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NCAT EVALUATES WARM MIX ASPHALT

The National Center for Asphalt Technology (NCAT) is evaluating warm mix asphalt (WMA) technologies. WMA technology allows the mixing, lay down, and compaction of asphalt mixes at significantly lower temperatures compared to hot mix asphalt (HMA). The technology can reduce production temperatures by as much as 30 percent. Asphalt mixes are generally produced at 300°F (149°C) or greater temperatures in the U.S. depending mainly on the type of binder used. WMA mixes can be produced at temperatures of about 250°F (121°C) or lower.

WMA offers the following significant advantages:

- **Reduced Fuel Consumption.**

The most obvious benefit of WMA is the reduction in fuel consumption. Fuel is used to dry and heat the aggregate. Studies have shown that lower plant mix temperatures associated with WMA can lead to as much as 30 percent reduction in energy consumption costs.

- **Decreased emissions.** WMA produces emissions (both visible and non visible) from the burning of fossil fuels

at a significantly reduced level compared to HMA. This would permit asphalt plants to be located in and around areas such as large metropolitan areas that have air quality restrictions. The decrease in emissions may represent significant cost savings.

- **Decreased fumes and odor.** WMA produces lower fumes and odor both at the plant and the paving site compared to HMA. This would also result in improved working conditions at both places.

- **Decreased binder aging.** Short-term aging of liquid asphalt binder takes place when it is mixed with hot aggregate in the pug mill or mixing drum. This aging is caused by the loss of lighter oils from the liquid asphalt

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In addition to lower emissions warm mix asphalt has several advantages over hot mix asphalt such as fuel energy savings, decreased binder aging and an extended paving season (Photo courtesy: Matthew Corrigan, FHWA)

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NCAT Evaluates Warm Mix Asphalt

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binders during mixing at high temperatures. It is believed that the short-term aging of the binder will be reduced significantly because the loss of lighter oils will be less at relatively lower mixing temperatures, possibly enhancing pavement durability.

- **Extended paving season.** By producing WMA at normal HMA temperatures, it may be possible to extend the paving season into the colder months of the year in some regions of the U.S. since the WMA additives or processes act as a compaction aid. In addition, by narrowing the difference between compaction temperature and ambient air temperature the rate of cooling is decreased. WMA may also be transported over longer distances as compared to HMA with reduced loss of mix temperature in the hauling units.

- **Compaction aid for stiffer mixes.** WMA additives and processes may be used to improve the compactibility of stiff mixes when mix is produced closer to typical HMA production temperatures. Smaller reductions in temperature may also be possible. There is extensive experience with the use of certain types of WMA with SMA in Europe.

Similar to many of the recent advances in asphalt paving, such as stone matrix asphalt and porous



Existing facilities can easily be converted to accommodate WMA. At this Florida plant, a specially built feeder (right) was used to blow Aspha-min into the drum using an existing fiber addition line.

European mix, WMA technology comes to the United States from Europe. Laboratory experiments to produce WMA began in Europe in 1995. WMA has received public attention in Europe and Australia since 2000. HMA industry representatives observed the demonstration of WMA technology during a European Scan tour organized by the National Asphalt Pavement Association in 2002.

NCAT was given the task of evaluating some proprietary WMA technologies from Europe and one WMA technology recently developed in the U.S. The objective was to perform a laboratory study to determine the applicability of WMA technologies/products to typical paving operations and environmental conditions commonly found in the United States. The studies were designed to answer the following questions:

- Does WMA technology affect the compactibility of asphalt mix in the Superpave gyratory compactor and, therefore, its optimum asphalt content?
- Does WMA technology affect the structural strength of the asphalt mix in terms of resilient modulus?
- Does WMA technology increase the rutting potential of asphalt mix at high temperatures?
- Does WMA technology necessitate some cure time for the asphalt mix before opening to traffic?
- Does WMA technology increase the potential for moisture damage since the mix is produced at significantly lower temperatures, resulting in incomplete drying of the aggregate and moisture damage from water trapped in the coated aggregate?

The three most widely used technologies in Europe for producing WMA are all proprietary processes that

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**National Center for Asphalt Technology, 277
Technology Parkway, Auburn, Alabama 36830
Phone: (334) 844-NCAT (6228) Fax: (334) 844-6248**

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E. Ray Brown, Director
Prithvi (Ken) Kandhal, Associate Director Emeritus/ Editor
Cheryl Cobb, Associate Editor, College of Engineering

differ significantly in their approach. These technologies are: (a) Aspha-min®, (b) Sasobit®, and (c) WAM-Foam®. Only the first two processes have been evaluated by NCAT with the participation of their suppliers. A fourth technology, Evotherm, developed in the U.S. has also been evaluated by NCAT.

The description of the preceding four WMA technologies follows together with NCAT's findings from their evaluations, if available.

Aspha-min®

Aspha-min is a product of Eurovia Services GmbH based in Germany. Aspha-min is a manufactured synthetic sodium aluminum silicate, better known as zeolite. The crystalline structure of zeolite has large interconnected spaces, which can hold water molecules. Eurovia's Aspha-min contains approximately 21 percent water by mass, which is released in the temperature range of 185-365°F (85-185°C). When Aspha-min is added to the mix at the same time as the liquid asphalt, water is released. This water release causes the asphalt binder to microscopically foam, which allows increased workability and aggregate coating at lower temperatures. According to Eurovia's recommendations, Aspha-min is added at a rate of 0.3 percent by mass of the asphalt mix, which can result in a potential 50°F (28°C) reduction in typical HMA production temperatures.

Aspha-min zeolite is approximately a 50-mesh material, which may be added directly to the pug mill of a batch plant. It can be added to a drum plant through RAP collar or pneumatically fed using a specially built feeder. Aspha-min is available as a fine white powder in 25- or 50-kilogram bags or in bulk for silos.

