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Hot Mix Asphalt for High Stress Applications
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Rut-resistant HMA

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Hot Mix Asphalt for High Stress Applications

INTRODUCTION

Hot Mix Asphalt (HMA) is used as a pavement surface for all types of traffic requirements. Applications include low-volume roads, high-volume roads, airfields, bus lanes, toll booths, intersections, and industrial areas. Not only does traffic vary widely, Hot Mix Asphalt pavements must also perform in weather extremes ranging from very hot desert in the Southwest, to very cold weather in the Northeast and Midwest. Each different application places different demands on the pavement and requires some minimum properties for satisfactory performance.

One of the most important requirements for good mix performance is rut resistance. Ruts may occur in HMA if the mixture is improperly designed or constructed. A rut is defined as a depression in the wheelpath of an HMA pavement.

For given weather conditions, there are two main factors which affect rutting. The first factor is the number of heavily loaded trucks: the more trucks, the more resistance to rutting is required. The second factor is the speed of traffic: pavements carrying slow moving or stopped traffic require more rut resistance than pavements carrying fast moving traffic. Therefore, asphalt mixes used in intersections, bus stops, and toll booths must meet the demands of traffic weight, speed, and volume.

The purpose of this document is to provide guidance for matching HMA properties to the intended use. First, we will look at factors which influence the rut resistance properties of HMA.

Issues to be addressed are:
- What is performance?
- How thick does a pavement need to be?
- How should the asphalt mix be designed?
- What size aggregate should be used?
- What type of stone is needed to make a good asphalt pavement?
- What about the asphalt binder to be used in the mix?
- Is there anything new which can be used?
- How can I tell in advance how a mix will perform?

Then, we will look at designing and building pavements which meet the traffic demands. Both new construction and repair of existing pavements will be discussed.

Factors Affecting Rutting

- number of trucks — more trucks, more rut resistance needed
- speed of traffic — slower speeds, more rut resistance needed
FACTORS AFFECTING HMA PERFORMANCE

What is performance?
Performance is the ability to maintain a smooth surface and provide skid-resistant friction for the life of the pavement. Asphalt pavements must resist rutting, shoving, polishing, cracking, raveling, and all other problems.

How thick does a pavement need to be?
Adequate thickness is essential for good performance, especially in critical pavement areas. Designing the correct thickness and then constructing it correctly should protect lower pavement layers from overloading. If a pavement layer is overloaded, the pavement pushes out, resulting in rutting or shoving at the pavement surface.

During construction, the thickness of each layer must be within acceptable design tolerance. Also, materials must meet the specification requirements. If reduced thickness or inferior materials are used, individual layers will be over stressed, resulting in rutting at the pavement surface. Also, during construction each layer, including the subgrade, must be fully compacted and meet density specification requirements. If the materials are not adequately compacted during construction, they will further compact under traffic, which results in rutting at the pavement surface.

Thickness Design
- consider loads
- evaluate materials
- build as designed

How should the HMA be designed?
The most common mix design method in the United States is the Marshall procedure, but the Hveem method is also used in a number of states. In the future, states will begin to adopt a new mix design procedure called Superpave. All of these methods can be used to design a quality asphalt mixture. Basically, all of the mix design methods combine acceptable aggregate (in varying percentages of different aggregate sizes) and a designed asphalt cement binder content.

If the Marshall method is selected for mix design, a 75-blow compactive effort should be used for mixtures to be placed in critical areas (intersections, Interstate highways, bus stops, toll booths, etc.). The 75-blow compaction effort will result in a mixture with higher density compared to a 50-blow compactive effort. This mixture may require more rollers during construction, and will be more resistant to rutting and shoving.

There are several adjustments that can be made to an asphalt mixture to make it more resistant to rutting and shoving. Making one or more of these adjustments will result in a more stable mixture that will better resist rutting at critical loading areas. These adjustments include:

1. Choose a gradation of aggregate to optimize stability.
   The stability of an asphalt mix depends upon the strength of the aggregate skeleton inside the mix. The gradation should be adjusted to maximize stone-on-stone contact which provides the strongest skeleton and the greatest resistance to rutting for the type of aggregate being used.

