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NCAT Hosts Test Track Conference

The National Center for Asphalt Technology (NCAT) held its third Pavement Test Track Conference on February 10-11, 2009. Attendees from across the U.S. were given an overview of recent findings and state implementation, as well as a glimpse of future plans at the track.

Dr. Joe Mahoney of the University of Washington delivered the keynote address, in which he discussed the history and significance of accelerated pavement testing. Four technical sessions followed over the course of the two-day conference. Test track tours gave attendees an opportunity to see how test sections performed and learn about trucking operations, structural section instrumentation and testing equipment.

The 1.7-mile NCAT Pavement Test Track was originally constructed in 2000. It is divided into 46 200-foot long sections, providing an opportunity for sponsors to evaluate pavement issues. Five heavily loaded tractor trailers circle the track five days per week, 16 hours per day, resulting in 10 million ESALs (equivalent single-axle loads) applied over a two-year test period. This accelerated traffic period provides answers to specific pavement performance questions in a safer and faster manner than open-road highway test sections.

At the end of each three-year research phase, test sections are either left in place for additional traffic loading or replaced, as determined by individual sponsors. Some sections are perpetual pavements with distresses confined to the experimental surface layers, while other sections have layers of varying

thickness and are instrumented for structural evaluations. The third research cycle began in 2006, with a combination of old and new sections in service. Eight original sections built in 2000 (all of them surface mix performance) remained in place and have accumulated 30 million ESALs. Sixteen sections (12 mix performance and four structural) built in 2003 also remained in place from the previous cycle and have accumulated 20 million ESALs. Twenty-two new sections (15 mix performance and seven structural) were built in 2006.

Mix Performance Section Findings

RAP Study

State agencies typically allow up to 15-20 percent reclaimed asphalt pavement (RAP) in surface mixes. Using higher percentages of RAP can result in substantial cost savings, but there has been little documentation of field performance for high-RAP mixes. High-RAP mixes were defined by the FHWA expert task group as mixes containing 25 percent or more RAP.

Six sections at the track were devoted to evaluating the construction and performance of mixes with moderate (20 percent) and high (45 percent) RAP contents. To compare the effects of virgin binder grade on RAP mixes, the sections were designed using three different binder grades (PG 52-28, PG 67-22, and PG 76-22). As expected, binder stiffness influenced the compactability of the mixes. Although greater compactive effort was required for the 45 percent RAP sections with PG 76-22, target density was achieved for all sections.

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at AUBURN UNIVERSITY

The RAP sections performed very well in the field, showing excellent rut resistance despite some sections having low air voids and high voids filled with asphalt (VFA). The mixes were also tested in the lab using the Asphalt Pavement Analyzer (APA), which gave similar rut measurements. Most of the RAP sections exhibited no cracking and the minor cracking that occurred in two sections was attributed to factors other than the mix.

Results at the track indicate that high RAP mixes can perform successfully and that the use of softer virgin binder grades in high-RAP mixes is not necessary. Further lab tests are ongoing, and it is likely that many of these RAP sections will remain in place through the next phase of testing at the track. As noted in *Specification Corner*, several states are increasing the allowed percentages of RAP.

Low Air Voids Experiment

The Indiana Department of Transportation (DOT) sponsored four 100-foot subsections to address concerns regarding the potential costs associated with low-quality-control (QC) air voids. These subsections were constructed with low QC air voids by adjusting the aggregate blend and/or increasing the asphalt content. Each mix used an unmodified PG 67-22 binder.

Trafficking began in the fall of 2006. Significant rutting occurred during the summer of 2007 such that all four subsections were milled and replaced in February 2008 for safety reasons. A similar rutting pattern was observed in the replacement low-void mixes during the summer of

2008. Results showed that the rate of rutting increased considerably for QC air voids less than 2.75 percent, indicating that removal and replacement might be necessary below that level. Previous research at the track indicates that the relationship is very different for mixes with polymer-modified binders.

Validation of the Energy Ratio Concept

A common pavement distress is top-down cracking, which is caused by a combination of factors including loads, thermal stress and aging. No single mix property has been identified to predict and prevent this problem. However, an energy ratio concept has been proposed and two sections of the track were sponsored by Florida DOT to test this concept. One section used a polymer-modified binder to achieve a higher energy ratio. The mix with the higher energy ratio proved to be more resistant to top-down cracking, but further study is needed to establish energy ratio criteria for different traffic levels.

Permanent Deformation Evaluation

Permanent deformation performance of surface mixes was evaluated in the lab using the Asphalt Pavement Analyzer (APA) and the flow number (F_n) test, which was conducted using the Asphalt Mixture Performance Tester (AMPT). Lab specimens were prepared from twelve different plant-produced mixes at the track. A good correlation was developed between the lab tests and field rut depth at five million ESALs. Maximum acceptance criteria were developed for both tests based on a conservative critical field rut depth of 9.5 mm.

