NCAT COMPLETES TWO NATIONAL STUDIES ON SMA AND SUPERPAVE

The National Center for Asphalt Technology (NCAT) has just completed two National Cooperative Highway Research Program (NCHRP) Projects: NCHRP 9-X, "Designing Stone Matrix Asphalt (SMA) Mixtures." and NCHRP 9-9, "Refinement of Superpave Gyratory Compaction Procedure." Dr. Ray Brown, NCAT director, was the principal investigator on both projects.

The first project on SMA represented a $1 million, four-year research effort. SMA is defined as a gap-graded hot mix asphalt (HMA) that maximizes the asphalt cement content and coarse aggregate fraction. This provides a stable stone-on-stone skeletal structure held together by a rich mixture of asphalt cement, filler, and stabilizing agent. SMA has been used in Europe for more than 25 years to provide a durable and rut-resistant pavement. Within the United States, SMA has been used successfully since 1991 on numerous pavements subjected to high traffic volume, heavy wheel loads, and high tire pressures. Some states routinely use SMA even though a nationally accepted mixture design procedure has not been available until now. Generally, recipe type specifications are used for SMA in Europe. If a food mixture design procedure is developed and adopted, it should be possible to improve the performance of SMA.

The primary objective of this project was to develop a straightforward, standard mix design procedure for SMA (Continued on page 2).
(SMA and Superpave. Continued from page 1) SMA and validate the developed procedure in the field. The following primary tasks were completed:

- **State of the Art.** The available information was summarized.
- **Critical Material and Mixture Properties.** This task entailed evaluating aggregate, mortar, and mixture properties.
- **Selection of Laboratory Tests.** Testing under this task was performed to determine what laboratory tests could be used to evaluate SMA mixtures.
- **Mixture Design Procedure.** Based on the results from the preceding tasks a mixture design procedure was finalized. This was accomplished by adapting the Superpave volumetric design procedure for SMA.
- **Mixture Analysis.** The properties of SMA mixtures produced using the proposed mix design procedure were analyzed. Testing included under this task was the indirect tensile creep and wheel tracking.
- **Field Evaluation of SMA Mix Design Procedures.** This task entailed going to various SMA construction projects throughout the United States and collecting actual field data.
- **Develop Quality Control/Quality Assurance Procedures for SMA Mixtures.** The QC/QA procedures also included a troubleshooting guide to aid in determining the specific cause of potential problems.
- **Develop SMA Construction Guidelines.** The purpose of this task was to develop SMA construction guidelines to assist producer during the production and placement of SMA mixtures.
- **Verify Laboratory Mixing and Compaction Temperatures.** A procedure for establishing the mixing and compaction temperatures for SMA mixtures was evaluated.
- **Verify Density Requirements.** At the present time, most SMA projects are being compacted to in-place air void contents of 5 to 6 percent. This appears acceptable, but there is some evidence that indicates that SMA mixtures are permeable to water at a lower air void content than dense-graded mixtures. This possibility was investigated using laboratory and field permeability tests.
- **Accuracy and Precision of Nuclear Gauge for Determining Field Density.** By nature, SMA mixtures have a rough surface texture. As a result, the use of density gauges to determine in-place density is questionable. Therefore, this task evaluated the accuracy of nuclear gauges for determining the density of SMA mixtures.

A final report documenting the research effort on this SMA research project was prepared for NCHRP. Included within this report were the final mixture design procedure, the guidelines for SMA construction, the outlined the proposed SMA mix design procedure is given in “Implementation Notes” accompanying this newsletter.

The second NCHRP project on the refinement of Superpave gyratory compactor represented a $500,000, two-year research effort. The overall goal of this project was to provide guidance in the following:

- **Evaluate the current N_{design} levels can be consolidated.**
- **Determine Superpave procedures for stone and gap-graded mixtures.**
- **Evaluate the potential for using the compaction temperature as the short-term aging temperature.**
- **Determine the appropriate design number of gyrations for mixtures** as a function of depth in the pavement structure.
- **Evaluate the current density requirements at N_{min} and N_{max} and determine whether the specification values are appropriate.**

Recommended N_{design} Levels

Currently there are a total of 28 possible N_{design} levels, specified in AASHTO PP 2X. To be used for the compaction of Superpave mixtures. Some states have recognized that the number of levels is excessive and...
(SMA and Superpave, Continued from page 2)

confusing and have, therefore, reduced them. Further, some of the levels only differ by one or two gyration levels. Research results from this project has shown that the current \( \text{N}_{\text{design}} \) compaction matrix can be consolidated from 28 to four compaction levels and still provide a range of mixture quality for all traffic categories. The recommended compaction matrix was discussed by the FHWA Mix ETG (expert task group) in September and some revisions were made. Table 1 (page 5) is the revised table which will be recommended by the mix ETG to AASHTO for adoption. As seen in the table there are four recommended \( \text{N}_{\text{design}} \) levels (50, 75, 100, and 125 gyrations). Five traffic levels are shown in the table because two traffic levels: 3-10 millions ESALs and 10-30 million ESALs have the same compaction matrix but different requirements on coarse aggregate properties.

Large stone mixtures (37.5 nominal size) can be compacted and designed in the Superpave gyratory compactor in the same manner as conventional mixtures as shown in Table 1.

Gyratory Compaction of Gap-Graded Mixtures

It is recommended that gap-graded mixtures, such as stone matrix asphalt (SMA), be designed using 100 gyrations as provided in Table 1. However, there are some cases where the design level should be decreased to 75 gyrations. The decision of the design gyration level should be based upon the experience of the user agency. For higher traffic volume roadways, the designer should consider using 100 gyrations, while 75 gyrations could be used for lower volume roadways. Also, when designing mixtures with aggregates which tend to break down during lab compaction (i.e., Los Angeles Abrasion values greater than 30), the design number of gyrations should be 75.

Short Term Aging Procedure for Superpave Mix Design

It is recommended that the short term oven aging temperature used in the Superpave volumetric mix design process be changed from 135°C to the compaction temperature of the asphalt mixture as determined from the temperature-viscosity relationship of the asphalt binder. Based upon a limited study with a low absorption aggregate (less than 2 percent water absorption), the Superpave mixture expert task group’s (ETG) recommendation of a two-hour short term aging period for mixtures with low absorption aggregates is valid. However, additional research should be performed with aggregates having a range of absorption values to make further recommendations concerning the reduction of the short term aging time from four to two hours.

