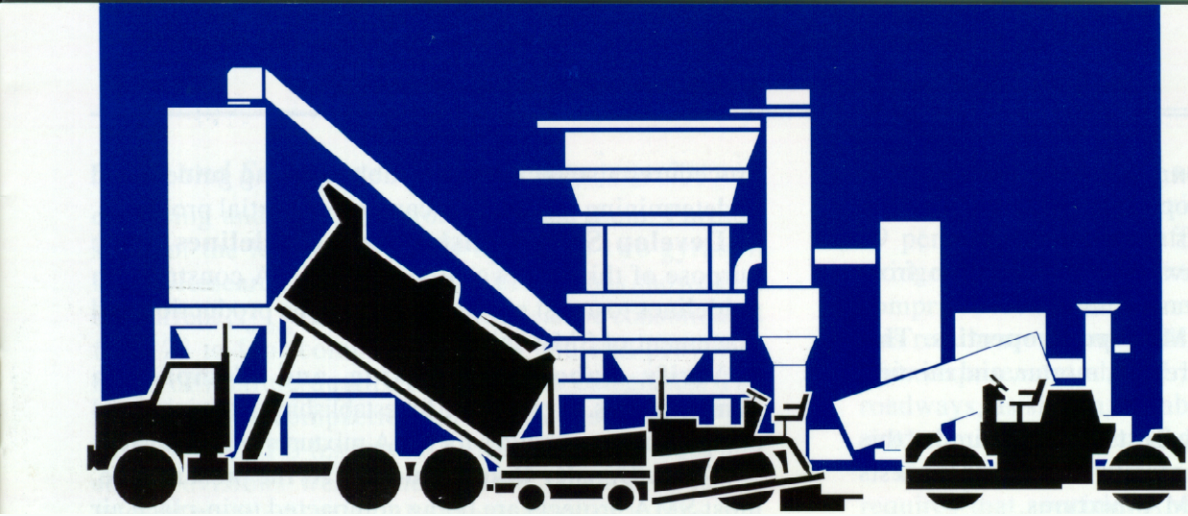

ASPHALT TECHNOLOGY NEWS

A Publication of the National Center for Asphalt Technology, Auburn University — Volume 10, Number 2 — FALL 1998

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 XI 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 he possible to improve the performance of SMA.

The primary objective of this project was to develop a straightforward. standard mix design procedure for

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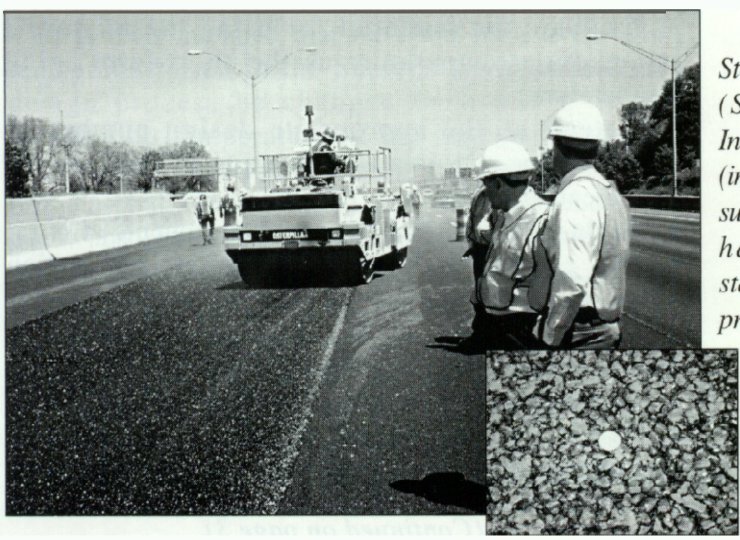


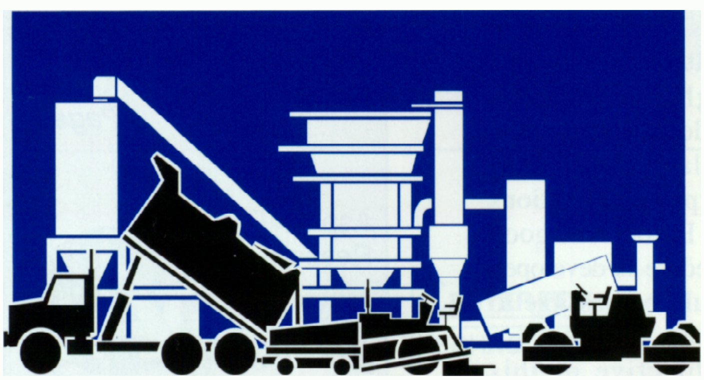
Stone matrix asphalt (SMA) paving on Interstate 85 in Atlanta (inset: closeup of SMA surface texture). NCAT has developed a standard mix design procedure for SMA.