Structural Section Findings

Eleven sections were part of a broad structural study aimed at further refining mechanistic-empirical (M-E) design procedures and calibrating pavement response models. Historically, asphalt pavement thickness has been designed based on vehicle type, normalized



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Dr. Nam Tran discusses laboratory testing at the test track.



Dr. David Timm, associate professor of civil engineering, discusses FWD testing and structural section instrumentation.

axle loads and basic material properties coming from the AASHTO Road Test. However, the recently developed *Mechanistic-Empirical Pavement Design Guide* (MEPDG) uses engineering principles to design pavement structures that will resist specific distresses. For instance, fatigue cracking is dependent upon the horizontal tensile strain at the bottom of the hot mix asphalt (HMA). An accurate prediction of this strain is critical in designing a long-lasting, cost-effective pavement structure. Before the MEPDG gains wide acceptance and use, it must further be refined and validated.

Structural sections sponsored by several highway agencies were built with design variables that included total HMA thicknesses, HMA mix types, base materials types and sub-grade materials types. The structural sections were instrumented with strain gauges to measure pavement response under loading. Comparisons of actual and predicted pavement responses indicate that pavements can withstand higher levels of field-measured microstrain and still resist fatigue cracking. This may allow pavement engineers to design perpetual pavements with thinner cross-sections than previously thought. This would make HMA more competitive in life cycle cost comparisons with other pavement types.

In a mechanistic-empirical (M-E) framework, accurately characterizing materials is vital to predicting performance. Dynamic modulus (E^*) is the fundamental property used in characterizing the viscoelastic properties of HMA, and as M-E design has progressed E^* has become a basic design input due to its ability to reflect the time and temperature dependency of HMA. Comparisons were made between three common dynamic modulus models and laboratory measured E^* values to determine which model most accurately reflected E^* values determined in laboratory testing. The Hirsch model proved to be the most reliable E^* model for predicting the dynamic modulus of an HMA mixture.

State Implementation

The NCAT Pavement Test Track provides an invaluable opportunity for sponsors to evaluate new materials and design concepts in a controlled environment with accelerated traffic conditions. Since 2000, a wealth of practical research at the track has been implemented by sponsoring agencies. For example, several state DOTs have changed their specifications to allow fine-graded mixes on high-volume roads based on their favorable performance at the track. Several states presented their experience, including the following:

Georgia

Georgia DOT sponsored three sections to compare the performance of open-graded friction course (OGFC) mixes using different aggregate and construction techniques. One section used the conventional aggregate currently allowed in Georgia OGFC mixes, while another section used the more cubical aggregate specified for SMA. A third section was constructed with a twin-layer OGFC such as is commonly used in Europe to improve drainage and reduce noise. For this section, a European twin-layer asphalt paver was used to simultaneously place a finer-graded OGFC over a coarser-graded OGFC.

Results indicated that the OGFC with more cubical aggregate actually had less drainability than the OGFC with conventional aggregate. Consequently, Georgia DOT will retain their current aggregate specification for OGFC mixes. The twin-layer OGFC proved to be more drainable than the single-layer OGFC mixes, and it was also the quietest surface at the track. All three sections exhibited excellent rut resistance. Because of the outstanding performance of the twin-layer OGFC, Georgia DOT would like to place some trial sections on active highways. However, current funding levels have prevented this since the twin-layer section is more expensive than conventional OGFC because of the special paving equipment required.



Conference attendees view pavement trenches while Dr. Richard Willis explains forensic investigations at the track.

Missouri

In the 2003 test cycle, Missouri DOT evaluated SMA mixes using aggregate that did not meet its current SMA specifications. At the time, 50 percent of coarse aggregate in SMA were required to be “hard/ durable” aggregate, but only one source of material within the state met that specification. Consequently, the haul cost to other areas of the state raised the price of SMA significantly, limiting the tonnage of SMA that could be placed annually in Missouri. Limestone aggregate sources, which are much more widespread in Missouri, had never been allowed in SMA mixes. To determine if limestone SMA mixes were a viable option, Missouri DOT sponsored three sections of the 2003 test cycle – one with traditional SMA and two with 100 percent limestone aggregates. Results showed that the 100 percent limestone SMA mixes performed well. Consequently, Missouri DOT changed its specifications to allow 100 percent limestone SMA mixes, thus expanding the use of SMA to all interstate and high-volume roads. In just the first five projects using the revised specification, Missouri DOT estimated cost savings of approximately \$535,000.