Requirements for \( \text{N}_{\text{initial}} \) and \( \text{N}_{\text{maximum}} \)

It appears that the requirement of \( \%G_{\text{mm}} \) at \( \text{N}_{\text{initial}} \) of 89 percent for lower traffic volume roadways is too stringent. Fine-graded mixtures in the study which were comprised of crushed fine aggregate materials failed this requirement, especially at the lower \( \text{N}_{\text{design}} \) values. This requirement should be raised for lower volume roadways, as shown in Table 1, to allow for more fine-graded mixtures to be used.

Currently, the gyratory compaction procedure requires that specimens be compacted to \( \text{N}_{\text{maximum}} \) and densities and volumetric properties be back-calculated at \( \text{N}_{\text{design}} \). This causes an error in the calculated volumetric properties at \( \text{N}_{\text{design}} \). Since the mixture is designed based upon its volumetric properties at \( \text{N}_{\text{design}} \), Superpave volumetric mix designs should be completed by compacting specimens to their respective \( \text{N}_{\text{design}} \) values, and not \( \text{N}_{\text{maximum}} \) as currently exists. Once the optimum asphalt content of the mixture has been determined, triplicate specimens should be prepared at the optimum asphalt content and compacted to the respective \( \text{N}_{\text{maximum}} \). The average specimen density should then be calculated and compared against the density requirement at \( \text{N}_{\text{maximum}} \) of less than 98.0 percent of \( G_{\text{mm}} \).

Adjustment of \( \text{N}_{\text{initial}} \) and \( \text{N}_{\text{maximum}} \) Values During Field Process Control

During quality control or quality assurance testing of a mixture’s volumetric and densification properties, the specification values of density at \( \text{N}_{\text{initial}} \) should be raised or lowered to account for the change in the mixture’s air voids at \( \text{N}_{\text{design}} \). The amount that the specification values are changed should be equal to the difference in the measured and design \( \%G_{\text{mm}} \) at \( \text{N}_{\text{design}} \). For example, if the measured air voids in the field is 4.5 percent, then the requirements for \( \text{N}_{\text{initial}} \) and \( \text{N}_{\text{maximum}} \) should be decreased by 0.5 percent.

Interpretation of the Gyratory Compaction Slope

Based on the test results, the gyratory compaction slope does not appear to be a good indicator of the strength of the aggregate structure of the asphalt mixture. Mixtures designed at lower levels of \( \text{N}_{\text{design}} \) have higher compaction slopes than mixtures designed at higher \( \text{N}_{\text{design}} \) levels. However, the slope does recognize changes that occur in the mixture’s asphalt content within a given \( \text{N}_{\text{design}} \) level, with gradation being constant. Therefore, the slope could possibly be used in the quality control or quality assurance testing of an asphalt mixture.

Aggregate Consensus Property Requirements for Revised \( \text{N}_{\text{design}} \) Levels

Although not specifically an objective of the research (Continued on page 4)
(SMA and Superpave, Continued from page 3) project, some adjusting of aggregate consensus property requirements was necessary to match revised \( N_{\text{design}} \) levels and to formulate a standard or uniform table. Consensus property requirements are shown in Table 1. By observing Table 1, it is evident that specification values used in the past remain approximately constant. It was not an objective of the research project to determine if these values are correct in their current form. Each \( N_{\text{design}} \) level specified has one set of consensus property requirements, with the exception of the \( N_{\text{design}} \) level of 100 gyrations. Because the range of ESALs at this \( N_{\text{design}} \) level was wide (3 to 30 million ESALs), aggregate property requirements were specified for two levels of ESALs (3 to 10 million and 10 to 30 million ESALs) in the table revised by the mix ETG.

SUPERPAVE MIX COMPACTION
IN THE FIELD
—“THE TENDER ZONE”

The existence of a tender zone while compacting some Superpave mixes in the field has been reported. The tender zone is the HMA pavement temperature zone in the range of 250 to 170°F (this can vary) where compactive effort does not result in any additional density in the pavement. It has been suggested that the breakdown roller should be used very close to the paver so that at least 90 to 92 percent compaction is achieved before the HMA mat cools down into the tender zone. Rolling can resume after the mix cools below the tender zone and continue until minimum density requirements are met. The big question is—what are the causes of the tender zone in some Superpave mixes? We would like to hear from the readers.

The preceding statement appeared in the last issue of the Asphalt Technology News. We have received the following responses, which have been edited for reasons of consistency and space.

Mike Geller (Compaction Consultant, New Jersey)

This behavior is not confined to Superpave mixtures. The tender zone appears to be an interim stage in the compaction process, which is influenced primarily by the overall viscous behavior of the mix. The viscous behavior of the mix at any temperature is comprised of the influence of the asphalt binder (particularly its thin film behavior), the fines-asphalt binder relationship, and the physical qualities of the aggregate and its gradation.

In the tender zone, say 170°F-250°F, the least line of resistance is lateral rather than vertical and there isn’t enough confining area under the steel roller to prevent it. At lower temperatures, the asphalt binder has resistance to lateral flow and some further vertical compaction then takes place, sometimes very readily by a static finish roller.

As a practical matter, the solutions fall into two possible categories. The first deals with the compactor and the second deals with eliminating or mitigating influences within the mix which give rise to a tender zone.

Without trying to claim this will solve all tender zone situations, I have observed that sometimes wide base pneumatic tires have overcome tender mix behavior. Theorizing, the rubber tire should be a wide base compactor type with the largest possible contact area at an effective contact pressure. I mean 11:20 tires or larger, fully ballasted with an air pressure that generates a sufficiently high contact pressure to overcome this temporary condition.

With respect to the second solution, the description of mix resistances given by Nijboer in his book, can provide a clue. One or more of these resistances could be modified by a minor reduction in asphalt content and/or a minor increase in filler content. I suspect that what might be happening is that there is a minute lateral movement of the mix facilitated by the narrow strip of contact area confinement of a steel drum. Density does not increase, in fact it may go up and down slightly with continued rolling in the tender zone.