In This Issue

National Center for Asphalt Technology

(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 from more than 100 references was summarized.
- **Critical Material and Mixture Properties.** This task entailed evaluating aggregate, mortar, and mixture propcrtics.
- **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 propcrtics 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 arc being compacted to in-place air void contents of' 5 to 6 percent. This appears to be acceptable, but there is some evidence that indicates that SMA mixtures are permeable to water at a lower air void content than are 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 nuclear density gauges to determine in-place density is questionable. Therefore. this task evaluated the accuracy of nuclear gauges for determining thr density of SMA mixtures.



A final report documenting the total research effort on this SMA research project was prepared for the NCHRP. Included within this report were the final mixture design procedure. the QC/QA procedures. and guidelines for SMA construction. The outline of 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} compaction matrix and determine whether the levels can be consolidated.
- Determine Superpave mixture design procedures for large stone and gap-graded mixtures.
- Evaluate the potential for using the mixture's compaction temperature as the short-term aging temperature.
- Dctcrminc thr appropriate design number of gyrations for mixtures as a function of depth in the pavement structure.
- Evaluate the current density requirements at $N_{initial}$ and $N_{maximum}$ and determine whether the specification values are appropriate.

Recommended N_{design} Levels

Currently there are a total of 28 possible N_{design} level?, specified in AASHTO PP 2X. to he used for the compaction of Superpave mixtures. Some states have recognized that this number of levels is excessive and

(Continued on page 3)

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(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 N_{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 N_{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 $N_{initial}$ and $N_{maximum}$

It appears that the requirement of $\%G_{mm}$ at $N_{initial}$ 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 N_{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 $N_{maximum}$ and densities and volumetric properties be back-calculated at N_{design}. This causes an error in the calculated volumetric properties at N_{design}. Since the mixture is designed based upon its volumetric properties at N_{design}, Superpave volumetric mix designs should be completed by compacting specimens to their respective N_{design} values, and not $N_{maximum}$ 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 $N_{maximum}$. The average specimen density should then be calculated and compared against the density requirement at $N_{maximum}$ of less than 98.0 percent of G_{mm}.

Adjustment of $N_{initial}$ and $N_{maximum}$ 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 $N_{initial}$ should be raised or lowered to account for the change in the mixture's air voids at N_{design}. The amount that the specification values are changed should be equal to the difference in the measured and design $\%G_{mm}$ at N_{design}. For example, if the measured air voids in the field is 4.5 percent, then the requirements for $N_{initial}$ and $N_{maximum}$ 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 N_{design} have higher compaction slopes than mixtures designed at higher N_{design} levels. However, the slope does recognize changes that occur in the mixture's asphalt content within a given N_{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 N_{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_{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_{design} level specified has one set of consensus property requirements, with the exception of the N_{design} level of 100 gyrations. Because the range of ESALs at this N_{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

Estimated Design Traffic Level (Milion ESALs)[2]	Superpave Compaction Parameters			$\%G_{mm}$ $N_{initial}$ Requirement	Aggregate Consensus Properties					
					Coarse Aggregate Angularity[3]		Fine Aggregate Angularity[4]		Sand Equivalent Value[5]	Flat and Elongated[6]
	$N_{initial}$	N_{design}[7]	$N_{maximum}$		≤ 100 mm	> 100 mm	≤ 100mm	> 100 mm	All Mixtures	All Mixtures
< 0.3	6	50	75	≤ 91.5	55/-	-/-	-		40	
0.3 -	7	75	115	≤ 90.5	75/-	50/-	40	40	40	< 10 %
3 - 10	8	100[8]	60	≤ 89.0	85/80	60/-	45	40	45	< 10 %
10 - 30	8	100[8]	160	≤ 89.0	95/90[5]	80/75	45	40	45	< 0 %
>30.0	9	125	12	≤ 89.0	100/100	100/100	45	45	50	< 10 %

Notes:
(1) It is recommended that Superpave mixtures be compacted to N_{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_{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) Criterion based upon a 5:1 maximum to minimum ratio.
(7) (a) N_{design} compactive effort is for typical traffic speeds. For slow/standing traffic increase N_{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_{design} of 125 gyrations.)
(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_{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 Arah Oil Embargo of 1973, and vihratory 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 baghousc 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 decrcascs, however, in this situation the compactive effort exceeds rhe 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 thc past, not all mixes will react in this manner; however, there will he 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. Wc have also seen tenderness in several projects wirh 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.