2. Use a high percentage of crushed aggregate.
   Asphalt mixes which contain a high percentage of crushed aggregate provide better aggregate interlock, and thus resist deformation.
performance is obtained when both the fine aggregate and coarse aggregate are angular. For best performance, the coarse aggregate should be crushed and the fine aggregate should have a relatively high National Aggregates Association (NAA) flow value.

3. Ensure that voids in laboratory compacted samples are sufficiently high.

Regardless of the mix design method used, the mixture must be designed at the ultimate density it will attain in the field after being subjected to traffic. At the design density, the asphalt cement content should be selected so that 4 percent air voids exist in the mixture. If a mixture is designed at 3 percent air voids or less, rutting and shoving are likely to occur during the life of the pavement. If significantly more than 4 to 5 percent air voids are designed, cracking and raveling may occur.

4. Use of modifiers or other mix additives.

The most common type of modifier increases stiffness of the asphalt cement at high temperatures, and hence increases resistance to rutting. However, in a well-designed asphalt mixture with high quality aggregates, about 80 percent of rut resistance comes from the aggregate structure. The remaining 20 percent comes from the asphalt binder. Therefore, adding a modified asphalt cement in a well-designed mix may not dramatically improve rut resistance, but may, nevertheless, improve performance.

Other types of additives can be added to the asphalt mixture such as fibers and fillers. These materials are used to reinforce the aggregate skeleton and make it more resistant to rutting. They are not, however, a substitute for good mix design practice and high quality aggregate materials.

5. Ensure that mixture is resistant to moisture damage.

Some combinations of asphalt cement binder and aggregate are susceptible to moisture damage. Such mixes will, in time, lose the bond between the asphalt and aggregate as water works its way into the mix. In other words, the asphalt is stripped from the aggregate. The mix then becomes weakened and can not carry the loads for which it was designed. During the mix design, an evaluation of susceptibility to moisture damage should be done and an anti-stripping additive should be added if necessary.

What size aggregate should be used?

Each individual layer of HMA must be designed for the position it occupies vertically in the pavement structure. Surface mixes typically use 3/8” to 3/4” (9.5 to 19mm) with 1/2” (12.5mm) maximum size aggregates being the most common. Binder mixes, which are placed under the surface mixture, usually contain either 3/4” or 1” (19 or 25mm) maximum
size aggregate. Base mixes, which are the bottom HMA layer in a pavement structure, contain maximum size aggregates from 1" up to 2 1/2" (25 to 63mm).

Each asphalt mix is constructed in a layer with a thickness two to three times the size of the maximum aggregate size. Thus, a surface mixture with 1/2" (12.5mm) maximum size aggregate should be constructed 1 1/2" (37.5mm) thick. Multiple layers of surface mixes should not be placed one on top of the other. In new construction, only one layer of surface mix is usually used. If an existing pavement is to be repaired, a new surface mix should not be laid on top of the old surface. Either the repair should include a binder and surface mixture, or the old surface mixture should be removed by cold milling before placing the new surface.

What type of stone is needed to make a good asphalt pavement?

The quality of stone used in HMA pavements is critical to good performance. The more angular the stone is, the more internal friction is created; hence, the stone skeleton is stronger and more resistant to rutting. Stone-on-stone interlock provides strength to resist rutting. Natural sands and gravels tend to be rounded and have less internal friction than crushed stone. Sometimes sand and gravel do not have enough stone skeletal strength to stand up to the traffic.

For high traffic volumes, it is critical that the stones have crushed faces to resist rutting. Sometimes it can be difficult to get enough crushed pieces with gravel aggregates. Gravel aggregate can have enough crushed faces if the rocks in the gravel pit are large enough to be crushed. If the gravel particles are small, there will not be as many crushed faces and the aggregate will not lock together to make a strong stone skeleton. In this case, another source of coarse aggregate may be required.

Some natural sands are more angular than others, and will provide better resistance to rutting. To evaluate the angularity of sands, the NAA flow test may be used. This test ranks natural and manufactured sands according to the interparticle friction each generates.

What about the asphalt cement binder to be used in the mix?