Christopher Gale (Maryland DOT)

I have observed that PG graded binders have a very narrow temperature range in which they exist in a plastic state as opposed to a completely liquid or a semi-solid state. This being the case, I would speculate that the tender zone is the result of some portion of the binder having returned from a liquid state to a semi-solid state and acts more as an aggregate particle than as a portion of the binder in response to compaction. This is a phenomenon I have observed in the compaction of very clayey soil samples where the water has not been given adequate time to fully lubricate the clay particles. The unhydrated clay lumps thus resist the compactive effort applied the same as would a similar sized rock particle. The temperature range of the tender zone reflects, I believe, the average temperatures the mix must reach for a discontinuous state to begin to form and then the average temperature at which substantially all the binder has returned to a semi-solid state. At this point there would no longer be a discontinuity in the state of the binder and the mix would again perform within uniform parameters. In the tender zone, some binder may be sufficiently solid that the mix under compaction performs as if it had insufficient binder content because the semi-solid fragments are not lubricating the movement of the actual aggregate particles.

(Continued on page 6)
Table 1. Superpave Design Compactive Effort and Aggregate Consensus Property Requirements

<table>
<thead>
<tr>
<th>Estimated Design Traffic Level (Million ESALs)²</th>
<th>Superpave Compaction Parameters</th>
<th>Aggregate Consensus Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N_{\text{initial}}$</td>
<td>$N_{\text{design}}$</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>55/-</td>
<td>-/-</td>
</tr>
<tr>
<td>0.3 - 3</td>
<td>7</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>75/-</td>
<td>50/-</td>
</tr>
<tr>
<td>3 - 10</td>
<td>8</td>
<td>100⁸</td>
</tr>
<tr>
<td></td>
<td>85/80</td>
<td>60/-</td>
</tr>
<tr>
<td>10 - 30</td>
<td>8</td>
<td>100⁸</td>
</tr>
<tr>
<td></td>
<td>95/90⁸</td>
<td>80/75</td>
</tr>
<tr>
<td>&gt;30.0</td>
<td>9</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>100/100</td>
<td>100/100</td>
</tr>
</tbody>
</table>

Notes:
1. It is recommended that Superpave mixtures be compacted to $N_{\text{design}}$ gyrations.
2. Values shown are based upon 20 year ESALs. For roadways designed for more or less than 20 years, determine the estimated ESALs for 20 years and choose the appropriate $N_{\text{design}}$ level.
3. "85/80" denotes that 85% of the coarse aggregate has one fractured face and 80% has two or more fractured faces.
4. Criteria are minimum presented as percent air voids in loosely compacted fine aggregate. Test to be run in accordance with AASHTO TP-33.
5. No distinction is made between depth from surface. Test to be run in accordance with AASHTO T176.
6. Criteria based upon a 5:1 maximum to minimum ratio.
7. (a) $N_{\text{design}}$ compactive effort is for typical traffic speeds. For slow/standing traffic increase $N_{\text{design}}$ by one (1) traffic level or increase high temperature binder grade by one. (No changes in aggregate properties with increased compactive effort and do not exceed $N_{\text{design}}$ of 125 gyrations.)
7. (b) For pavement layers, where the top of the design layer is more than 100 mm below the surface, decrease the compactive effort by one level, but not less than $N_{\text{design}}$ of 50 gyrations.
8. Use for Stone Matrix Asphalt (SMA). However, when the L.A. Abrasion value for the aggregate used in SMA exceeds 30, consider dropping to the next lower compaction level (75 gyrations).
(TENDER ZONE, Continued from page 4)

Carl Lubold, Jr. (LTAP, Pennsylvania)

In my opinion, the tender zone is not really a mystery, one has only to have been around before the use of baghouse fines, the Ahf Oil Embargo of 1973, and vibratory rollers. With the advent of air quality standards came the development of baghouse fines and their use in mixes. Prior to the use of baghouses, the fines for the most part went out the stack, leaving gradations that were more coarse. This gave us mixes that had high VMA and were more forgiving. With the use of baghouse fines and the oil embargo, the industry began to look at the aggregate gradation as a means to minimize the asphalt content by developing gradations that closely tracked the maximum density curve. This decreased the asphalt film thickness and also made the mixes more sensitive. Small changes in the asphalt content caused large changes in the mix characteristics. A 0.4 percent increase in asphalt content led to rutting and flushing, a similar decrease led to segregation and raveling. Superpave designs have taken us back to the rime where the asphalt binder once again plays an important role in how the pavement will react during construction. The tender zone occurs because the compactive effort being supplied by the vibratory roller exceeds the binder’s ability to resist deformation. The viscosity of the asphalt binder increases as the temperature decreases, however, the compactive effort exceeds the increase in viscosity of the binder causing a tender zone. The reason this was not as evident in times past was because the three wheel breakdown roller, pneumatic tired roller, and finish roller were not able to increase the density as rapidly, thus allowing the binder viscosity to increase at an acceptable rate. Just as was the case in the past, not all mixes will react in this manner; however, there will be a few and they will cause concern. The secret is to match the compaction effort with the rate of cooling or increase in viscosity.

Dave Powers (Ohio DOT)

In our opinion, the tender zone is a function of two primary causes: the base asphalt viscosity and mix aggregate structure. Since most of our problems have been with polymer modified binders with soft base binders (600-800 poises at 60°C), we attribute the majority of problems to just this since at high placement temperatures the base binder properties appear to control compaction. The old flow test at higher temperatures would probably pick this up as well as specific aggregate structures that tend toward high flows. We have also seen tenderness in several projects with PG 64-22 mixes, one of which was corrected by a simple PG 64-22 supplier change. We are tracking PG 64-22 viscosities for trends. We do have a concern with how suppliers are creating and/or adjusting their asphalt binders.

Bob Jouhert (The Asphalt Institute, Massachusetts)

I have observed the tender zone compaction problem with some Superpave mixes in the state of New York. In my opinion, the potential causative factors for this phenomenon are: aggregate gradation, asphalt binder properties, and mat temperature.

In mixtures with the steep S-shaped grading, the steep slope of the grading curve as it crosses the maximum density line, and the flatness of the grading curve as it approaches the 0.075 mm sieve, is noticeably different than conventional non-Superpave mixtures. This grading characteristic affects the relative percentages of fine and coarse aggregate. This type gradation approaches a gap-graded mixture, which means there are gaps in the material left on intermediate sieve sizes. This is another way of saying one size aggregate does not nest with the next larger or smaller size aggregate in the same manner that it occurs in most conventional mixtures.

These mixtures may have unique handling characteristics that vary from most conventionally designed dense-graded mixes and far and largely most

(Continued on page 7)
other Superpave mixes as well.

We know that some blends of fine and coarse aggregates are more inherently stable (even without asphalt binder) than others. A simplified example is the stability of aggregate base courses compacted versus stone. Construction equipment compacts the former and moves the latter all around, cl-eating ruts.