The ground breaking ceremony of NCAT's oval test track (accelerated pavement loading facility) was held on September 29.

Bob Jouhert (The Asphalt Institute, Massachusetts)

I have observed the tender zone compaction problem with some Superpave mixtures in the state of New York. In my opinion, rhe 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)

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other Superpave mixes as well.

We know that some blends of fine and coarse aggregates arc more inherently stable (even without asphalt binder) than others. A simplified example is the stability dense-graded aggregate base courses provide versus a layer of single size stone. Construction equipment compacts and stabilizes the former and moves the latter all around. cl-eating ruts.

On some of the steep S-shaped gradations the trend toward single sire can be dominant enough to have a significant contributing influence toward placement instability until fully constructed. Another way of looking at it is to say that for field placement the gradation may he 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 in the gradation criteria. and voids in the mineral aggregate criteria that may limit adding fine aggregate.

The stiffness or workability cohesion of the mix is coming from 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 significant cohesion 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 some Superpave steep S-shaped mixtures, the balance of coarse to fine aggregate may be such that there is much less workability cohesion contributed by the fine aggregate and the asphalt binder at high temperatures. Conventional HMA mats "sort of stick themselves together," stiffen. and fundamentally only compress or move vertically to progressively higher 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 or fluffed condition of the HMA mat material. That is, the face of the roller ha:, more surface support at this time due to the loose condition or depth to 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 as 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 seeks to relieve the inability to resist by sliding or creeping (remarkably, without cracking) forward and sideways. This occurs because the mat is reacting by creeping away from the increased pressures or pounds per square inch after breakdown that the roller is now delivering to the mat.

Prithvi Kandhal (National Center for Asphalt Technology)

In my opinion, some Superpave mixtures may he exhihiting this phenomenon due to very coarse gradation. and the resulting thicker asphalt binder film around the aggregate particles compared to conventional HMA.

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

(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 l-3. 1998: January 5-7, 1999: January 26-28. 1999; and March 16-18, 1999. These workshops consist of two and a half days of intensive lecture, demonstration. and hands-on training on Superpave mix design procedures. Upon completion the participants will be able to conduct the Superpave mix designs in their laboratories.

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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 thickness 2-2½ 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 mixtures). 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 mixtures 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 mixtures 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 mixtures. 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)

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

(ASPHALT RESPONSES, Continued from page 8)

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 cur-rent/y specify stone matrix asphalt (SMA) mix design and plant control utilizing the gyratory compactor?

Do any states require compaction to N_{max} and then back calculate air voids at N_{design} for plant control on Superpave mixes? If so, have you adjusted N_{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_{max} and then "backcalculation" of air voids at N_{design} for plant control, including acceptance testing. No adjustment is made for N_{design}; it is dctcrmincd 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 on "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 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 dctcrmincs 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 alter NCHRP Project Y-7.

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(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 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.

ASPHALT FORUM

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 10 Superpave projects. All projects have had the gradation pass below the restricted zone. One project was designed to the 0.3-I 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.

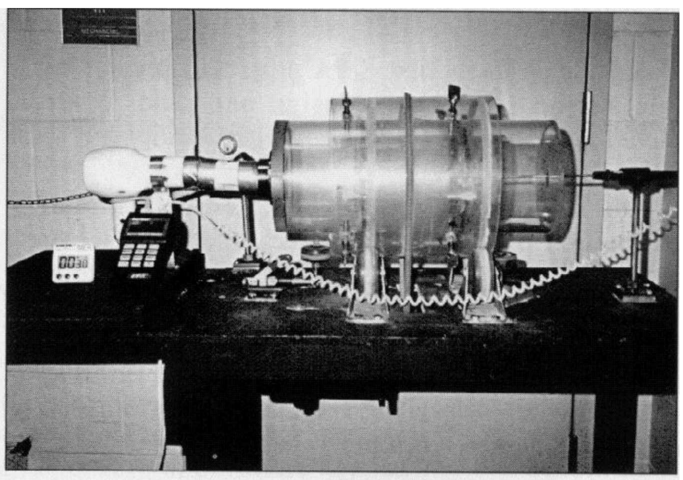
Vermont (Timothy Pockette, Vermont DOT)

Has any agency imposed an upper limit for $G^*/\sin\delta$ 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.