The grade of asphalt cement binder used in an area is typically specified by the state department of transportation (DOT). Usually a good performing asphalt mix can be made with the DOT recommended grade. Some states use modified asphalt cement binders for special applications.
cements which stiffen the asphalt binder at high temperature and improve rutting performance. A recent specification for asphalt cements, called Superpave, is being implemented. The Superpave classification system evaluates the benefits of the modifiers. With this system, asphalt binders are specified based on traffic levels, and the high and low temperature conditions to which the pavement will be subjected. With Superpave asphalt binders, an asphalt cement can be selected to give more rutting resistance without causing the pavement to crack in colder climates.

Is there anything new which can be used?

Most of the HMA pavements built in the United States use dense-graded asphalt mixes. A new family of asphalt mixes is now gaining acceptance based on gap-graded mixture technology. Two examples of gap-graded mixture technology include Stone Matrix Asphalt (SMA) and Superpave mixtures.

Gap-graded mixtures emphasize a strong stone-on-stone aggregate skeleton to carry the heavy loads, and a relatively passive matrix which fills the stone skeleton. In SMA mixtures, the matrix is composed of asphalt cement and fine powder (filler). SMA mixtures have higher asphalt binder contents than dense-graded mixtures. The strong stone-on-stone skeleton gives a long rut-resistant life. The high asphalt cement content makes the SMA extremely resistant to aging.

SMA mixtures are durable and have a long life. Although higher in cost, SMA should be considered a mix for applications where the benefits outweigh the additional expense.

In Superpave mixtures, a strong stone skeleton is formed to carry the traffic loads. The passive material filling the skeleton is a combination of sand and asphalt. The skeleton of Superpave mixtures does not have the same strength as an SMA mixture skeleton and the asphalt cement content is similar to regular dense-graded mixes; therefore, the life of a Superpave mix will not equal an SMA, but will last longer than many dense-graded mixes.

How can I tell in advance how a mix will perform?

There are torture test methods which can be used to see how well various mixes compare with each other. The most common is a rut tester. A slab of HMA is made in the lab and is subjected to a rolling wheel. The slabs will resist rutting depending on the stone skeleton in the mix, the interparticle friction in the skeleton, and the properties of the asphalt cement binder.

Mixes with known performance can be tested alongside new proposed mixes. Those mixes which do better in the torture test will perform better on the road. Therefore, a decision can be made whether a new proposed mix is better than one currently being used.
• Asphalt Cement—meet criteria for location. One approach is to use Superpave PG (performance graded) asphalt cements for critical loading areas such as intersections where there is standing traffic. The Superpave grade may require that the asphalt cement be modified.

• Air Voids—design and then control the asphalt mixture to have 4 percent air voids in laboratory compacted samples.

• Compaction—compact the asphalt mixture on roadway to maximum densification. The resulting air voids should be 5 to 8 percent.

If performance problems occur for a given environment or for a particular use, enhanced performance can be obtained by requiring a higher percentage of fractured faces for the coarse aggregate, by using a higher Superpave grade of asphalt cement, or by using a gradation having more coarse aggregate (a maximum of 30-45 percent passing the No. 4 (4.75mm) sieve).

Using the guidelines presented in this document, Hot Mix Asphalt pavements can be designed and constructed to provide economical, long-life pavements for high stress loading conditions, ranging from airfields to bus lanes to high-traffic urban intersections.

Additional Recommended Reading:
NAPA QIP-111 — Design of HMA for Heavy Duty Pavements
NAPA IS-103 — Large Stone Mixes: A Historical Insight
NAPA IS-104 — Performance of Open-Graded “Big Rock Mixes” in Tennessee and Indiana
NAPA IS-105 — Design & Performance Study of a Large Stone HMA under Concentrated Punching Shear Conditions
NAPA IS-118 — Guidelines for Material, Placement, and Production of Stone Matrix Asphalt (SMA)
### APPROXIMATE CONVERSIONS TO SI UNITS

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**NOTE:** Volumes greater than 1000 L shall be shown in m³.

### APPROXIMATE CONVERSIONS FROM SI UNITS

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* SI is the symbol for the International System of Measurement.

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