On some of the S-shaped gradations the trend toward single size can be dominant enough to have a significant contributing influence on the gradation instability until fully constructed. Another way of looking at it is to say that for field placement the gradation may be deficient of fine aggregate.

Generally a balanced blend of coarse and fine aggregate is best for workability or placement and compaction characteristics. However, such blends may prevent the Superpave design criteria from being met. Adjusting the gradation by adding fine aggregate is not always easy, as there is a restricted zone of gradation voids in the mineral aggregate criteria that may limit adding fine aggregate.

The stiffness or workability of the asphalt binder but mostly the fine portion of the mix. It is often referred to as the "mastic" by mix technologists in trying to explain the combined effects that really give the mix during the construction process. A clear understanding of this feature will help explain why some Superpave mixtures behave the way they do during compaction.

In many S-shaped mixtures, the fine aggregate may be such that there is much less workability cohesion contributed by the asphalt binder at high temperatures. Conventional HMA mats "sort of stick themselves together," stiffen, and fundamentally only move vertically as densities under roller action.

One can ask the question—how come breakdown rolling can be done in such cases?

Two elements are at play here:

(a) In the fluffed up, or loose, condition (25 + percent greater than the mat's compacted depth), the roller's energy and compaction effort is substantially absorbed by the low resistance of the loose condition of the HMA mat material. That is, the roller has, more support at the face of the surface, at this time of the loose condition to depth which the roller penetrates the mat.

(b) Roller pressure or pounds per lineal inch of compaction effort grows very rapidly after one or at most two passes. In other words, the stresses are changing at the mat interface with the roller. Most mats at this point are now set up to start resisting ever increasing forces in the same way pressure occurs with conventional mixtures.

However, with these unique mixes the cohesion resistance of the mastic is not strong enough yet (after breakdown passes) to hold the mixture together and resist movement. The result is that the mat is reacting by creeping forward and sideways. This occurs because the mat is reacting by creeping away from the increased pressures or pounds per square inch breakdown that the roller is now delivering to the mat.

Prithvi Kandhal (National Center for Asphalt Technology)

In my opinion, some Superpave mixes may be exhibiting this phenomenon due to very coarse gradation, and the resulting very thick asphalt binder film around the aggregate.

A typical, conventional 9.5 mm surface course mix has about 45% 50 percent material passing the 2.36 mm sieve (the amount of fine aggregate). Sometimes, to meet the minimum VMA requirement of 15.0 percent or to obtain a different aggregate structure, the gradation of a Superpave mixture is made very coarse by lowering the gradation curve toward the lower 2.36 mm control point. Such a mix can have as low as 32 percent fine aggregate.

A typical 9.5 mm open-graded asphalt friction course (OGFC) has about 15 percent fine aggregate which results in stone-on-stone contact.

Therefore, a very coarse Superpave mix is neither dense-graded like a conventional mix nor is it open-graded (with stone-on-stone contact) like an OGFC mix. It is in a "gray area" with which we have hardly any past construction or performance experience. Such a mix requires further investigation.

(Continued on page 9)

SUPERPAVE VOLUMETRIC MIX DESIGN WORKSHOPS

Superpave volumetric mix design workshops will be held at NCAT on October 27-29, 1998; December 1-3, 1998; and March 16-18, 1999. These workshops consist of two and a half days of intensive lecture, demonstration, and hands-on training on the Superpave mix design procedures. Upon completion the participants will be able to conduct the Superpave mix designs in their laboratories.

Please call (334) 844-NCAT (6228) for brochure or information, or visit our website at: http://www.eng.auburn.edu/center/ncat
ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the Fall 1998 Asphalt Forum.

We understand that the Federal Highway Administration and Florida DOT are recommending that the minimum lift thickness for Superpave should be four times the nominal maximum aggregate size. This change would have an economic impact on our hot mix asphalt program which currently uses lift thicknesses 2-2 1/2 times the maximum aggregate size. Are other states impacted by this recommendation? What are the minimum anticipated lift thicknesses for Superpave mixes in other states? Do others plan to use Superpave mixes on overlay projects as well as full construction/rehabilitation projects? (Dale Peabody, Maine DOT)

Louisiana (Chris Abadie, Louisiana Transportation Research Center)

Louisiana continues to specify minimum lift thicknesses equal to two times the nominal maximum aggregate size (40 mm for wearing course and 50 mm for binder course mixes). Contractors have achieved the 92 percent Gmm minimum with 90 PWL (percent within limits) by compacting up to an average of 93 percent Gmm with some sublots up to 94 percent Gmm. Some mix design changes may be required if higher compaction limits are specified.

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

At present, for its Superpave projects, Kentucky uses minimum lift thicknesses of three times the nominal maximum aggregate size. This policy does not result in a significant change from current minimum lift thicknesses. Using four times the nominal maximum aggregate size would be a major change resulting in a significant economic impact.

Kentucky plans to use Superpave mixes on overlay projects as well as full construction/rehabilitation projects.

Georgia (Lamar Caylor, Georgia DOT)

Currently Georgia has no plans to increase the minimum lift thickness for Superpave mixes. This position is due to the significant increased cost factors as well as our overall acceptable field compaction results. In the few cases where compaction problems have been experienced, there were too many variables between jobs to verify that lift thickness was the main factor in compaction variation.

Georgia plans to use Superpave mixes on resurfacing projects as well as new construction, and is still using minimum layer thicknesses of two times the maximum aggregate size (or three times the nominal maximum aggregate size.)

1. What procedure do other states use to determine percent moisture in HMA mixtures? Is this procedure used as part of mix production process control?
2. What procedure do other states use to approve a particular anti-strip additive for use in HMA mixtures? (Bruce Peebles, Illinois DOT)

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

Kentucky does not approve anti-stripping additives for use in Superpave mixes. The contractors are permitted to use the additive of their choice, if necessary, to satisfy the 80 percent retained strength requirement.

Louisiana (Chris Abadie, Louisiana Transportation Research Center)

Louisiana has an in-house procedure “TR 319” for moisture content. It requires a truck sample about 5 kg (10-12 lbs) spread into a pan and oven dried at 160°C (320°F) until constant mass is achieved. The maximum allowable moisture content in a plant mix is 0.5 percent by weight of mix. Antistrip additives are prequalified using “TR 317”—a boil test using a group lab standard aggregates and 0.5 percent antistrip. All mixes require antistrip. The minimum for each mix is determined by “TR 322,” a modified Lottman comparing control specimens at 7 percent voids to conditioned specimens that are moisture saturated and put through a “freeze-thaw” cycle. A minimum retained indirect tensile strength of 80 percent is specified.