Future Plans

Plans are underway for construction of the 2009 NCAT Pavement Test Track to be completed this summer. The



Dr. Jay Gouge, President of Auburn University, welcomes conference attendees.

focus will be expanding the structural experiment while continuing to evaluate surface mix performance. Although many sections will be individually sponsored, a six-section group experiment is planned to include high-RAP mixes, warm mix asphalt (both foam and additive technologies) and OGFC. All sections within the Group Experiment will have a total asphalt thickness of seven inches over the same base and subgrade.

These sections will be fully instrumented to measure pavement response, making it possible to compare actual and predicted performance.

Potential sponsors also have numerous options to participate aside from the Group Experiment. Existing sections may remain in place for additional traffic loading to evaluate longer-term performance and durability. Sponsors may also choose to mill and inlay on existing perpetual pavement sections or thinner structural sections. Other options include new structural sections, either independent of the Group Experiment or complimentary to it. Additional sponsorship information can be found at <http://www.pooledfund.org/projectdetails.asp?id=1232&status=1>



Dr. Joe Mahoney receives a test track memento from Dr. Randy West, NCAT Director.

A rich diversity of materials will be used in construction of the 2009 Track. Alternative binder modifiers will be used, as well as material that is intended to replace a large percentage of the liquid asphalt. Surface treatments will also be used, and for the first time at the Test Track, mix will be placed using asphalt modified with ground tire rubber.

Ongoing research at the NCAT Pavement Test Track continues to provide valuable information concerning pavement materials and structural pavement design.



States Using Permissive Warm Mix Asphalt Specifications

Warm mix asphalt (WMA) is the new hot trend in asphalt paving. Whether using additives or the water injection/foaming process, warm mix technologies significantly reduce the temperature at which asphalt mixes are produced, thus reducing energy costs and emissions. Other potential benefits of WMA technologies include:

- Aids in compaction
- Allows longer haul distances
- Allows increased use of reclaimed asphalt pavement (RAP)
- Extends paving season in cold climates
- Improves working conditions for paving crews
- Decreases plant aging of the binder, resulting in improved long-term durability
- Eliminates bumps due to crack sealant expanding under overlays

Although WMA is relatively new to the United States, it has been used successfully in Europe for more than 10 years. European experience indicates that WMA should provide equal or better performance than hot mix asphalt (HMA).

Performance of WMA has been investigated at the NCAT Pavement Test Track. Two sections at the track were constructed using the warm mix additive Evotherm in 2005. Both sections remained in place throughout the 2006 phase of testing, receiving 10 million equivalent single axle loads (ESALs) during the two-year research cycle. One section used PG 67-22, while the other had a latex-modified PG 76-22 binder. During construction of one section, the haul truck gate became stuck in the material transfer device. Although the situation took about an hour to correct, the production crew had no problems placing the remaining material and achieving density. Both WMA sections have exhibited outstanding performance in terms of both rut resistance and durability. WMA sections using both foaming and additive technologies will be placed on the 2009 NCAT Pavement Test Track this summer.

Caltrans has also evaluated the performance of three WMA technologies using the Heavy Vehicle Simulator (HVS). Results indicated that the WMA sections had no increased risk of rutting compared with conventional HMA. Caltrans is currently investigating moisture sensitivity of WMA using HVS testing.

Several state agencies are moving forward with WMA, allowing it as an option on many highway projects. In 2008, the Texas Department of Transportation (TxDOT) placed more than 300,000 tons of WMA. Some states, including Texas, Florida and Alabama, have developed special provisions allowing WMA, using department-approved additives/processes, on any project. In Missouri, contractors may use WMA produced by any method on

any project, provided that standard performance-based specifications are met. Kentucky allows WMA produced using the foaming process and will consider other WMA technologies on a project-specific basis. Following the success of several 2008 WMA trial projects, Ohio is taking an approach similar to Kentucky, with the exception that WMA will not be permitted in heavy-traffic surface courses yet. The Warm Mix Asphalt Technical Working Group has established a guide specification for WMA, which can be found at www.warmmixasphalt.com.

Research is currently underway through NCHRP 9-43 to develop a mix design procedure for WMA. Advanced Asphalt Technologies of Sterling, Virginia is conducting that study. At present, HMA mix design procedures are used, followed by a trial plant run using the warm mix additive or process for verification. Quality Control/Quality Assurance (QC/QA) testing is performed at the warm mix temperature and must meet standard HMA requirements. NCAT has just been awarded NCHRP 9-47A which will document field performance of WMA technologies across the U.S., compare engineering properties of WMA to HMA, and evaluate energy savings and emissions reductions for WMA production.

Several publications are available through the National Asphalt Pavement Association (NAPA), including *Warm Mix Asphalt: Contractors' Experiences*, *Warm Mix Asphalt: Best Practices* and *Warm Mix Asphalt: The Future of Asphalt*. Please visit www.hotmix.org, for more information.