Prototype equipment developed by NCAT for testing the bulk specific gravity of fine aggregates. The temperature gradient of incoming and outgoing warm air, drying the fine aggregate in a rotating drum, is used to determine the saturated surface dry (ssd) condition of the sample.

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 he designed by compacting specimens up to N_{design} gyrations only rather than N_{max} and back calculating the bulk specific gravity at N_{design} gyrations.

Colorado - The use of IOO-mm (4-inch) specimens is being considered in the Superpave mixture design because specimens of this size can he 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 "pcrccnt-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_{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_{design} specimens were made as were N_{design}+20 gyrations and N_{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.

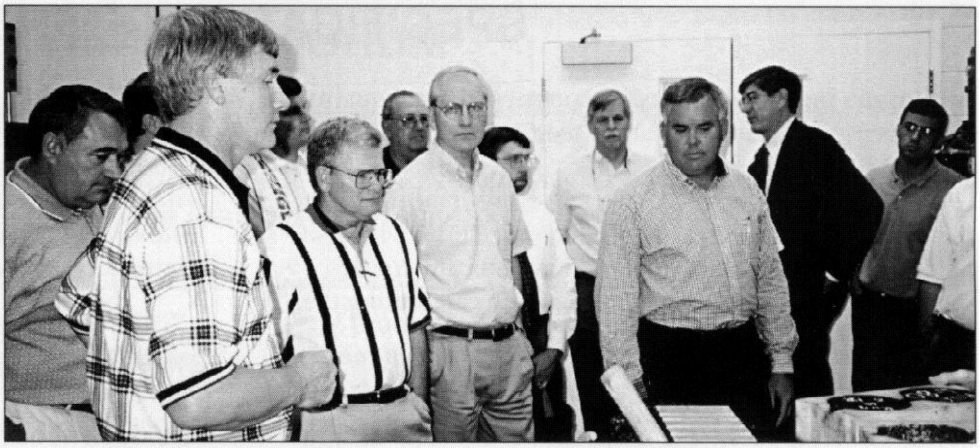
Missouri - The following changes have been made to HMA specifications for IYYY construction season: (a) Mixture within 150 mm (6 inches) of longitudinal joints of high type mixtures should be compacted no less than 2 percent below the specified density: (b) The requirement to construct test strips for high type mixtures has been incorporated into standard specifications, for the past IO 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 rhat have cxtrcmcly 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 five 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.

$$\text{Bearing Capacity (psi)} = \frac{stability}{flow} \qquad \frac{(120\ Flow)}{100}$$

Nehraska now specifies a minimum hearing 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 hinders as hase 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 bc 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 Supcrpavc mixes on eight projects (primarily rehabilitation of the interstate highway system) during 1996. Immediately after construction of a large interstate project. it was observed that water seemed to be absorbed into the pavement and was weeping out at the low side shoulder joint. The water would move laterally through the coarse graded Supcrpavc pavement until it reached the fine-graded Marshall mix that had been placed on the shoulder. With the shoulder acting as a dam. the water would then over-flow onto the paved shoulder. It was felt that it could very likely lead to a premature stripping failure of these multi-million dollar projects.

The present investigation was initiated with the primary objectives of developing a procedure for evaluating the water permeability of compacted asphalt mixtures; determining the extent and causes of water permeability of these Superpave projects; and recommending the necessary changes to the FDOT Superpave specifications in order to address this issue.

The projects consisted primal-ily of rehabilitating existing asphalt pavements by milling and resurfacing using Superpave mixes. Two types of coarse graded Supcrpavc mixes were used with nominal maximum aggregate sizes of 12.5 and 19.0 mm. An AC-30 asphalt cement. which would satisfy the requirements of a PG 67-22 binder. was used for all mixes. Using the volumetric design procedure. most of the mixtures were designed for an average high air temperature of less than 39°C with an N_{design} value of 109. All the mixtures would bc considered coarse graded (below the 0.45 maximum density line).

A new test method to measure the water permeability of hot mix asphalt (HMA) specimens in the laboratory 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 and evaluate the observed water permeability problem. The results indicated that six of the eight Superpave projects were excessively permeable as compared to existing fine-graded Marshall mixes.