Field demonstration projects using Aspha-min to



Sasobit prills for adding directly into pug mill or mixing drum

produce WMA have been constructed in Florida, Tennessee, and North Carolina in 2004. NCAT monitored the first demonstration project constructed at Hubbard Construction's equipment yard in Orlando, Florida in February 2004 and also collected WMA samples for testing. Aspha-min was introduced into the drum at the same point as the liquid asphalt. A vane feeder controlled the addition rate. The material was pneumatically blown into the drum.

The second Aspha-min field demonstration was conducted in Nashville, Tennessee in March 2004 as part of the World of Asphalt meeting. The third project was constructed in Charlotte, North Carolina in September 2004.

NCAT has completed the laboratory evaluation of Aspha-min. The final report, 05-04, can be accessed at NCAT's website, www.ncat.us.

The following conclusions were drawn from this study:

- The addition of Aspha-min zeolite lowers the measured air voids in the Superpave gyratory compactor (SGC). While this may indicate a reduction in the optimum asphalt content, additional research is required. In the meantime the optimum asphalt content of the mixture determined without the zeolite should be used. It should be noted that the optimum asphalt content of the mixture without the addition of the zeolite was used for all of the testing (with and without zeolite) completed in this study.

- Aspha-min zeolite improved the compactability of the mixtures in both the SGC and vibratory compactor. Statistics indicated an average reduction in air voids of 0.65 percent using the vibratory compactor. Improved

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Sasobit flakes for melting into asphalt binder

compaction was noted at temperatures as low as 190°F (88°C).

- Addition of zeolite does not affect the resilient modulus or density of an asphalt mix. Therefore, there would be no effect on pavement thickness design when using WMA produced with Aspha-min zeolite.

- Addition of zeolite does not increase the rutting potential of an asphalt mix. The rutting potential increased with decreasing mixing and compaction temperatures, which may be related to the decreased aging of the binder.

- There was no evidence of differing strength gain with time for the mixes containing zeolite as compared to the control mixes indicating that the addition of Aspha-min may not require a cure time for the asphalt mixture prior to opening to traffic.

- The lower compaction temperature used when producing WMA with Aspha-min may increase the potential for moisture damage. As mentioned earlier, lower mixing temperatures may result in incomplete drying of the aggregate and the resulting water trapped in the coated aggregate may cause moisture damage. Reduced tensile strength and visual stripping were observed in both the control and Aspha-min zeolite mixes produced at 250°F (121°C).

- Various anti-stripping agents were evaluated to mitigate the potential for moisture damage. Hydrated lime appeared to be effective with the granite aggregate. The addition of 1.5 percent hydrated lime resulted in acceptable performance in terms of both cohesion and moisture resistance over the warm mixtures without hydrated lime.

- Hamburg wheel tracking results confirmed the test results produced by the TSR testing, as well as suggesting the lime will also assist in the rutting



Placement of warm mix asphalt made with Aspha-min at the 2004 World of Asphalt Conference in Nashville, Tennessee (Photo courtesy: Matthew Corrigan, FHWA)

resistance of warm mixtures compacted at lower temperatures due to the lime stiffening the asphalt binder.

- More research is needed to further evaluate field performance, the selection of the optimum asphalt content, and the selection of binder grades for lower production temperatures.

Sasobit®

Sasobit is a product of Sasol International, Hamburg, Germany. Unlike Aspha-min, which relies on foam to enhance mix workability at lower temperatures, Sasobit is a paraffin-wax compound derived from coal gasification using the Fischer-Tropsch (FT) process. The smaller crystalline structure of the FT wax is believed to reduce brittleness at low temperatures as compared to bitumen paraffin waxes. Sasobit is designed as an “asphalt flow improver,” both during the asphalt mixing process and during lay down operations, due to its ability to lower the viscosity of the liquid asphalt. This decrease in viscosity allows working temperatures to be decreased by 30 to 97 F degrees (17 to 54 C degrees).

Sasol recommends that Sasobit be added at a rate of 0.8 percent or more by mass of the binder, but not to exceed 3 percent. Sasobit can be blended into hot liquid asphalt at the blending plant (terminal) without the need for high shear mixing. Sasobit is available in two forms: flakes for molten additions or prills (small pellets) for direct addition to the mix. In the United States, Sasobit has been blended with the liquid asphalt at the terminal or blown directly into the mixing chamber at the same point cellulose fibers were being added to an SMA. Commercial supplies of Sasobit are available in 25 kg

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Feeder for Sasobit prills (Photo courtesy: Matthew Corrigan, FHWA)

bags and 600 kg super-sacks. The Maryland State Highway Administration (SHA) used Sasobit in June 2005 to produce mix for repairing deep patches. The Sasobit was added not to produce warm mix, but to act as a compaction aid in case of a stiff 19-mm mix containing RAP. The mix with Sasobit was workable and readily compactible. In July 2005 Maryland SHA produced a SMA binder layer with Sasobit and reduced production temperature by approximately 50°F (28°C).

NCAT has completed the laboratory evaluation of Sasobit. The final report, 05-06, can be accessed at the NCAT web site.

The following conclusions which are generally similar to Aspha-min, were drawn from this study:

- The modified binder including Sasobit needs to be engineered to meet the desired performance grade. As an example in this study a PG 58-28 was used as the base asphalt with the addition of 2.5 percent Sasobit to produce a PG 64-22 binder.
- Sasobit improved the compactibility of the mixtures in both the SGC and vibratory compactor. Statistics indicated that an average reduction in air voids up to 0.9 percent was obtained.
- Addition of Sasobit does not affect the resilient modulus of an asphalt mix compared to mixtures having the same PG binder.
- Addition of Sasobit generally decreased the rutting potential of the asphalt mixes evaluated.
- Lower compaction temperature used in producing WMA may increase the potential for moisture damage. TSR tests indicated moisture damage in both the control and Sasobit mixes produced at 250°F (121°C). However, the addition of a liquid anti stripping agent improved the TSR values to acceptable levels.
- More research is needed to evaluate field performance, the selection of optimum asphalt content, and the selection of binder grades for lower production temperatures.