NCAT has also completed research on several warm mix additives, including Aspha-min, Sasobit and Evotherm. The published reports can be obtained through our website, www.ncat.us. NCAT continues to research WMA properties in cooperation with the Federal Highway Administration.



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.

Kentucky

(Allen H. Myers, Kentucky Transportation Cabinet)

Has any other state encountered tenderness issues with warm-mix asphalt (WMA)? In some cases, Kentucky has noted that the WMA mat is tender during compaction, resulting in poor density and smoothness of the finished pavement. Also, the WMA pavement may remain tender for several days after placement.

Missouri

(Joe Schroer, Missouri Department of Transportation)

Which states are planning to implement the Multiple Stress Creep Recovery (MSCR) Test in lieu of their current method of determining modification of binders? Are binder suppliers in favor of this? Missouri would like to see implementation by agencies and suppliers to avoid the questions following a failing test, only to find out the supplier followed another state's testing protocol.

Asphalt Forum Responses

The following responses have been received to questions raised in the Fall 2008 **Asphalt Forum**.

1. *Has any other state developed a positive incentive (bonus) on (a) HMA production testing and (b) pavement density? If so, is the incentive monetary or non-monetary (positive incentives negate negative incentives)?* (Nelio J. Rodrigues, Connecticut Department of Transportation)

Colorado (Roy Guevara, Colorado DOT)

CDOT has a maximum incentive of 5 percent based on acceptance test results for asphalt content, mat density, gradation and joint density. Disincentive can also be applied up to the point of 25 percent, at which point remove-and-replace starts to take effect. Currently CDOT does not offer incentives or disincentives on contractor testing. Incentive/disincentive payments are a percentage increase or decrease to the unit price paid for the HMA mix.

Florida (Gregory Sholar, Florida DOT)

FDOT has had a bonus system for nearly 10 years for volumetric properties measured at the plant and roadway density measured in the field. The maximum bonus is 5 percent. FDOT uses a percent within limits (PWL) specification.

Kentucky (Allen H. Myers, Kentucky Transportation Cabinet)

The Kentucky Transportation Cabinet (KYTC) permits an opportunity for incentives on air voids, lane density and longitudinal joint density (for surface mixes only). According to the terminology used by the Connecticut DOT, these incentives would be “non-monetary.” Incentives achieved (for air voids or density) will be allowed to offset any disincentives incurred (for asphalt content, air voids, VMA or density) in the same lot of production, but the overall pay factor for that lot cannot exceed one. In other words, KYTC will not pay a “net bonus” for asphalt mixture properties.

Missouri (Joe Schroer, Missouri DOT)

Missouri has a PWL specification for Superpave mixes. The combined pay factors are air voids, VMA, AC content and roadway density. The incentive/disincentive is monetary.

New Hampshire (Denis M. Boisvert, New Hampshire DOT)

We have a monetary incentive for pavement density.

Ohio (Dave Powers, Ohio DOT)

Ohio uses a monetary incentive/disincentive pay factor table for density only. For example, an incentive of 4 percent is given for 94.0-95.9 percent density based on cores and daily Rice values.

Ontario (Kai Tam, Ontario Ministry of Transportation)

Ontario has a very comprehensive PWL specification for both mix properties and in-place density, and provides both monetary incentives and disincentives. The attributes investigated include four sieves, AC content, air voids, VMA and compaction. For each of the attributes, the lower and upper limits of acceptance vary depending upon the mix type being investigated. For each 5000-ton lot (10 sublots are randomly sampled), the individual payment factors for each attribute are combined together to determine an overall payment factor using a comprehensive formula.

Texas (Dale A. Rand, Texas DOT)

The QC/QA hot-mix specifications in Texas do include both bonuses and penalties for in-place density (placement) and laboratory-molded density (production). We also have bonus/penalty provisions in our ride-quality specifications. We have been paying bonuses (and assessing penalties) since we implemented our QC/QA specifications in 1993. We average the production and placement bonus/penalty, so there are times that they cancel each other out.

2. *How are contractors managing their RAP piles? Are they allowed to continually add to them or do they have to have a separate pile for each source of RAP? We are finding that contractors that have the large, continuous piles are having a hard time producing mix to match their design for mixtures that contain 30 to 45 percent RAP.* (Gregory Sholar, Florida Department of Transportation)

Colorado (Roy Guevara, Colorado DOT)

Contractors can do whatever they want with their RAP piles. We only require a QC plan documenting it. Most of them just continually add to them. We also don't allow more than 25 percent RAP in our HMA mixes.

