HOW TO INCREASE VOIDS IN
MINERAL AGGREGATE

GUIDELINES TO INCREASE VMA OF SUPERPAVE MIXTURES

Prepared by

Ad Hoc Mix Design Task Group

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Introduction

The heart of the Superpave mixture design system is aggregate properties and volumetric properties. If all the requirements are met, the resulting mix design should have:

- a strong aggregate skeleton for permanent deformation resistance.
- sufficient asphalt binder for fatigue and asphalt binder aging resistance.
- sufficient air void space to hold plastic properties at bay and prevent permanent deformation.

Problem

An issue which has been experienced is the difficulty of obtaining adequate voids in the mineral aggregate (VMA). Although the number of mixtures which have experienced difficulty is in the minority, the mix designers have become frustrated. Problem mixes typically will have low VMA and will be non-responsive to changes in gradation.

For example, a 19.0 mm nominal maximum size mixture calls for 13.0% VMA. Say a mix designer who is trying to design below the restricted zone finds the estimated VMA in trial blends to be in the low 12's. Further, he finds that if the gradation is varied within the range available below the restricted zone that the VMA varies from the low 12's to the high 12's, 13.0% seems unachievable. The designer knows that adding additional sand will open up the mixture. But what about the restricted zone? What to do?

First, the designer should realize that the packing characteristics of aggregate particles and hence VMA is dependent on three factors:

- gradation
- surface texture
- shape

In the example, the designer has investigated the effect of gradation within the limits below the restricted zone but has not yet considered surface texture or shape. The mix designer is correct that additional fine aggregate will increase VMA but the specifications prevent adding sand because of the weakening effect which will occur in the aggregate skeleton. If the contract allows mixtures above the restricted zone the designer can investigate such mixes, although other problems will be faced, in particular, meeting density requirements at N initial.

Two competing demands are occurring during the mix design. Sufficient inter-particle space must be available for a minimum amount of asphalt binder and the aggregate must have a sufficiently strong skeleton to carry the traffic loads. Superpave specifications demand that adequate VMA be obtained without weakening the aggregate skeleton.

Gradation Effect

Changing the gradation (particle size distribution) of a mixture will influence the amount of space in the aggregate skeleton. The effect of gradation is separated from shape and surface texture effects if all sized particles have the same shape and texture. Research published by Nijboer in the 1940's, Goode and Lufsey in the 1960's and the Asphalt Institute in the 1980's provide a basis for the 0.45 power chart.

Nijboer investigated aggregate gradations plotted as the log percent passing versus log particle size. He showed a maximum packing density for both gravel and crushed aggregates when the slope was 0.45. Goode and Lufsey reconfirmed Nijboer's results on gravel aggregates. Hence, the basis of the 0.45 power chart. Work by the Asphalt Institute evaluated the drawing of maximum density lines on a 0.45 power chart for both gravel and crushed limestone mixtures.

Lower the Minus 0.075 mm Content

Lowering the dust content in a mixture will increase the VMA. This effect may not be entirely from the effect of gradation, but never the less it has one of the stronger effects on VMA. Reducing dust content to the lower end of the specification will maximize the amount of VMA which can be obtained.

If the dust content is coming from mineral filler adjusting the gradation can be simply a matter of reducing the amount being used. If the dust is coming predominately from one of the aggregate stockpiles, say screenings, try to reduce the amount of that stockpile. If the screenings are the only manufactured fines coming into the mix it may be necessary to wash them or blend them with a washed screening. But first check out other easier ways of increasing VMA.

Make sure to add baghouse fines during the mix design if the fines are going to be added back into the mix during production. These fines will reduce VMA of the produced mixture. If friable aggregate particles are used, a greater quantity of dust should be used during the design since they tend to create more dust during construction. Including baghouse fines in the mix will make the design more accurate and reduce the amount of "VMA collapse" which occurs from design to production.