WAM-Foam® (Warm Asphalt Mix Foam)

WAM-Foam is a two component binder system: a soft binder and a hard foamed binder, which are introduced at different times in the mixing cycle during the production of asphalt mix. WAM-Foam is a joint venture product of Shell International Petroleum Company Ltd., U.K. and Kolo-Veidekke, Norway. First, a soft asphalt binder is mixed with the aggregate at 212-250°F (100-121°C) temperatures to coat the aggregate fully. Next, a hard asphalt binder in the form of foam is mixed with the pre-coated aggregate. Cold water is injected into the hard asphalt binder to produce a large volume of foam. This combination of soft binder and



Placement and compaction of warm mix asphalt made with Evotherm near Indianapolis

foamed hard binder acts to lower the viscosity to provide increased workability. The resulting asphalt mixture can be placed and compacted in the temperature range of 175-195°F (79-91°C). The hard binder combines with the soft binder to achieve the desired PG grade in the mix. NCAT has not performed any laboratory evaluation of WAM-Foam.

Evotherm

Evotherm is a non-proprietary technology developed especially for WMA by MeadWestvaco Asphalt Innovations in the United States. It is based on a chemistry package that includes additives to improve coating and workability, adhesion promoters, and emulsification agents. The chemistry is delivered in an emulsion with a relatively high asphalt residue (approximately 70 percent). Evotherm is stored at about 175°F (80°C). The water in the Evotherm emulsion is liberated in the form of steam when it is mixed with hot aggregate. The resulting WMA appears like HMA in appearance. No plant modifications are required for using Evotherm. The mix can be stored in silos.

To date, ten field trials have been constructed in four countries using Evotherm. NCAT representatives attended and tested material from a field trial of Evotherm conducted near Indianapolis in July 2005. The WMA using Evotherm was produced in a hybrid batch/drum plant in drum plant mode. Discharge temperatures from the mixing drum stabilized at approximately 200°F (93°C). Even at such low temperatures, the WMA mixture appeared black like HMA with none of the brown or gray coloration generally associated with emulsions. After the WMA production, the bag house was examined. The bags and fines appeared dry.

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ASPHALT FORUM

*NCAT invites your comments and questions. Questions and responses are published in each issue of **Asphalt Technology News**. Some are edited for consistency and space limitations.*

Connecticut (Keith Lane, Connecticut DOT)

A task force has been set up to investigate options and recommend a course of action by the end of the year regarding the use of “quiet pavements.”

John Hanrahan (Innophos, Inc.)

Please refer to Asphalt Forum Responses in the spring 2005 issue of the Asphalt Technology News wherein some highway agencies had expressed concern on the use of polyphosphoric acid (PPA) modified asphalt binders. The PPA additive has been used in small amounts in the US and Canada by asphalt binder producers for many years. It has allowed them to improve the consistency of the asphalt binder and increase its performance grade (PG) by one to two grades in a safe, durable, and economical manner. PPA’s use in asphalt binder in the US is documented as early as 1972. Many thousand tons of PPA are used annually to modify millions of tons of asphalt binder in North America. Europe and Latin America have also recently begun to use PPA for improvement of asphalt rheology. The Association of Modified Asphalt Producers (AMAP) has issued the following statement regarding PPA:

“After a review of the available information on the use of polyphosphoric acid in the modification of paving grade asphalts, it is the position of AMAP that the

correct use of polyphosphoric acid in the appropriate amount can improve the physical properties of bituminous paving grade binders. AMAP endorses appropriate testing on the modified asphalt binder after the addition of any and all additives to determine the final product specification is met. However, incorrect application of the technology, as with many additives, can result in problems associated with construction and/or performance.”

NCAT (Prithvi “Ken” Kandhal, Editor, Asphalt Technology News)

In the past some highway agencies were allowing either fine-graded or coarse-graded Superpave mixtures and some were allowing both. What is the current practice in your agency and why?

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Delegation of Chinese engineers visited NCAT in June this year

ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the Spring 2005 Asphalt Forum.

What amount of diesel fuel (in gallons) are other states permitting to flush out filling lines on PG binder deliveries? (Keith Lane, Connecticut DOT)

Connecticut (Keith Lane, Connecticut DOT)

In response to my own question I would like to mention the practice in Connecticut. It has been determined that 5 to 10 gallons of diesel fuel are used to “clear” the lines for each PG binder delivery at the HMA plant. The average delivery is 6,000 gallons of PG binder delivered to an average 16,000-gallon capacity ground tank at the HMA plant.

Mississippi (Richard Sheffield, Mississippi DOT)

The Mississippi DOT does not allow any diesel for flushing out the lines.

Nebraska (Laird Weishahn, Nebraska DOT)

The Nebraska DOT does not specify gallons, but specifies that care shall be taken not to contaminate the PG binder.

South Carolina (Milton Fletcher, South Carolina DOT)

The South Carolina DOT does not have a specification on the amount of fuel used to flush out lines.

Is any agency using the latest AASHTO T-283 specification with hydrated lime to detect the use of acid modified PG binders? Is it successful? (Keith Lane, Connecticut DOT)

Mississippi (Richard Sheffield, Mississippi DOT)

We do not have any experience with acid-modified binders.

What is your opinion on FHWA Technical Advisory (TA) on PWL specification development? If you have a PWL specification, does your state conform to the TA? If you do not have a PWL specification, does the TA provide the basis and encouragement to implement such a specification? (Gregory Sholar, Florida DOT)

Alabama (Randy Mountcastle, Alabama DOT)

The Alabama DOT does not use PWL but has adopted something simpler. We use the average of the absolute values of the deviation from the target. For example: If

the target air voids are 4 percent and the contractor’s test results are: 4.5, 3.5, 3.2, and 4.2 percent, the average deviation is 0.5 percent. We pay bonuses and make deductions based upon this approach. We have found that this practice gives us enough information for QC/QA enforcement and it is simple enough for any high school graduate to understand and implement.

