by a variation in the percent passing the PCS. The mix type (coarse-graded, fine-graded or SMA) is very critical because a change in the percent passing the PCS may increase the VMA in one mix type and cause a decrease in VMA for a different type mix. The amount of change also varies depending on the mix type. SMA mixes are notorious for being extremely sensitive to the amount passing the primary control sieve.

Once the mix type is determined and the effects of the gradation on the PCS are accounted for, the Bailey Method then drills down into the internal distribution of particle sizes and how they affect the mix. Three different factors or ratios are determined for different segments of the gradation. The relationship of the particle sizes above the PCS is described by the "Coarse Aggregate Ratio." The aggregate material that passes the PCS is evaluated and analyzed using the "Fine Aggregate Coarse Ratio" and the "Fine Aggregate Fine Ratio."

PRINCIPLE 2 – THE COARSE AGGREGATE RATIO

The Coarse Aggregate Ratio (CA) is calculated using the percent passing a "half sieve," which is defined as half the Nominal Maximum Aggregate Size. The CA Ratio is determined by dividing the percentage of material passing the half sieve and retained on the PCS, by the percent retained on the half sieve. The ratio of smaller coarse particles to larger coarse

particles is a key element in predicting the nature of coarse-graded and SMA mixes. Recommended ranges for the CA Ratio are outlined in the procedure, along with potential problems which can arise, such as segregation and field compactability problems.

PRINCIPLE 3—THE FINE AGGREGATE COARSE RATIO

The Fine Aggregate Coarse Ratio (FAc) is a factor that examines the aggregate material that passes the PCS. It is important to remember that the fine aggregate is small enough to fit into the void spaces created by material retained on the PCS. The interesting thing to keep in mind is that the largest fine particles also create void spaces that smaller fine aggregate particles occupy. The critical size of the fine fraction is defined as $0.22 \times$ PCS, which creates a Secondary Control Sieve (SCS).

This creates an interesting dynamic. If the entire fine aggregate fraction was relatively coarse particles, there would be ample VMA within the aggregate structure. However, as the proportion of finer particles increases, the VMA falls rapidly, to a point.

As the proportion of finer particles within the fine fraction escalates, the overall fine fraction begins to become "one-sized" again and the VMA increases. The ratio of fine aggregate particles measured by the FAc Ratio is often found to have the greatest impact on the fluctuation of VMA within many mixes. The Bailey method can calculate the VMA change rate and direction of these variables within the mix.

PRINCIPLE 4—THE FINE AGGREGATE FINE RATIO

The Fine Aggregate Fine Ratio (FAf) is very similar to the FAc Ratio—only on a finer fraction of the mix. The material passing the SCS contains large enough particles to create voids that the smallest particles within the mix can occupy. A Tertiary Control Sieve is utilized for this factor and the reaction to changes in the FAf Ratio is similar to those described above under the FAc Ratio. It is important to remember that we are dealing primarily with minus #200 material, which makes up the majority of mineral filler and baghouse fines. Whether the overall mix VMA fluctuates up or down depends on the distribution of other particles within the mix. This explains why increasing or decreasing the amount of dust in a mix does not always result in the VMA change that one might anticipate.

All four of the Bailey Principles described in this article work together in determining the final characteristics of a mix. Some of the factors may increase the VMA, while others may decrease the VMA. A change in one segment of the gradation can affect the packing efficiency of the entire mix. The Bailey Method calculates the changes in the overall mixture by accounting for all four principles.

The Bailey method accounts for many things producers have known for years and ties it all together into one analytical package with mathematical relationships, parameters and recommended ranges of values to assist the asphalt mix designer and quality control manager. As one becomes proficient with this system, the applications become endless. ◼

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