Have others experienced difficulty in sealing cores from coarse Superpave mixtures (25 mm) in order to determine density? What methods have been used successfully? (Lamar Caylor, Georgia DOT)

Virginia (Bill Maupin, Virginia DOT)

I had also raised this question (problems associated with measuring correct density of coarse mixes) in the spring, 1998, issue. Since that time I have talked to others and found that they measure the volume of coarse mix cored specimens by using the specimen measurements rather than by weighing it in water. This type of measurement seems to give more realistic results for mixes where the water tends to drain from the “internal” voids exposed by the drilled surface on the (Continued on page 9)
sides of the specimens. Some type of standardization is needed for this type of measurement.

Louisiana (Chris Abadie, Louisiana Transportation Research Center)

150-mm cores are allowed in Louisiana and the mixtures tested did not require “scaling” as the difference between the air and saturated surface dry (SSD) weights of the cores was never greater than 1.25 percent, much less than the 2.0 percent allowed by specifications.

Do any states currently specify stone matrix asphalt (SMA) mix design and plant control utilizing the gyratory compactor?

Do any states require compaction to $N_{	ext{design}}$ and then back calculate Superpave mixture by adjusting $N_{	ext{design}}$ based on a history with the materials? (Chris Abadie, Louisiana Transportation Research Center)

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

Kentucky let its first SMA project in several years this season. Roth mix design and plant control, including acceptance testing, will be completed with the gyratory compactor.

For its Superpave projects, Kentucky requires compaction to $N_{	ext{design}}$ and then “backcalculation” of air voids at $N_{	ext{design}}$ for plant control, including acceptance testing. No adjustment is made for $N_{	ext{design}}$; it is determined by the ESAL’s for the project and the design high air temperature. (Please read the cover article on NCHRP 9.9 in this issue. It gives the recommendation “backcalculation” when designing a Superpave mixture. Editor)

Which states are implementing a QC/QA program in Super-pave mixtures? If a state is implementing a QC/ QA Superpave program, what type of Superpave QC/ QA specification is being developed (percent within

NCAT Director Ray Brown discussing the proposed test track sections with state DOT engineers in August.

limits, absolute average deviation, etc.)? (Milt Fletcher, South Carolina DOT)

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

Kentucky has implemented, and continues to refine, a QC/QA program for Superpave mixtures. Currently the program determines pay factors for binder content, air voids, VMA, and density based on ranges of acceptable values and deviations from target values. It is possible that revisions may be forthcoming in the QC/QA program for Superpave mixtures that would include a “percent within limits” approach.

Louisiana (Chris Abadie, Louisiana Transportation Research Center)

Louisiana has used a “percent within limits” scheme for nine Superpave projects this year. This was modeled after NCHRP Project Y-7.

(TENDER ZONE, continued from page 7)

“gray area” mix can have a peculiar mixture of traits from a dense-graded mix (compacting with the usual resistance) and an OGFC (compacting with only 2-3 passes of the roller).

A very coarse Superpave mix is also likely to have a thicker asphalt binder film around the aggregate particles compared to a finer Superpave mix or a conventional mix. The thicker asphalt binder film in coarse mixes results from specifying the same minimum VMA requirement (regardless of fine or coarse gradation in a 9.5-mm mix) and a significantly reduced aggregate surface area. When the asphalt binder film is thicker, the viscosity of the binder assumes a more influential role during the compaction process. Significantly lower compaction temperatures are needed to increase the binder’s resistance to compaction and support the weight of the roller as compared to conventional mixes.
NCAT invites your comments and questions. Questions and responses are published in each issue of Asphalt Technology News. Some are edited for reasons of consistency and space.

Alabama (Randy Mountcastle, Alabama DOT)

The Superpave binder tests show all polymers are about equal in performance. Are there any tests available to determine which polymers adequately resist rutting and fatigue cracking?

Louisiana (Chris Abadic, Louisiana Transportation Research Center)

Does any agency require percent within limits (PWL) for quality assurance of roadway density on Superpave mixtures? If so, what is the minimum specified?

Missouri (Jim Campbell, Missouri DOT)

Have other agencies experienced difficulty in comparing bulk specific gravity on Superpave mixtures compacted in different brands of gyratory compactors? How has verification of contractors’ mix designs been handled?

Montana (Sue Sillick, Montana DOT)

Montana has constructed 0 Superpave projects. All projects have had the gradation pass below the restricted zone. One project was designed to the 0.3-1 million ESAL criteria, two projects designed to the 1-3 million ESAL criteria, and seven projects designed to the 3 - 10 million ESAL criteria.

Montana DOT has noticed the characteristics of a PG 64-34 (characteristics which we believe are related to quality) can vary between suppliers, even though it passes all PG binder tests (excluding the direct tension test). Some PG 64-34 binders compact fine and “set up” or harden after cooling, other PG 64-34s have remained “alive” after compaction and have not gained the normal mat hardness for over a week after laydown. The latter will allow aggregate to pop out of the mix very easily and the durability of the mix looks poor. When tested in our Hamburg Wheel Tracking Device, using the same aggregate, some of the PG 64-34s do well while others fail very early. To avoid the poorer performing PG 64-34s we are considering adopting a “SHRP Plus” specification. Have other states run into this problem? If so, what additional tests have you adopted?

Utah (Murari Pradhan, Utah DOT)

We have not placed any Superpave mix that passed through the restricted zone. We have not experienced any problem with compaction and meeting the density requirements except for thin lifts. We would like to know if any agency has experience with a fine-graded (gradation passing above restricted zone) 12.5 mm Superpave mix.

Vermont (Timothy Pockette, Vermont DOT)

Has any agency imposed an upper limit for \( G*/\sin\theta \) obtained on neat asphalt binder and the RTFO residue. If so, how was the limit determined?

Australia (John Bethune, Australia Asphalt Pavement Association)

A working group is finalizing a report with the objective of providing a national approach towards grading of dense-graded HMA. In particular, the approach for heavy duty HMA has been to narrow the grading envelopes within which to design a target mix grading and coarser gradings at the sand component of the grading to stay below the Superpave restricted zone.