Kentucky (Allen H. Myers, Kentucky Transportation Cabinet)

The applicable specifications from the Kentucky Transportation Cabinet require RAP of different gradation, asphalt binder percentage, asphalt binder properties and aggregate properties to be maintained separately. However, this requirement is not always strictly enforced. In reality, our contractors often construct the “continuous” RAP stockpiles that the Florida DOT describes. Due to the inconsistency of some RAP used in Kentucky, asphalt mixtures produced with RAP contents greater than 20 to 25 percent frequently yield erratic volumetric properties. For this reason, most contractors in Kentucky limit RAP contents to 15 to 20 percent. In order to successfully utilize higher RAP contents, we believe that most of the RAP typically found in Kentucky would need to be crushed, screened and stored separately.

Missouri (Joe Schroer, Missouri DOT)

Missouri’s specification for RAP does not include restrictions for stockpile management. Although the specifications allow any amount of RAP, contractors have not used more than 20 percent, excluding a trial on one project, in order to avoid binder testing for grade determination. A few contractors are crushing and screening to provide better control of mixtures, to blend different stockpiles and to provide more flexibility in the use of different NMAAS mixtures.

Nevada (Darin P. Tedford, Nevada DOT)

Nevada is starting its first RAP job, using a maximum of 15 percent RAP. The contractor will be allowed to add to the RAP pile.

New Hampshire (Denis M. Boisvert, New Hampshire DOT)

Our contractors do not typically segregate their RAP piles. Processing appears to produce a surprisingly consistent product.

Ohio (Dave Powers, Ohio DOT)

Ohio just instituted specific restrictions on the large, continuous RAP piles mentioned. Contractors cannot add to a stockpile once it has been tested for uniformity. Alternately, a concurrent RAP process can be used. We also just approved increased RAP allowances with additional efforts required of the contractor. For more information, please go to: <http://www.dot.state.oh.us/Divisions/ConstructionMgt/Pages/ProposalNotesSupplementalSpecificationsandSupplements.aspx>.

Click on Supplemental Specifications, then click on the 800 pdf file. RAP requirements are found in section 401.04.

Ontario (Kai Tam, Ontario Ministry of Transportation)

Ontario has quality requirements for RAP (i.e. it cannot

be contaminated, it must be consistent, and it must meet consensus and agency properties). We do not have specific requirements about how the material is stockpiled by the contractor, just the base on which it is placed. We rely on our end-result specification (ERS), mix design, and independent mix check to ensure the correct type and percentage of RAP are used.

Virginia (G. W. “Bill” Maupin, Jr., Virginia Transportation Research Council)

Our contractors control their own RAP piles, and usually RAP is not separated. We did a limited study of RAP contents of 20 to 30 percent in several VDOT districts and did not determine any problems with control. The results are documented at <http://www.viginiadot.org/business/materials-download-docs.asp>. Some contractors do fractionate their processed RAP and obtain better control by this method. I would think that higher RAP contents would require better RAP control.

3. *When rehabilitating an existing HMA roadway that has transverse cracking or a PCCP roadway with joints, is the low temperature grade of the binder typically changed to try and prevent the reflective cracking that will occur? If you have experience using different low temperature grade binders for rehabilitation actions, does using a lower temperature grade binder improve the pavement performance by delaying reflective cracking?* (Cliff Hobson, Kansas Department of Transportation)

Florida (Gregory Sholar, Florida DOT)

FDOT does not change the low temperature grade for the conditions mentioned.

Kentucky (Allen H. Myers, Kentucky Transportation Cabinet)

The standard asphalt binder most often specified by the Kentucky Transportation Cabinet (KYTC) is PG 64-22. On a few occasions in the past, we have used a PG 64-34 or PG 70-28 binder in an attempt to retard reflective cracking from the underlying pavement. Although KYTC has not performed any formal evaluations of these pavements over time, we have received anecdotal reports that the different low-temperature grade binders did provide marginal improvements in the pavement performance by delaying the reflective cracks somewhat longer than would be expected with a conventional asphalt binder.

Missouri (Joe Schroer, Missouri DOT)

Missouri uses the same low temperature binder grade for full-depth and overlay construction. In general, we have seen that mixes with higher binder content, i.e. SMA, and larger NMAAS mixtures are more effective at retarding reflective cracking.

Nevada (Darin P. Tedford, Nevada DOT)

Nevada does not modify the low temperature grade for these conditions.

New Hampshire (Denis M. Boisvert, New Hampshire DOT)

New Hampshire only has HMA pavements. The same binder grade is used for both rehabilitation and new construction. Reflective cracking is caused by the reduced structure associated with placing a thin overlay over an existing crack, not the binder grade. We have moved to more “mill and fill” projects to remove more or all of the cracks and increase the thickness of the new pavement to extend the time before the crack reappears.

Ohio (Dave Powers, Ohio DOT)

No. Generally we have not found this to be the case unless polymers are used. It does depend in part on the type or cause of the crack.