Mississippi (Richard Sheffield, Mississippi DOT)

We have no intention of going to a PWL-based specification but would continue our current practice of using a running average of QC test results. For the quality assurance, we are planning to use independent verification samples rather than samples split with the contractors.

Nebraska (Laird Weishahn, Nebraska DOT)

The Nebraska DOT does not intend to adopt a PWL specification at the present time. Our practice of using the running average of four test values works very well for us.

Ohio (Dave Powers, Ohio DOT)

The Ohio DOT will be making some revisions to its specifications but not based on PWL. The DOT has an internal policy used by the construction personnel for payment deductions for out of specification test values, where material is sent to projects and used. If material is outside specific bands and a certain number and percentage of failed to passed tests occurs then specific deductions are applied. Therefore, although not exactly PWL it does address consistency in a similar manner as PWL. At only two HMA test series per production day, the DOT does not believe that there is enough representative test data to be analyzed for a statistical specification for most projects. The DOT has found during its 20 years’ experience with the QC/QA program that specifications and production responses have to be set up around each individual test because that is how the contractors respond to their tests.

South Carolina (Milton Fletcher, South Carolina DOT)

The South Carolina DOT has been using a PWL specification for several years and is presently comparing its procedures to those given in the FHWA
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—Asphalt Forum Responses

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Technical Advisory.

What is the experience of other states with asphalt binders modified with elastomeric terpolymers? Specifically for those states satisfied with the performance of SBS-modified asphalt binders, what is your opinion of replacing the SBS modifier with an elastomeric terpolymer? How does the performance of HMA pavements containing these two types of modifier compare? (Allen Myers, Kentucky Transportation Cabinet)

Ohio (Dave Powers, Ohio DOT)

Ohio has just started looking into this and would also like to hear about the experience of other agencies.

Editor: Mississippi, Nebraska and South Carolina responded to the above question by stating they do not have any experience with terpolymers.

NCAT Evaluates Warm Mix Asphalt

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The following conclusions, which are generally similar to those for Aspha-min and Sasobit, were drawn from the laboratory evaluation of Evotherm by NCAT:

- Evotherm improved the compactibility of the mixtures in the vibratory compactor. Statistics indicated an average reduction in air voids up to 1.5 percent.
- Addition of Evotherm does not affect the resilient modulus of an asphalt mix compared to mixtures having the same PG binder.
- Addition of Evotherm generally decreased the rutting potential of the asphalt mixes evaluated.
- Lower compaction temperature used in producing WMA may increase the potential for moisture damage.
- More research is needed to evaluate field performance, the selection of optimum asphalt content, and the selection of binder grades for lower production temperatures.

Additional research

NCAT will continue to evaluate the WMA technology with the partnership of the Federal Highway Administration, National Asphalt Pavement Association, state asphalt pavement associations, and suppliers of WMA processes/products.

Additional research is needed in the following areas:

- **Mix designs:** Modifications to Superpave mix

technology, if required, for designing WMA, need to be established. Selection of binder grades for lower production temperatures needs to be examined.

- **Long-term performance:** Durability of asphalt pavements constructed with WMA needs to be investigated in terms of binder effects (binder is either foamed or chemically modified) and increased potential for moisture damage.

- **Cost benefits:** Reduction in fuel consumption and emissions need to be quantified to ascertain cost benefits.

- **Plant operations:** The suitability of WMA for high production rates in the U.S. needs to be examined.

- **Control of mixing process:** Since WMA has a different mixing process than the conventional HMA, new guidelines need to be developed for proper QC/QA of the produced mix.

- **Workability at the paving site:** Although the WMA may appear workable and easily compactible when produced, it should remain workable at the paving site as well. This needs to be investigated on field demonstration projects.

- **Quick turnover to traffic:** More field demonstration projects are needed to verify that the WMA pavements can be opened to traffic as soon as possible after construction similar to or earlier than the conventional HMA pavements.

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 offered on January 30-February 3, 2006 and February 27-March 3, 2006, 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. NCAT will accept applications from private and public sectors practicing engineers 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 **334.844.6228 ext. 110** or visit our web site at **www.ncat.us**. Click on "Education" at the top of the page, then click on "Upcoming Training Courses" for a brochure or information. On-line registration is now available.

SPECIFICATION CORNER

Connecticut – After a couple of years of quality control testing by the contractor, which is used as the basis of payment, there is a renewed emphasis ensuring that a state testing representative be present during production. Additional resources are being allocated in time for the 2006 construction season.

Kentucky – The Kentucky Transportation Cabinet is constructing several experimental projects in 2005 as part of a research effort to address permeability concerns in HMA pavements. Multiple strategies to reduce permeability are underway. One approach involves a specification with an increased core density requirement for surface courses, which will require at least 93.5 percent of theoretical maximum density for the mainline and, at least 92.0 percent of theoretical maximum density for longitudinal joints. Another strategy features a specification for the permeability of HMA surface pavements as measured by an in-situ, air-induced permeameter developed by the Kentucky Transportation Center. Finally, on selected pavements, it is planned to construct the surface course layer at a lift thickness-to-nominal maximum aggregate size ratio of 4.

Mississippi – The Mississippi Department of Transportation is considering implementation of the Asphalt Pavement Analyzer (APA) as a specification requirement. Recent research results indicate a pretty good correlation between field performance and APA results for high-traffic surface mixes in Mississippi. Fine aggregate angularity (FAA) requirements are often difficult for the contractors to meet. The reproducibility of the FAA test is also a problem. The criteria for acceptable APA rut depths has not been established as yet, but when it is, it should be a relief for the contractors who do not meet the FAA requirements but meet the APA criteria.

Ohio - An incentive surface smoothness note has been developed for thin lifts and mill and fill jobs in addition to the existing note for thicker lift projects. There is a movement towards an IRI specification with high-speed equipment. Eventually all projects will have smoothness requirements.