We have received a very good response to the “Pavement Work Tips” issued jointly by AUSTROADS (State Road Authorities) and Australian Asphalt Pavement Association. These are one-page publications which aim at disseminating information on the practical aspects of asphalt technology to field construction and maintenance workers.
SPECIFICATION CORNER

Alabama-Independent  quality control (QC) and quality assurance (QA) samples rather than split samples will be used to comply with the FHWA guidelines. NCAT's recommended number of gyrations will be used in designing Superpave mixtures. The mixtures will also be designed by compacting specimens up to $N_{\text{design}}$ gyrations only rather than $N_{\text{max}}$ and back calculating the bulk specific gravity at $N_{\text{design}}$ gyrations.

Colorado  The use of 100-mm (4-inch) specimens is being considered in the Superpave mixture design because specimen of this size can be tested in the Hveem stabilometer to obtain stability values.

Connecticut  A QC/QA density specification was implemented on three trial projects this year. Performance-graded (PG) binder specifications are being implemented and suppliers are now required to submit and adhere to a quality control plan in conformance to AASHTO PP 26.

Georgia  As of July 1, 1998, Georgia DOT has fully implemented the Superpave mix design system in place of the Marshall mix design system.

Kentucky  The elastic-recovery requirement for PG 76-22 binders has been increased from 50 percent to 75 percent. Research is being planned to use the Asphalt Pavement Analyzer in an attempt to develop phase-angle specification for modified PG binders. There is a plan to adjust Superpave mixture specifications to include several points from the “lead states guidance statement.” Kentucky plans a new specifications book for year 2000. Many portions will include end-result specifications. In the hot mix asphalt (HMA) area, it is planned to develop a “percent-within-limits” approach for acceptance.

In 1998 to date, Kentucky has completed four Superpave projects (108,000 metric tons). Ten Superpave projects (600,000 metric tons) are under construction. For 1999, Kentucky plans to let approximately 60 Superpave projects. Full implementation of Superpave will occur in 2000.

Louisiana  Nine Superpave implementation projects were constructed this summer incorporating NCHRP 9-7 QC/QA recommendations. The wearing course and binder course consisted of 19 mm and 25 mm mixtures, respectively. Validation lots 1000 tons each were tested by the contractor (5 samples) and by the department (5 samples) requiring 90 percent within limits (PWL) for all test parameters. All specimens were made at the contractors QC lab on-site. Designs included low, medium and high levels of traffic. There were 152, 174 and 204 gyrations ($N_{\text{max}}$) specified. The compaction requirement in the field was Y2 percent of plant Gmm with 90 PWL. Consolidation due to traffic will be followed for three years and will be compared to the compaction curve generated by the gyratory compactor. $N_{\text{design}}$ specimens were made as were $N_{\text{design}}+20$ gyrations and $N_{\text{design}}-20$ gyrations for comparison. These projects will be used to set future Superpave specifications.

Michigan  The following will be implemented in 1999: All PG binders will be extracted from daily HMA samples and recovered binder properties will be compared with Superpave binder specifications; and Superpave mixtures will be used on all roadways. Marshall mixtures will be used on shoulder, temporary roads, and freeway ramps.

Missouri  The following changes have been made to HMA specifications for IYYY construction season: (a) Mixture within 150 mm (6 inches) of longitudinal joints of high type mixtures should be compacted no less than 2 percent below the specified density; (b) The requirement to construct test strips for high type mixtures has been incorporated into standard specifications, for the past 10 years it was done through a special provision; (c) Superpave with QC/QA will be specified for all medium and heavy duty pavements for the 1999 construction season, one year sooner than anticipated. (d) Performance graded asphalt binders specified will be either PG 64-22 for all low or medium duty pavements, PG 70-22 for all heavy duty pavements, and PG 76-22 for areas of pavements that have extremely heavy or slow-moving traffic.

Montana  The PG binder specification was adopted in April, 1998. All HMA projects let after April specify a performance graded binder. When selecting a PG grade in Montana a grade is bumped at 3 million ESALs rather than IO million. Montana has called for as many as 3 different performance graded binders: PG 64-22, 64-28, 64-34, 70-28, and 58-28, with the most common being 64-28 and the least common being 64-22.

Montana’s Superpave specification does not require the contractor to develop the mix design; it also does not require the gradation to stay out of the restricted zone. So far, on all of the Superpave projects, the contractors have requested that Montana DOT do the mix design. All mix designs developed hy the Montana DOT consisted of a gradation outside the restricted zone. Our Superpave specification requires in-place compaction of 92 percent of Rice specific gravity.

(Continued on page 12)
State DOT engineers touring the NCAT laboratory in August.

(SPECIFICATION CORNER. cont. from page 11)

(Gmm) with a compaction incentive given at 94 to 95 percent of Gmm.

Nebraska - Nebraska had problems in the design of HMA mixes for use in recreation area parking lots and camper pads. The mixes would not support stationary loads. The paper by C.T. Metcalf, titled “Use of Marshall Stability Test in Asphalt Paving Mix Design” published in Highway Research Board Bulletin 234 (1959) was reviewed. The following formula was recommended by Metcalf to calculate the bearing capacity of HMA.

\[
\text{Bearing Capacity (psi)} = \frac{\text{stability}}{\text{flow}} \times \frac{120 \text{ Flow}}{100}
\]

Nebraska now specifies a minimum bearing capacity of 235 psi for HMA in such applications and the problem has been solved.

Ohio - The DOT will specify polymer-modified PG 70-22 in lieu of PG 67-28 for high volume roads. This change has been made to avoid tender mix and flushing problems associated with some PG 67-28 binders which used lower viscosity PG 58-28 binders as base asphalt. A dual Superpave specification has been recently approved. This specification allows the option of either straight Superpave aggregate requirements or the use of local materials at the option of the district, based on pavement performance and budgetary needs.

Texas - The QC/QA specification is in its fifth year and results are getting better as more experience is gained.

Utah - Although a minimum of 1 percent lime is required in all HMA mixtures, Lottman moisture-susceptibility test results on some produced mixtures have indicated that the specified minimum retained tensile strength was not obtained. This issue has been addressed by revising the specification as follows: (a) lime slurry mixing of minimum of 1 percent lime and 3 percent water in all HMA mixtures and (b) QC/QA and price adjustments using Lottman test on HMA samples taken behind the paver.

Twenty-five percent reclaimed asphalt pavement (RAP) material is allowed in all mixtures with the adjustment in the PG binder grade.

Vermont-The ignition test is now allowed to determine both the asphalt content and gradation of hot mix asphalt.