One of the projects with relatively lower permeability values was the I-95 project in Brevard County. On this project. the 12.5 mm was placed in two 50-mm lifts. The higher density levels, and lower permeability values recorded for this project suggest that increased lift thicknesses. as compared to those used for dense-graded Marshall mixes, may he required for coarse-graded Superpave mixes to enhance compactihility and reduce permeability. Further. the curve for the air void-permeability relationship for coarse-graded Superpave mixes seems to indicate that there is no significant change in permeability when the amount of air voids falls below 7 pcrccnt. However. when the air void content is less than 6 percent the pavement is "virtually impermeable." that is the permeability level is negligible. Even small increases in air void content above the 7 percent level would result in a pronounced increase in permeability.

Furthermore. several well-performing pavement sections with fine-graded Marshall mixes were sampled for comparative purposes. The permeability results tend to indicate that the fine-graded mixes arc relatively impermeable even at air voids significantly higher than the 7 percent air void level needed to make the permeability of the Superpave coarse-graded mixes acceptable. as determined in this study. These low permeability values suggest that a larger amount of in-place voids in a fine-graded mix are not interconnected as compared to a coarse-graded mix.

Based on the findings of this investigation, it was recommended that FDOT increase its density specification for coarse-graded Superpave mixes to a minimum of 94.0 percent of G_{mm}, as determined from cores taken from the completed pavement. The pavement's permeability should be evaluated if this in-place density is not achieved and falls below 93.0

(Continued on page 14)

RESEARCH IN PROGRESS

We have discontinued the publication of this column in this newsletter because 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 Departments of Transportation and other sources.

(*PRACTICE*, continued from page 13)

percent of G_{mm}. A tentative permeability limit not exceeding 100 x 10^{-5} cm/s was suggested when evaluating the in-place Superpave mix pavement permeability. In addition, it was also suggested that the lift thickness of Superpave mixes be increased, as a rule of thumh. 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 expcricnce, beginning in the early 1970s, has indicated that hot recycling of reclaimed asphalt pavement (RAP) material is a highly beneficial approach from technical, economic. and environmental perspectives. With the evolution of the Superpave system a need has arisen for the development of Superpave guidelines for the use of RAP in HMA mixtures. This research study was undertaken to investigate the effect of incorporating different percentages of aged RAP binder on the performance characteristics of the resulting blend of virgin and RAP binder at high, intermediate, and low service temperatures. This would facilitate determination of the optimum amount of RAP to bc used in the recycled mix.

Six asphalt cements from the SHRP Materials Reference Library having a wide range of temperature susceptibility, were used in the study. Two of the asphalt cements were artificially aged in the laboratory to simulate the stiff binders generally found in RAP materials. These two aged (or RAP) binders were combined at different percentages with the remaining four virgin hinder?. The resulting asphalt blends were tested by dynamic shear rheomctcr (DSR) for rutting parameter (G*/sin δ) before and after rolling thin film oven (RTFO) aging. The blends were also tested by DSR for fatigue parameter (G* sin δ) and low temperature parameters (stiffness S and creep slope m) hy the bending beam rheometer after RTFO and pressure aping vessel (PAV) aging. Thus four sets of binder tests were conducted on the blends.

The following conclusions were drawn from this study:

- Four blends of RAP hinder and virgin hinder should be prepared and tested using all Superpave hinder tests at low, intermediate, and high service temperatures. Plots should be made of percent virgin binder in the blend (on the x-axis) and the Superpave binder parameter (on the Y-axis). The percentage of RAP binder which satisfies all Superpave binder specification criteria can be obtained from these plots.
- For the binders studied in this study. up to 15 percent use of RAP did not cause any change in the performance grade of the virgin binder while a RAP content of 25 percent caused one grade change at high temperature. and no change or one grade change at low temperature.