It is planned to use notched wedge longitudinal joint with specific equipment requirements for constructing the joint. Field trials are expected in 2006. Also, as part of this change the Ohio Department of Transportation (ODOT) will be measuring and paying for density at the joint as well as the mainline as a modification to the existing incentive density specification.

ODOT has added requirements for specific paving equipment to be equipped with anti-segregation devices to eliminate dual parallel longitudinal cracking due to longitudinal segregation created by this equipment. They are based on an ODOT review and the original study conducted in Colorado.

ODOT has started a new program for approving paving foremen and superintendents. It requires specific training conducted by industry. The focus for retaining approval is a “meaningful immediate response to deficiencies as outlined in the specifications.”

South Carolina – South Carolina Department of Transportation had originally planned to use the Superpave gyratory compactor for designing 100 percent of the mixes in the state. However, due to some unforeseen circumstances, this action has been delayed to early 2006.

The Department is presently reviewing its RAP specification to allow a higher percentage of RAP in mixtures if a contractor utilizes fractionation of the RAP on the 1/4 inch sieve.

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Prithvi (Ken) Kandhal
Associate Director Emeritus, NCAT
277 Technology Parkway
Auburn, AL 36830
pkandhal@eng.auburn.edu

PROFESSOR TRAINING COURSE IN ASPHALT TECHNOLOGY

NCAT has written and published an up-to-date college textbook on asphalt technology. NCAT has also developed a training program for college and university civil engineering faculty that will allow them to offer state-of-the-art undergraduate and elective courses in asphalt technology. This 8-day intensive course is conducted at NCAT in June every year. In 2006, it will be held on June 20-29. The course has been updated to include Superpave binder and mix technology, and stone matrix asphalt (SMA). Some financial assistance to defray course expenses is possible. Please call NCAT at **334.844.NCAT** for brochure or information or visit our web site at **www.ncat.us**.

SUPERPAVE SYSTEM DEVELOPMENT UPDATE

The Superpave system of asphalt paving materials selection and mixture design was an outcome of the 5-year, 50-million dollar Strategic Highway Research Program (SHRP), completed in 1993. During the last 12 years incremental improvements have been made to the Superpave system based on experience during its implementation and research conducted on specific topics. Major Superpave related research projects have been sponsored directly or indirectly by the state highway agencies and the industry. The major research projects listed below were undertaken by the National Cooperative Highway Research Program (NCHRP) to improve the Superpave System.

The Superpave System has been improved incrementally in terms of specifications and test

methods based on the results from the Superpave related research projects. In the past, this newsletter has carried a column "Superpave Update" to report the progress. The following update including some excerpts is based on the report of the TRB Superpave Committee submitted to AASHTO and the Federal Highway Administration (FHWA) in April this year.

• High-Temperature Binder Selection Procedure

Recent FHWA-directed research has sought to refine the procedure used to select the high-temperature performance grade for Superpave PG binders. "The original SHRP-developed procedure used as a selection criterion the average pavement temperature of the
(continued on page 11)

NCHRP Projects undertaken for improving the Superpave System

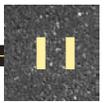
- 9-07 Field Procedures and Equipment to Implement SHRP Asphalt Specifications
- 9-09 Refinement of Superpave Gyratory Compaction Procedure
- 9-09(1) Verification of Gyration Levels in N_{design} Table
- 9-10 Superpave Protocols for Modified Asphalt Binders
- 9-12 Incorporation of Reclaimed Asphalt Pavement in the Superpave System
- 9-13 Evaluation of Water Sensitivity Test
- 9-14 Investigation of the Restricted Zone in the Superpave Aggregate Gradation Specification
- 9-16 Relationship Between Superpave Gyratory Compaction Properties and Permanent Deformation of Pavements in Service
- 9-18 Field Shear Test for Hot Mix Asphalt
- 9-19 Superpave Support and Performance Models Management
- 9-25 Requirements for Voids in Mineral Aggregates for Superpave Mixtures
- 9-29 Simple Performance Tester for Superpave Mix Design
- 9-30 Experimental Plan for Calibration and Validation of HMA Performance Models for Mix and Structural Design
- 9-30A Calibration of Rutting Models for HMA Structural and Mix Design
- 9-31 Air Void Requirements for Superpave Mix Design
- 9-33 A Mix Design Manual for Hot Mix Asphalt
- 9-34 Improved Conditioning Procedure for Predicting the Moisture Susceptibility of HMA Pavements
- 9-35 Aggregate Properties and Their Relationship to the Performance of Superpave – Designed HMA: A Critical Review
- 9-36 Improved Procedure for Laboratory Aging of Asphalt Binders in Pavements
- 9-38 Endurance Limit of HMA Mixtures to Prevent Fatigue Cracking
- 9-39 Procedure for Determining Mixing and Compaction Temperatures of Asphalt Binders in HMA
- 9-42 History of Superpave and its Implementation (anticipated)

RESEARCH IN PROGRESS

We have discontinued the publication of this column in this newsletter because it can now be accessed on NCAT's homepage (www.ncat.us). Click on "Information" at the top of the page, then "Research in Progress." It is updated frequently based on the information received from the Departments of Transportation and other sources.

NCAT HAS DOMAIN NAME

NCAT has a domain name, to make it easier to find our web page. www.ncat.us is the new address, but you can also reach our web page by going to our old address, www.eng.auburn.edu/center/ncat/.



hottest consecutive seven-day period. While this criterion provided improved resistance to pavement rutting, performance observations showed that considerable variation in rutting has occurred at geographically disparate sites with similar seven-day high temperature histories and similar traffic characteristics. Using the flexible pavement performance models included in the NCHRP 1-37a Pavement Design Guide, the FHWA research showed that this variation could be reduced if the selection procedure considered cumulative hours at elevated pavement temperatures instead of the seven-day average. This criterion does a better job of distinguishing between, for example, the binder grade requirements of pavements in Idaho and Florida. While both locales might have the same average highest seven consecutive day temperature, over a summer season the Florida pavements will accumulate many more hours at elevated temperature. This difference is reflected in a greater propensity for rutting and, thus, the need for a stiffer asphalt binder. This new selection criterion has been added to the latest version of the binder selection software (LTPPBind Version 3.0).”