Ontario (Kai Tam, Ontario Ministry of Transportation)

In Ontario, PGAC grading selection is based on climate zones for the region and traffic volume of the road under consideration. We do not change the grade of AC because of the reflective cracking. Instead, mix and pavement designs are used to mitigate reflective cracking.



Specification Corner

Colorado – We have made a few changes to our RAP specifications. We recently increased the amount allowed in the top lift from 15 to 20 percent. CDOT also developed a procedure to use millings from a project as RAP on the same project. Both changes were made to assist contractors in using more RAP.

Florida – We will allow warm mix asphalt in all structural and friction course mixtures at the contractor’s option. FDOT will have a website with approved warm mix products/processes. To be approved, a warm mix supplier will need to work with a contractor and FDOT to construct a demonstration project, while meeting all of the FDOT construction specifications.

We will allow up to 20 percent RAP in dense-graded friction course mixtures. We have removed restrictions on the amount of RAP that a contractor can add to structural courses. The contractor will need to meet volumetric properties at mix design and during construction.

Kentucky – The Kentucky Transportation Cabinet (KYTC) is modifying its asphalt mixture selection warrants to again include 0.50-in. nominal-maximum size surface mixtures and PG 76-22 asphalt binder on limited applications involving elevated levels of traffic loading. Also this year, we are requiring gyratory compactors to be calibrated by the internal angle; the external angle is no longer an option.

Additionally, KYTC has developed a number of supplemental specifications for the 2009 construction season:

- We have revised our standard specifications to permit warm-mix asphalt (WMA) produced by the water injection/asphalt foaming process at the contractor’s option. Kentucky is also interested in exploring other WMA technologies on a project-specific basis.

- We have modified our incentive/disincentive payment policy for asphalt mixture properties. Incentives achieved (for air voids or density) will be allowed to offset any disincentives incurred (for asphalt content, air voids, VMA or density) in the same lot of production, but the overall pay factor for that lot cannot exceed one. In other words, KYTC will not pay a “net bonus” for asphalt mixture properties.
- In order to improve pavement durability, Kentucky is lowering the number of gyrations required for asphalt-mixture design and acceptance. For routes with 20-year ESALs of less than three million, we are lowering the number of N_{des} gyrations from 75 to 50. For routes with 20-year ESALs between three and 30 million, N_{des} is decreasing from 100 gyrations to 75. Finally, for routes with 30 million ESALs or more, we are revising the number of N_{des} gyrations from 125 to 100. We anticipate that these revisions will permit the design of mixtures with gradations that are finer and less “harsh” and produce mats that are more easily compacted. We are also hopeful that the fewer gyrations will result in higher optimum asphalt contents and ultimately more durable pavements.
- We are increasing the minimum VMA requirements for plant-produced mixtures by 0.5 percent. As revised, the VMA specified for full pay on acceptance results will be the same as that required according to AASHTO M 323 for laboratory mix designs. Previously, we allowed a 0.5-percent VMA tolerance for plant-produced mix. In conjunction with the lower gyration levels explained above, Kentucky is

implementing these VMA modifications in order to achieve higher optimum asphalt contents and more durable pavements.

- For selected jobs, KYTC is increasing the minimum level of core density required for longitudinal joints in surface mixtures. For these pilot projects, we are increasing the minimum requirement for full pay from 89 percent of theoretical maximum density to 90 percent. The performance of longitudinal joints in asphalt pavements continues to be a major concern in Kentucky, and we expect that denser joints will provide better performance.

Missouri – We are working on a specification that may allow permeability testing with the field permeameter as an alternate to density with cores. An investigation was performed in 2008, and the report should be available soon. The testing was performed by MoDOT, and data analysis and recommendations were provided by Dr. Chris Williams at Iowa State University.

New Hampshire – We are implementing the following changes for the 2009 construction season:

- Increased RAP in HMA – This specification change has several impacts as it totally changes our approach to RAP products.
 - Introduction of new terminology – Total reused binder (TRB). This eliminates a variable in HMA formulations due to varying AC content in RAP sources.
 - Increase in allowed RAP without testing – A maximum of 0.8 percent TRB (20 percent RAP, assuming four percent AC in RAP) will be allowed without testing.
 - Overall increase in allowed RAP – One and a half percent TRB (37.5 percent RAP). Testing is required at this level to determine the appropriate PG grade of virgin binder to be added.
 - The TRB terminology eliminates the concept of "known" and "unknown" RAP sources.
 - Use of asphalt from roof shingles is allowed.
- Price adjustment – Historically, NH has given RAP millings to the contractor. Liquid asphalt price adjustment was paid on all binder after a 10 percent increase. We no longer pay an adjustment on binder from RAP. Adjustment on virgin binder is paid on any change from the bid price.
- Material transfer vehicles – Material transfer vehicles are now required for construction on Interstate and many secondary-system highways. This requirement is intended to improve end-of-load segregation problems.
- Preparation of rumble strips before applying an overlay – Thin lift overlays over rumble strips were causing laydown, density, and cracking problems. This specification requires milling of all rumble strips for single lift applications.