3. TESTS FOR PLASTIC FINES IN AGGREGATES RELATED TO STRIPPING IN ASPHALT PAVING MIXTURES (Kandhal, Lynn, and Parker)

The presence of plastic fines in the line aggregate portion of hot mix asphalt (HMA) may induce stripping in the mix when exposed to moisture. This study was undertaken to determine the best aggregate test method or methods that indicate the presence of detrimental plastic fines in the fine aggregate. which may induce stripping in HMA mixtures. The following three 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 relative proportions of plastic fines or clay-like material in fine aggregates. Fine aggregate passing the 4.75 mm (No. 4) sieve is placed in a graduated. 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. The sand

(Continued on page 15)

(PRACTICE, continued from page 14)

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 hy 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 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 (montmorillinite) group, organic matter. and iron hydroxides present in fine aggregate. The principle of the test ıs 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 aggrcgatc sample passing the 75 µm (No. 200) sieve is tested for methylene blue value (MBV). Ten gram\ of the sample are dispersed in 30 grams of distilled water in a beaker. A standard methylene blue (MB) solution is titrated step wise in 0.5 ml aliquotes from a burrette into the continually stirred fine aggregate suspension. After each addition of MB solution and stirring for one minute, a small drop of the aggregate suspension is removed with a glass rod and placed on filter paper. Successive additions of MB solution are repeated until the end point is reached, which is indicated when a permanent light blue coloration or "halo" is observed in the ring of clear water on the filter paper. The MB value of a specific fine 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 times 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 ill 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 hlcnds 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) hut 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 validation 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 hack 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 mixtures.

It should he noted that the sand equivalent test measures the relative amount of clay-sired 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 he present in a fine aggregate.

NCAT's 1998 PROFESSORTRAINING COURSE ATTENDEES AND INSTRUCTORS

Left to Right: (Front Row) Jeffrey Davis, Dinesh Katti, Steve Arnold, Ashraf Ghaly, Musharraf Zaman, Norb Delatte. (Row 2) James Tsai, Duk-Won Park, Bill Strength (Row 3) Brian Coree, Han Zhu, Mike Jackson, Danny Hutchinson, William Mincks, Jean Sexton. (Row 4) James Stoner, Manjriker Gunaratne, Wei-Chou Ping, Mark Jensen, Greg Punske, Moujalli Hourani. (Back Row): Doug Hanson, Dean Mentjes, Jerry Isenburg, Joe Gunderson. Not Pictured: E. R. Brown P.S. Kandhal, Rajib B. Mallick, S. Buchanan, A. Cooley, and Suleiman Ashur.

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Implementation Notes

Note No 5 (Fall 1998)

DESIGNING STONE MATRIX ASPHALT (SMA) MIXTURES

Stone Matrix Asphalt (SMA) has been used in Europe fur 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.

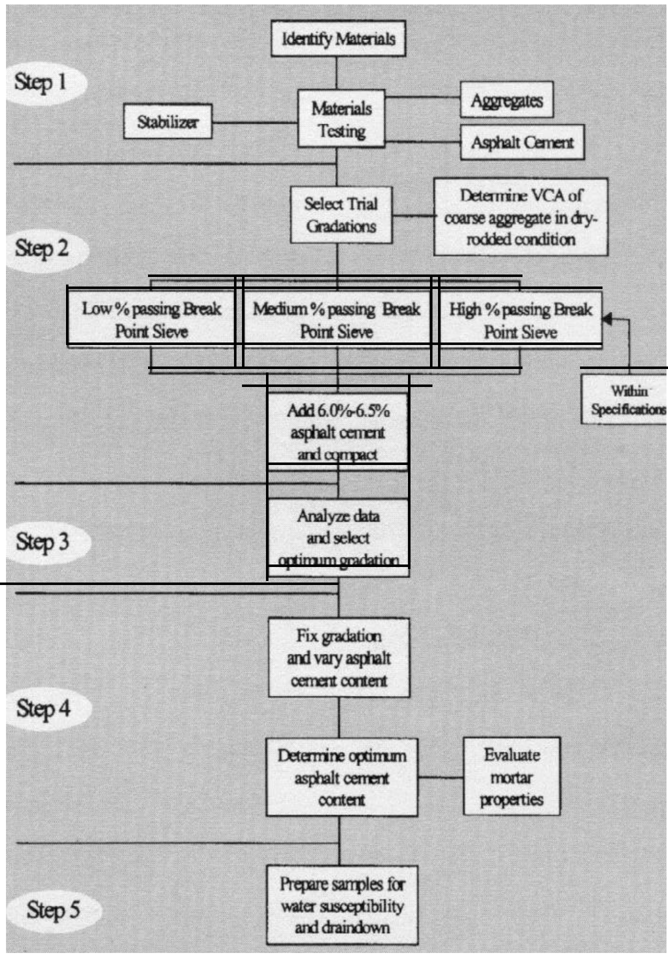

Figure: SMA Mixture Design Overview

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 tiller 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 hinder 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 hinder 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 au 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.