Gap-Grade the Gradation

Try to blend the aggregates to give a gap grade. If the amount of material between two sieves can be reduced, the mixture will have a higher VMA. The reason has to do with packing. Smaller particles fill space in between larger ones. By gap grading the mixture the amount of a coarse sieve is increased and the amount of material between the next two sieves is decreased. Hence the mixture can not compact together as tightly, that is, VMA is increased.

Re-screen the Stockpiles

If the stockpiles contain a broad range of sizes it may be necessary to re-screen the piles into different sized products and re-blend them together at different percentages. For example, with a mobile plant where the aggregate for a single project is to be crushed in a gravel pit, the aggregate may need to be split into more than two stockpiles. If the stockpiles already exist when the mix design is being done, one of the piles may need to be re-screened on the 9.5 mm (3/8 inch) screen. Part of the sand may be excess. The mix design may not be able to use all of the sand which is present in the pit.

Even if the mix design is using manufactured aggregate products there may be instances where splitting a stockpile and using different percentages in the design may be necessary. If VMA can not be obtained with a set of stockpiles the option of splitting one of them may be more desirable than obtaining an alternate stockpile from a different source.

Surface Texture Effect

The way in which aggregate particles pack together for any given gradation is influenced by the surface texture of the particles. Rougher textures generate more friction between aggregate particles and resist compaction. Therefore, under a standard compactive effort, say a design number of gyrations, the mixture will not compact as much and VMA will be higher. Typically crushed faces have more texture than non crushed faces. In the case of gravel aggregate, the more of the particle surface which has a crushed face, the more surface texture will be available. Usually the more crushed a particle is, the more surface texture it will have but not always. Some aggregates fracture with very smooth faces so crushing may not always increase texture

Increase Manufactured Sand

If manufactured sand and natural sand are being used together in a mix design the manufactured sand portion can be increased to increase surface texture. Switching out 20% natural sand for a washed manufactured sand with good "bite" can increase VMA by 2%. Good bite? Squeeze a handful and feel the way the particles bite into one another.

Be aware of any offsetting gains in surface texture caused by increased dust. For example, if the natural sand is clean and the manufactured sand has a high minus 0.075 mm content, the benefit of increased surface texture may be offset or completely erased by increased dust content.

Increase Crush Count

Surface texture of the coarse aggregate can be increased by increasing the crush count, particularly crushed-two-face particles.

Shape Effect

For any given gradation the density to which aggregate particles will pack is influenced by the shape of the particles. Cubical particles will not pack as tightly as flat "potato chip" particles. In the gyratory compactor, as under traffic, the flat particles lay down flat, one on top of the other. Therefore, there is not much space between them. The VMA is low.

Under traffic, particles are flattened out. They roll down. The same effect occurs in a gyratory compacted specimen. Under Marshall compaction the particles are not so free to rotate. In fact, flat particles tend to bridge in a Marshall mold and give high VMA. Therefore be aware of the influence of particle shape when comparing Marshall specimens to Superpave specimens.

Evaluated Flat and Elongated

If a mix design is giving low VMA measure the flat and elongated particles. Superpave specifications limit the percentage of particles with a ratio 5:1. Measure the percentage of particles which exceed a 3:1 or 2:1 ratio.

If the percentages are high, say greater than 40%, try adding a coarse aggregate which has a lower percentage. It may be possible to change just one of the coarse aggregate stockpiles for another which is more cubical. Adding an intermediate sized coarse aggregate with cubical shapes will disturb the larger particles from lying flat, one on top of the other. The VMA will increase.

The crushing operation can make a difference. Examining the feed rate, cone settings, etc. is beneficial. Vertical shaft impact (VSI) crushers tend to produce more cubical particles than cone crushers.

Conclusion

Obtaining adequate VMA in a Superpave mixture is an important part of the mix design which must be met. VMA is only one parameter, aggregate skeleton strength is another. The challenge to Superpave mix designers is to select aggregates which will give the proper amount of VMA without weakening the skeleton. Many mixtures meet the Superpave requirements without difficulty, others require more design work. The guidelines contained in this paper are intended to help mix designers with the decision of which materials to use.

For more information regarding VMA and its role in Superpave, contact Gerry Huber or Bob McGennis.