• Improved Data Screening for the Direct Tension Test

“AASHTO Test Method T 314 Determining the Fracture Properties of Asphalt Binders in Direct Tension, is used in combination with the Bending Beam Rheometer test to determine the critical cracking temperature of asphalt binders. Variability of test results has inhibited general use of this test. Recent research under the direction of FHWA has developed a new data screening method aimed at reducing this variability. The Expert Task Group (ETG) on Asphalt Binders reports that it has monitored this research and has concluded the new screening process would be a useful addition to Test Method T 314.”

• Asphalt Binder Modification

Research is continuing at the FHWA to extend the Superpave binder selection standards to modified asphalt binders more reliably. “It has always been a goal to make the Superpave system blind to modifiers and additives. In other words, the system would be as reliable in characterizing critical properties of asphalt modified with any additive as it is with unmodified asphalts. Because various additives and modifiers rely on different mechanisms to modify the physical properties of asphalt, this is a challenging assignment. Although incomplete, the FHWA research has identified some promising test methods to characterize the high-

temperature behavior (i.e. rut resistance) of modified asphalts.”

There appears to be a growing use and mixed reaction to acid modification of asphalt binders for improving rut resistance. “Preliminary research confirms that addition of small quantities of polyphosphoric acid does indeed increase the high-temperature stiffness of asphalt binders without, apparently, adversely affecting the low-temperature properties. There is a body of anecdotal experience, however, that indicates acid modification interacts adversely with anti-stripping agents added to control moisture damage and that the increased rut resistance declines over time. Some instances of early failure of pavements using acid-modified asphalt have led some state DOTs to ban its use. We raise this issue not because we have any recommendations on the merits or demerits of acid modification – we have seen insufficient evidence to do so – but because it illustrates the need to continue research to develop methods to reliably characterize the properties of modified asphalts. There will always be new modifiers. What is needed is a set of laboratory test methods to adequately assess a specific modifier’s potential to improve pavement performance.”

• Superpave Gyrotory Compactor Issues

The verification of the angle of gyration is essential to ensure comparable results from different Superpave gyrotory compactors (SGC). The mixture ETG has concluded that measurement of the internal angle may lead to better comparability between compactors than using the external angle measurement. Consequently, an optional provision to measure the angle of gyration externally as well as internally has been included in AASHTO T 312-03, “Preparing and Determining the Density of Hot-Mix Asphalt Specimens by Means of
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SUPERPAVE MIX DESIGN WORKSHOP

Superpave mix design workshop will be held at NCAT on March 21-24, 2006. This workshop consists of three and a half days of intensive lecture, demonstration, and hands-on training on Superpave volumetric mix design procedures. Upon completion the participants will be able to conduct the Superpave mix designs in their laboratories.

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the Superpave Gyrotory Compactor.” A provisional standard has also been published for the dynamic angle validator (DAV) operation. Devices have been developed to measure internal angle without using HMA in the mold. The Asphalt Institute is evaluating the effectiveness of such mixless devices under an existing FHWA contract.

• Simple Performance Tests for HMA

Both NCHRP Project 9-19 "Superpave Support and Performance Models Management" and 9-29 "Simple Performance Tester for Superpave Mix Design" are nearing completion. These two projects respectively developed simple performance test methods and test equipment to be included in the Superpave system.

“These new tests will assess the potential of specific mixtures to meet performance expectations. The completion of these projects has been long awaited by the state DOTs. The first production models of the test equipment have been delivered and ruggedness testing is underway to determine whether the test protocols will yield results of suitable repeatability. Completion of this work is expected by the end of 2005. The ETG on Mixtures and Aggregates is currently reviewing the test methods and monitoring the ruggedness testing.”

• Dynamic Modulus of HMA Mixtures

“Both the newly developed Simple Performance Test and emerging pavement design and performance prediction models rely on the determination of dynamic modulus. Soon the Simple Performance Test and new models will be evaluated by the state DOTs and others. So that these evaluations can be correlated with one another, it is essential to develop a uniform standard for the determination of a dynamic modulus that minimizes the variability of the test results. To meet this goal, the mixture ETG recommended a large number of changes to the AASHTO provisional standard on determining dynamic modulus of HMA mixtures.”

• Capturing the History of Superpave

Superpave is a research success story. SHRP was designed with a vision that properly focused, high-intensity research could resolve growing concerns about performance of asphalt pavements. A lot of research was conducted during the SHRP and the subsequent 12 years of further Superpave development. However, the documentary background of Superpave is scattered through more than 200 publications of at least six organizations. This disorganized state of Superpave related information is not in the interest of the future development of Superpave system and will also limit the lessons to be learned from the Superpave experience. Therefore, it is necessary to capture the history of Superpave starting from the initiation of the SHRP project. A forthcoming NCHRP project is likely to achieve this objective.

Asphalt Pavement Awards Presented at NCAT

The Asphalt Pavement Alliance's (APA) Perpetual Pavement Awards were presented in a special ceremony hosted by the National Center for Asphalt Technology in May 2005. Jack Lettiere, Jr., 2005 President of the American Association of State Highway and Transportation Officials (AASHTO), made the presentations. This year's winners included the Colorado DOT, Illinois DOT, Kentucky DOT, Minnesota DOT, Ohio DOT, Santa Clara Roads and Airport Department, South Carolina DOT, Tennessee DOT, and Texas DOT. The honored stretches of pavement ranged from interstate to rural two-lane roadways. To qualify for this prestigious award, a pavement must meet strict criteria and demonstrate hot mix asphalt's long-life characteristics: excellence in design, quality in construction, and value to the traveling public. It also must have been constructed at least 35 years ago. Engineers at NCAT evaluated the nominations and a panel of industry experts validated the winners.