Ohio – Ohio recently instituted changes to RAP requirements, including stockpile restrictions and increased RAP allowances with additional efforts required of the contractor. Please go to: <http://www.dot.state.oh.us/Divisions/ConstructionMgt/Pages/ProposalNotesSupplementalSpecificationsandSupplements.aspx>

Click on Supplemental Specifications, then click on the 800 pdf file. RAP requirements are listed in section 401.04.

Ontario – The Ontario Ministry of Transportation is planning to implement the following changes:

- Special Provision 103F31 Modified: Smoothness by Inertial Profilers – An MTO/industry task group was set up in 2007 to investigate how MTO can begin the transition from QC acceptance based on PI measurements by California Profilograph to QA acceptance based on IRI and localized roughness measurements by inertial profiler. A draft Special Provision, a new Laboratory Standard for calibrating, correlating and taking measurements with inertial profilers, and a list of equipment requirements for inertial profilers have been created. During the 2009 construction season, MTO is planning to implement these new specifications in selected contracts.
- Special Provision: Full-Depth Crack Repairs – A task group was set up in 2008 to develop a specification to provide consistency across the province for full-depth crack repairs. This specification will be completed shortly and will be used in some contracts during the 2009 construction season.
- Special Provision: Increased RAP Usage – We are currently revising our specifications to permit greater percentages of RAP in our mixes. Currently no RAP is permitted in our premium surface courses. Although RAP will still not be permitted in our SMA mixes, up to 20 percent will be permitted in all other surface courses. Up to 20 percent RAP will be permitted in binder courses within 150 mm of the pavement surface for facilities carrying more than 3 million ESALs over the 20-year design life, and 40 percent RAP will be permitted for all other binder courses. This modification is to be completed shortly and will be used in some contracts during the 2009 construction season.
- Designer Guidelines for Constructability of Longitudinal Joints – An MTO/industry task group produced a document on designer guidelines and is

preparing another document on best practices. These documents are intended to facilitate the design and construction of better-performing longitudinal joints.

Texas – TxDOT recently developed a special provision (designated SP 341-020) that allows Warm Mix Asphalt (WMA) on any project. If WMA is required on the plans, the contractor must produce the mix within the temperature range of 215 and 275°F. TxDOT placed over 300,000 tons of WMA in 2008, and we anticipate that we may reach the one million ton mark in 2009. We currently have over 400,000 tons of WMA under construction.

The special provision also allows fractionated RAP to be used at the rates of 20 percent for surface mixes, 30 percent for sub-surface mixes, and 40 percent for base mixes that are placed more than 8 inches below the surface. Unfractionated RAP is also allowed at the rates of 10 percent for surface mixes, 20 percent for sub-surface mixes, and 30 percent for mixes placed more than 8 inches below the surface.

We are working on allowing alternate binder grades to be used in lieu of the grade that is specified. We tend to be conservative and specify a more expensive, higher grade binder since we do not know the exact materials that a contractor will be using. If we knew a contractor was going to use RAP (or better aggregate, additives, etc.), we would probably lower the required binder grade by one grade or more. We envision a special provision that will give contractors the incentive to use RAP combined with the lowest binder grade necessary to meet our desired Hamburg Wheel requirement for rutting resistance. This would combine the economic savings from using RAP with the savings from using less expensive binders. This would also avoid mixes that are overly stiff due to using high percentages of RAP with stiffer binders.

Virginia – Work is in progress to develop end-result tack and bond strength specifications for tack materials. Also included is development of specifications for approval of various “trackless tacks.”



Research Roundup

AAPTP 04-04: Evaluation of Stone Matrix Asphalt (SMA) for Airfield Pavements (Prowell, Watson, Hurley, Brown)

Stone Matrix Asphalt (SMA) has been used on highways in the U.S. since the early 1990’s and has shown good performance. Although SMA has been used successfully on airfields in other countries, there has been little use of SMA on airfields in the U.S.

Cracking is the major form of distress on airfields, with rutting being a secondary concern. Airfield pavements also present several unique challenges. Skid resistance is extremely important, and the Federal Aviation Administration (FAA) requires that airfield pavements be grooved to reduce the risk of hydroplaning. Airfield pavements must also be durable and resistant to fuel spills and deicing chemicals. Raveling is a particular concern as well, since dislodged particles can cause foreign object damage (FOD) to aircraft.