West Virginia - Four Superpave projects are under construction in 1998. All four are 100 mm Interstate overlay projects. The projects specify 70 mm of a 19 mm Superpave mix and a 30 mm lift of a 9.5 mm Superpave skid resistant surface mix. All standard Superpave materials and design requirements are being used on these projects. Superpave specifications are anticipated to be used on all Interstate overlays and any new construction projects in 1999.

Ontario, Canada - A specification for using the contractor’s quality control (QC) test results for acceptance of hot mix asphalt is being refined. A new specification for visually defective mix was included on two contracts and is being developed further.

Two new end-result specifications for smoothness, one for single and two-lift resurfacing and one for new construction with two-lift or three-lift resurfacing contracts, have been developed.

A “1998 Guide For the Use of Performance Graded Asphalt Cement (PGAC)” has been developed for highway contracts.

Australia - A working group involving State Road Authority, Industry and ARRR Transport Research has been formed to develop performance specifications for asphalt binders, which integrate all binder types, including bitumen, polymer modified bitumen, and multigrade. This will involve developing binder property/performance relationships and supporting equipment and test methods.
PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of the Association of Asphalt Paving Technologists (AAPT) held in Boston, in March, 1998. We are reporting observations and conclusions from these papers which may be of value to field engineers. These comments are obtained mostly from research projects with a limited scope: before application to practice we recommend that you read the entire paper to determine its limitations. Titles of the papers are given, with names of authors in parentheses, followed by a brief summary.

I. INVESTIGATION OF WATER PERMEABILITY OF COARSE GRADED SUPERPAVE PAVEMENTS (Choubane, Page and Musselman)

The Florida Department of Transportation (FDOT) placed approximately 325,000 tons of Superpave mix on eight projects (primarily into the rehabilitation of interstate highways) in 1996. Each project was evaluated by water seepage into the coarse graded Marshall mix that had been placed on the shoulder. With the shoulder acting as a dam, the water would overflow onto the paved shoulder. It was felt that such water discharge would likely lead to a premature failure of these projects.

The primary objectives of developing a procedure for evaluating the permeability of coarse-graded Superpave projects, was to determine the causes of water, and recommending the necessary changes to the design procedure. The projects consisted of milling and resurfacing existing pavements using Superpave mixes, which were considered coarse graded (below the 0.45 maximum density line).

A test method to measure the water permeability of hot mix asphalt (HMA) was developed by the FDOT for this investigation. It consisted of a falling head permeability testing device. Following the development of the water permeability test procedure, a sampling and testing plan was initiated to quantify the observed water problem. The results indicated that six of the eight Superpave projects were excessively permeable as compared to existing fine-graded Marshall mixes.

I. RESEARCH IN PROGRESS

We have discontinued publication of this column in this newsletter. It can now be accessed on NCAT's homepage (http://www.eng.auburn.edu/center/nut). Click on “Research in Progress.” It is updated frequently based on the information received from the Florida Department of Transportation and other sources.
percent of $G_{mm}$ was suggested when evaluating Superpave permeability. In addition, it was also suggested that the lift thickness of Superpave mixes be increased as a rule of thumb to a minimum of four times the nominal maximum aggregate size of the mix to facilitate adequate compaction.

2. OPTIMIZING USE OF RECLAIMED ASPHALT PAVEMENT WITH THE SUPERPAVE SYSTEM (Kennedy, Tam, and Solaimanian)

Pact experience, beginning in the early 1970s, has indicated that hot mix asphalt (HMA) recycling from environmental Superpave guidelines for the pavement would allow them to offer state-of-the-art undergraduate and elective courses in asphalt technology. This intensive course will be conducted at NCAT in June every year. It will be held on June 15.

The sand equivalent test (ASTM D422) is used to determine the presence of detrimental plastic fines in the fine aggregate, which may induce stripping in HMA mixes. The following fine aggregate tests have been used in the past for this purpose.

- Sand Equivalent Test. The sand equivalent test (AASHTO T176) is used to determine the proportions of plastic fines or clay-like material in fine aggregates. A plastic aggregate is one passing the 4.75 mm (No. 4) sieve that is also wet passed through a transparent cylinder which is filled with a mixture of water and a flocculating agent. After agitation and 20 minutes of settling, the sand separates from the clay-like fines, and the heights of sand and sand plus clay are measured.
equivalent is the ratio of the height of the sand to the height of sand plus clay times 100. Higher sand equivalent will be obtained in case of a cleaner fine aggregate. Super-pave specifies the sand equivalent test for testing fine aggregates.

- **Plasticity Index.** Plasticity Index (AASHTO T90) is being used by several agencies to measure the degree of plasticity of fines. Plasticity Index (PI) is the difference between the liquid limit and the plastic limit of the material passing the 425 μm (No. 40) sieve. Typically, standard specifications limit the PI of this fraction passing the 425 μm (No. 40) sieve (including the mineral filler) to a value of 4 or less. Some states specify a maximum PI for the material passing 75 μm (No. 200) sieve. A review of literature indicates no reported correlation between the PI and the field performance of HMA. Precision data have not been established for liquid limit and plastic limit tests which are based on a subjective judgement and experience of the tester.

- **Methylene Blue Test.** This French test method is recommended by the International Slurry Seal Association (ISSA) to quantify the amount of harmful clays of the smectite (montmorillonite) group, organic matter, and iron hydroxides present in fine aggregate. The principle test is to add quantities of a standard aqueous solution of the dye methylene blue to a sample until adsorption of the dye ceases.

The portion of the fine aggregate passing the 75 μm (No. 200) sieve tested in methylene blue (MBV). Ten gram of the sample are dispersed in 30 grams of distilled water in a beaker. A standard methylene blue solution is titrated with 0.5 ml aliquotes from a burette into the continuously stirred suspension. The MBV value of a specific aggregate fraction is reported as milligrams of methylene blue per gram of specific fine aggregate fraction. The MBV is proportional to the product of the clay content and the specific surface of the clay. The methylene blue test is simple and practical, and its cost is reasonable. An Ohio DOT version of the test was used in this study.

Six fine aggregates (natural sand, limestone, dolomite, granite, blast furnace slag, and limerock) were used to give a wide range of mineralogical compositions and sand equivalent values. In addition, four fine aggregate blends were made to produce a wider range of sand equivalent values. HMA mixtures (9.5 mm maximum nominal size) were prepared using these 10 fine aggregates. All mixes contained a common limestone coarse aggregate (33 percent) and different fine aggregates. Superpave volumetric mix design was used to determine the optimum asphalt content to give 4 percent air voids for mix with each fine aggregate.