Recipients of the Asphalt Pavement Alliance's Perpetual Pavement Award are seen here with Jack Lettiere, 2005 AASHTO President. **Back row**, left to right are Eric Harm, Illinois DOT; Gerald Nicely, Tennessee DOT; Larry O'Donnell and Luke Stango, co-chairmen of the APA; Jack Lettiere, AASHTO; Dan Collen, County of Santa Clara, Calif.; and Tom Peterson, Colorado Asphalt Pavement Association, who accepted on behalf of the Colorado DOT. **Front row** are Sam Beverage, Kentucky Transportation Cabinet; David Kopp, Texas DOT; Andrew Johnson, South Carolina DOT; Aaron Behrman, Ohio DOT; and Patrick Hughes, Minnesota DOT.

PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of the Association of Asphalt Paving Technologists (AAPT) held in Long Beach, California in March. We are reporting observations and conclusions from them, 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 paper are given, with names of authors in parentheses, followed by a brief summary.

1. Determining Minimum Lift Thickness for Hot Mix Asphalt (HMA) Mixtures (Brown, Hainin and Cooley, Jr)

Proper compaction of HMA mixtures is needed to ensure that a stable and durable pavement is built. For dense-graded mixes, initial in-place air voids should be below approximately 8 percent. One of the major factors affecting compaction is lift thickness. Although there have been many studies on the effect of thickness on compactibility of HMA mixtures, no documented research has been performed to systematically determine the minimum desired thickness of a HMA lift. The Superpave construction guidelines (1997) suggest that a minimum thickness (t) to nominal maximum aggregate size (t/NMAS) ratio of at least 3.0 should be used. But this was based more on existing practice than on documented research. Some state agencies have recommended that a minimum t/NMAS of 4.0 to be used. Thus, there is a need to determine the recommended minimum lift thickness for optimum compaction.

The objective of this research was to determine the minimum recommended lift thickness $t/\text{nominal maximum aggregate size}$ (t/NMAS) ratio for optimum compaction of HMA. A research plan was developed involving extensive laboratory and field-testing. In order to determine the minimum recommended lift thickness for optimum compaction, various laboratory samples were prepared using both a Superpave gyratory compactor (SGC) and a laboratory vibratory compactor (AVC). Also, seven field sections were built.

A total of 36 HMA mixes were designed that consisted of different aggregates types and gradations. The

aggregates utilized in this research included a crushed siliceous gravel, granite, and limestone. The asphalt binder utilized for all mixes was a PG 64-22. All samples were compacted using a Superpave gyratory compactor at the temperature that provided recommended viscosity in the asphalt binder. For the Superpave mixes, each sample was compacted to 100 gyrations. The 100-gyraton level was selected because it was a commonly used compaction effort and it has likely presented the most problems with compaction. All designs were selected at 4.0 percent air voids.

The experiment included four gradation shapes and three NMASs. Three gradations fell within the Superpave gradation control points and one gradation conformed to stone matrix asphalt (SMA) specifications. For the gradations meeting the Superpave requirements, NMASs of 9.5, 19.0 and 37.5 mm were investigated. For the SMA gradations, NMASs of 9.5, 12.5, and 19.0 mm were utilized.

The property selected to define lift thickness in this experiment was the ratio of thickness to NMAS (t/NMAS). This ratio was selected for two reasons: (1) the ratio normalizes lift thickness for any type of gradation and (2) a general rule-of-thumb for Superpave mixes has been to use a minimum t/NMAS ratio of 3.0. For each NMAS in the experiment, three t/NMAS ratios were investigated. For the 9.5 and 19.0 mm NMAS Superpave mixes and all three SMA NMASs (9.5, 12.5, and 19.0 mm), t/NMAS ratios of 2.0, 3.0, and 4.0 were used.

For the 37.5 mm NMAS Superpave mixes, ratios of 2.0, 2.5, and 3.0 were investigated. The 4.0 t/NMAS was excluded for the 37.5 mm NMAS mixes since this ratio would produce a 150 mm lift thickness, which is unlikely to be used in the field. The desired thicknesses of compacted specimens were achieved by altering the mass placed in the mold prior to compaction. Three replicates of each aggregate type-gradation-NMAS-thickness combination were compacted using a compaction effort similar to that used in the mix design.

Testing of each sample after compaction included measuring the bulk specific gravity of each replicate using the vacuum sealing method. The relationships

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between air voids and $t/NMAS$ were analyzed to determine the minimum $t/NMAS$ for a given $NMAS$ and mix type. Since a constant compaction effort was used, the differences in air voids should be caused by the differences in the thicknesses of the specimens. It was expected that as the $t/NMAS$ ratios increased the air voids would decrease until the minimum desired $t/NMAS$ has been reached. It was intended to determine the $t/NMAS$ at which the air voids began to level out and to pick that $t/NMAS$ level as the minimum level recommended for achieving best compaction results.

Based upon the results of this research, the following conclusions were drawn and recommendations were made:

- The density that can be obtained under normal rolling conditions is clearly related to the $t/NMAS$ ratio. For improved compactibility, it is recommended that

the $t/NMAS$ be at least 3 for fine-graded mixes and at least 4 for coarse-graded mixes. The data for SMA indicates that the ratio should be at least 4. Ratios less than these suggested numbers could be used but it would generally require more compactive effort to obtain the desired density. This work should not be used to establish the maximum $t/NMAS$ ratios. Within the range of $t/NMAS$ values evaluated, a $t/NMAS$ greater than 4 did not significantly decrease the density obtained for the standard compactive effort. However, care must be exercised when the thickness gets too large to ensure that adequate density is obtained.