The following two mixture tests were used to evaluate the stripping potential of all HMA mixtures. AASHTO T283 (Modified Lottman Test). This test is specified in Superpave.

- Hamburg Wheel Tracking Device (HWTD). The HWTD measures the effect of moisture damage by rolling a steel wheel and forth across the surface of a HMA slab that is submerged in water maintained at 50°C (122°F).

Roth AASHTO T283 and HWTD test data indicated that methylene blue is the fine aggregate test which is best related to stripping of HMA. Therefore, the methylene blue test was recommended to indicate the presence of detrimental plastic fines which may induce stripping in HMA mixes.

It should be noted that the sand equivalent test measures the relative amount of clay-sized particles in a fine aggregate whereas the methylene blue test determines both the amount and nature of potentially detrimental material, such as clay and organic material, that may be present in a fine aggregate.

---

**A SHORT COURSE IN ASPHALT TECHNOLOGY**

This training course has been developed by NCAT for practicing engineers who are involved with hot mix asphalt (HMA). The purpose of this one-week intensive course, which will be held on February 1-5, 1999, and March 22-26, 1999, is to provide a general understanding of all phases of HMA technology. Upon completion, the participant will be able to make knowledgeable decisions related to HMA pavements and communicate effectively with asphalt specialists when the need arises. NCAT will accept applications from practicing engineers from both private and public sectors in the United States and abroad. This includes personnel from the FHWA, state DOTs, FAA, Corps of Engineers, Air Force, Navy, county engineers, city engineers, consulting engineers, and contractors. Please call (334) 844-6241 or visit our website at:

[http://www.eng.auburn.edu/center/ncat](http://www.eng.auburn.edu/center/ncat) for brochure or information.
NCAT's 1998 PROFESSORTRAINING COURSE ATTENDEES AND INSTRUCTORS

DESIGNING STONE MATRIX ASPHALT (SMA) MIXTURES

Stone Matrix Asphalt (SMA) has been used in Europe for more than 25 years to resist wear from studded tires and provide resistance to rutting. Because of its success in Europe, several states within the U.S. have constructed SMA projects since 1991. As done in Europe, the mixture designs were predominantly by recipe using 50 blows of the Marshall hammer. Even with the success of these projects, more specific guidance for developing SMA mix designs was needed. For this reason, the National Cooperative Highway Research Program established Project 9-X “Designing Stone Matrix Asphalt Mixtures” and research was conducted by the National Center for Asphalt Technology.

SMA Mixtures

SMA is a hot mix asphalt consisting of two primary parts, a stable coarse aggregate skeleton and a binder rich mortar. The philosophy of SMA is therefore twofold. First, the mixture must have an aggregate skeleton with coarse aggregate-on-coarse aggregate contact (generally referred to as stone-on-stone contact) to resist rutting. Secondly, sufficient mortar of the desired consistency must be provided to ensure durability. Satisfactory mortar consistency, and thus good SMA performance, requires that a relatively high asphalt binder content be used. Because of the high asphalt binder content, SMA has the potential problem of the asphalt draining from the coarse aggregate skeleton during transportation and laydown (called draindown). To combat this potential problem, SMA requires a high percentage of material passing the 0.075 mm (No. 200) sieve (filler) (continued on back)
and the use of a stabilizer. The presence of this high filler content stiffens the asphalt binder helping minimize draindown. The high filler content will not prevent draindown, and for this reason agencies require stabilizing additives such as cellulose or mineral fiber and/or polymers to be added to the mixture to prevent draindown.

**Mixture Design Overview**

Five steps as illustrated in the figure are required to design a satisfactory SMA mixture: 1) select acceptable materials, 2) **determine** an aggregate gradation yielding stone-on-stone contact, 3) ensure chosen gradation meets or exceeds minimum voids in mineral aggregate (VMA) requirements, 4) choose an asphalt binder content that provides the desired air void level, and 5) evaluate moisture susceptibility and draindown sensitivity.

The first step, as in any mixture design process, is to select suitable materials. Materials for SMA include coarse aggregate, fine aggregate, asphalt binder, mineral filler, and a stabilizing additive. Using the selected materials, **three** trial gradations are developed that meet SMA gradation requirements and fall along the coarse and fine limits of the break point sieve along with one passing near the middle. After selection of the three trial gradations, the voids in the coarse aggregate (VCA) are determined for the coarse aggregate fraction using AASHTO T19, “**Unit Weight and Voids in Aggregate**.” The three trial blends are next combined with asphalt binder and compacted with either 50 blows of the Marshall hammer or 100 gyrations (in certain cases 75) of the Superpave **gyratory** compactor. **These** SMA mixtures are analyzed to determine air void content, VMA, and VCA of the compacted SMA mixture. A coarse aggregate skeleton with stone-on-stone contact occurs when the VCA of the SMA mixture is equal to or less than the VCA of the coarse aggregate fraction as determined by the dry **rodded** test (AASHTO T19). Based on the analyzed criteria, a trial blend is selected.

Next, using the selected trial gradation, the asphalt binder content is varied and specimens compacted. Again, the air void content, VMA, and VCA of the compacted SMA mixture are determined. Optimum asphalt binder content is selected based on four **percent** air void content. With the optimum asphalt binder content, the mixture must have a minimum VMA of 17 percent to ensure durability and the VCA of the compacted mixture must be less than the VCA of the coarse aggregate fraction to ensure stone-on-stone contact for **rut** resistance.

The mortar (material passing 0.075 mm sieve, asphalt binder, and stabilizing additives) can also be evaluated to ensure satisfactory properties. The mortar should be stiff enough to resist rutting at high temperatures but not so stiff during construction to be unworkable. The mortar properties may also affect low-temperature performance. Superpave binder tests can be used to evaluate the mortar.

Once the optimum gradation and asphalt content are established, the SMA mixture must be evaluated for moisture susceptibility and sensitivity to asphalt binder draindown. Moisture susceptibility is evaluated using AASHTO T283. Draindown is evaluated using a test method developed during the NCHRP 9-8 study. This test involves placing heated SMA mixture into a basket made of 6.3 mm (0.25 in) sieve cloth, placing the basket and mixture in an oven for one hour at the specified mix temperature, and determining the amount of asphalt binder draining from the mixture at the end of the one hour.

A copy of the detailed SMA mixture design procedure can be obtained from NCAT.