- The results of the evaluation of the effect of mix temperature on the relationship between density and $t/NMAS$ indicate that one of the reasons for low density in thinner HMA sections (lower $t/NMAS$) is the more rapid cooling of the mixture. Hence, for thinner layers it is even more important that rollers stay very close to the paver so that rolling can be accomplished prior to excessive cooling. For the conditions of this study, the mixes placed at the NCAT test track at 25 mm thickness cooled twice as fast as mixes placed at 37.5 mm thickness. For thicker sections (larger $t/NMAS$) the rate of cooling generally does not create a significant compaction problem.

- Evaluation of the effect of $t/NMAS$ on applied energy to achieve a selected density level based on gyratory compacted samples suggests that as $t/NMAS$ ratio decreases, more applied energy is required to compact mixes to a specified density. This required energy begins to increase rapidly for decreasing $t/NMAS$ when the $t/NMAS$ drops below 4. This does indicate that the energy calculated in the Superpave gyratory compactor can be used to help understand the effect of $t/NMAS$ on compaction.

2. Evaluating Wisconsin Warranty Projects: Before, During and After the Warranty (Dukat and Schwandt)

HMA pavements in Wisconsin were exhibiting premature cracking, raveling and rutting in the late 1980s. In 1987, the Transportation Research Board formed a Task Force on Innovative Contracting Practices. This Task Force recommended several new contract methods with the potential to reduce department costs and improve quality. The Wisconsin Department of Transportation (WisDOT) chose to investigate warranties as a method of obtaining quality HMA pavements.

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Monte Symons Joins Auburn University

Monte Symons, P.E. has been appointed Director of the Airfield Asphalt Pavement Technology Program (AAPT) at Auburn University. This \$1.6 million per year grant program from the Federal Aviation Administration (FAA) administers research contracts on asphalt airfield pavement issues. Six to eight projects are awarded each year on a competitive basis.

After serving in the US Army in the late 1960s, Monte Symons graduated from the University of Illinois with a Bachelor's and Master's degree in Civil Engineering in 1974 and 1975, respectively. In July 1975, Monte started his 30-year career working for the Federal Highway Administration. Monte has served in various FHWA pavement and materials related positions and locations throughout the United States. In 1992, Monte was assigned as a loan staff to SHRP and then helped FHWA administer the Long Term Pavement Performance (LTPP) program for nine years. In the LTPP program, he was instrumental in the development and implementation of the LTPPBind program. Monte's last FHWA assignment before coming to Auburn University was with the Resource Center in Atlanta where he directed the National Pavement and Materials Technical Service Team.



Monte Symons



BOMAG Americas provided instruction and demonstration of their milling and paving equipment for NCAT engineers and their employees. Demonstrations were held at NCAT Test Track. This photograph shows attendees being instructed on a paving simulator set up in the NCAT Laboratory.

The first issue in developing a Wisconsin warranty specification was to define the desirable quality of the Wisconsin HMA pavements. It was necessary to develop thresholds for different pavement distress types that WisDOT, the contractors, and the bonding companies felt comfortable in terms of risk. WisDOT wanted the thresholds set so that the risk of premature pavement failure was minimized and pavement quality enhanced. The contractors wanted thresholds that were achievable and provided a reasonable chance of success.

Therefore, the development of warranty thresholds hinged on the comfort levels of the Department and the HMA industry. This comfort level was achieved by analyzing the extensive WisDOT Pavement Management System data. The key indicator in WisDOT's PMS is the Pavement Distress Index (PDI). To determine the PDI, the HMA pavement is evaluated based on 12 identifiable surface distresses (alligator cracking, block cracking, transverse cracking, longitudinal cracking, flushing, edge raveling, surface raveling, patching, rutting, transverse distortion, longitudinal distortion and segregation). These distresses were divided into tolerable and non-tolerable. A tolerable distress was defined as one where a small amount does not pose a safety or performance concern. Further, it was realized that zero-tolerance would increase costs without significantly improving the performance. A non-tolerable distress would be one

that posed a safety or performance concern. The pavement distress types to be included in warranty specification were listed and threshold level for each distress type was identified. The distress threshold levels for tolerable distress types such as longitudinal cracking, transverse cracking and rutting were the most challenging to develop. For these distresses, the problem was determining an acceptable level after five years of traffic. It was agreed to target the threshold levels so that 90 percent of the Pavement Management System data at five years of age would succeed in meeting the threshold.

This paper was prepared to answer three questions, which arose after the expiry of warranty of the first generation of warranty projects in Wisconsin. First, what happens a day after the warranty expires was answered by the performance data given in the paper that shows that pavements built under a performance warranty have better performance histories. The initial data shows that pavement life is increased by a minimum of five years.

The second question was how better performing pavements are achieved with warranty specifications. The key is empowerment or ownership of the project by the contractor crew and a working atmosphere of teamwork between the state and the contractor to produce a good product – a long lasting pavement. Quality control testing on a warranty project by the contractor is typically conducted at a rate equal or higher than a conventional project to reduce the contractor's risk.

The third question was how could the overall costs of performance warranty projects be less than conventional projects. It is easily answered – time and materials. Often, the HMA per ton cost is more for warranty mix. However, the state is spending less money for supervision, testing and pavement maintenance. The contractor has to spend less time working on (perceived) specification issues and can spend more effort on obtaining the best possible results from available materials. The net result is performance warranty projects are cost effective.

NCAT's Professor Training Course in Asphalt Technology June 14-23, 2005



Back row, L-R: Muhieddine Maaz, Dr. Ray Brown (Instructor), Adam Zofka, Jie Han, Michael Leaverton, Joe Wilson, Yongrak Kim, Laith Tashman. **Middle row, L-R:** Xiang Shu, Xingjun Li, Don Watson (Instructor), B.L. Swami, Brian Fuder, Brantley Bain, Daren Zywicki, Jim Lynch. **Front row, L-R:** Osamu Takahashi, Claude Villiers, Feng-Bao Lin, Gabriel Garcia, Imad Basheer, Roy Guevara, Hao Wang, Kitae Nam, Stacey Reubush Diefenderfer



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