The Study

This study was conducted with the following objectives:

1. Evaluate and document performance of SMA for airfields
2. Develop a specification for design and construction of SMA for airfields
3. Develop an implementation plan to expand the use of SMA on airfields, where appropriate

A literature review and survey of existing SMA airfields in Australia, China, Europe and Mexico revealed that SMA can provide a durable and rut-resistant airfield pavement. China is a leader in using SMA on airfields, reporting substantial benefits with its use including improved skid resistance, greater durability, resistance to fuel and oil spills, reduced reflective cracking, low maintenance and lower life-cycle costs. Limited problems were observed at several international airfields, primarily related to inappropriate level of in-place density or too-soft binder. Several international airfields reported that SMA pavements stayed wet longer than



SMA overlay on runway at Spangdahlem Air Force Base, Germany

dense-graded pavements, requiring greater use of deicing agents in colder climates such as northern Europe. SMA was used on airfield pavements at U.S. Air Force bases in Italy (Aviano) and Germany (Spangdahlem), reportedly providing good friction without being grooved.

A laboratory study was conducted to refine the SMA design procedure for airfields. A range of aggregate types, with L. A. Abrasion values ranging from 18 to 37 percent, were used in designing the SMA mixes. Laboratory compaction levels included 50-blow Marshall and 50, 65, 80 and 100 gyrations. Because modified asphalt is highly recommended for SMA, a PG 76-22 binder was used in all mixes, except for one subset that was tested with PG 64-22 for potential use on general aviation airfields. A P401 mix with PG 76-22 and 3.5 percent air voids was produced as a control. The SMA mixes were initially designed at 3 percent air voids (to help facilitate in-place density), with a minimum VMA of 17.0 percent and $VCA_{\text{Mix}} < VCA_{\text{DRC}}$ ($VCA_{\text{Ratio}} < 1.0$, to help ensure stone-on-stone contact).

SMA mixes were evaluated in the lab for rutting potential, cracking resistance, moisture susceptibility, fuel resistance, resistance to deicing agents and durability of grooves. Rutting susceptibility was evaluated using three methods: Marshall stability and flow, repeated load permanent deformation and the Hamburg wheel-tracking device. The Hamburg wheel-tracking tests were conducted wet in order to assess moisture susceptibility as well as rutting. Cracking resistance was evaluated using the Texas overlay tester. Resistance to fuel and deicing chemicals was evaluated using the CITGO Fuel Soak Test and the Immersion Tension Test, respectively. Finally, a three-wheel polishing device was used to assess groove durability.

The volumetric and permanent deformation data were analyzed to determine a gyratory compaction effort equivalent to the standard 50-blow Marshall, while still providing good rutting performance. A model was developed to estimate an equivalent number of gyrations dependent on aggregate properties (L. A. Abrasion loss and percent of flat and elongated particles). Based on the model, SMA mixes with harder, more cubical aggregate can be designed with a higher number of gyrations, while mixes with softer or more flat and elongated aggregate require lower design gyrations.

Conclusions

Conclusions drawn from this study include the following:



NCAT's Tim Vollor (not pictured) and Jenna Michael performing QA testing at Spangdahlem Air Force Base

- SMA can be successfully designed using coarse aggregate with L. A. Abrasion loss higher than 30 percent, but this appears to reduce durability.
- SMA can be designed with greater than 20 percent flat and elongated particles at the 3 to 1 ratio. These mixes showed good performance in the laboratory. The effect on field compaction was not determined.
- SMA can be designed using gravel aggregate sources.
- Optimum asphalt content should be selected at 4 percent air voids. The mixes in this study were designed at three percent air voids to help improve compaction in the field. However, it was noted in several cases that 3 percent air voids fell on the wet side of the VMA curve, which could increase rutting potential. With increased asphalt content, VCA_{Ratio} also increased, making design difficult. This, in conjunction with the expectation that VMA and air voids should decrease during production due to aggregate breakdown, led to the conclusion that 4 percent air voids should be used for the selection of optimum asphalt content
- Mixes designed at 4 percent air voids using either the 50-blow Marshall or 65 gyrations with a Superpave gyratory compactor should produce similar volumetric properties and allow a range of aggregate properties while still providing good rutting performance.
- Stability and flow does not appear to be an accurate predictor of rutting potential for SMA

mixes and is not recommended based on German experience.

- Based on laboratory evaluations, the SMA mixes performed similar to the P401 mix in terms of permanent deformation.
- Laboratory resistance to fuel and deicing chemicals was approximately equal for SMA and P401 mixes. Experience in China indicates improved fuel resistance for SMA mixes.
- Lab testing showed that grooved SMA can withstand accelerated loading without raveling or collapse of the grooves.
- The Texas overlay tester indicates a significant increase in crack resistance for SMA compared to the P401 mix. This increased durability is the most significant benefit of SMA mixes and will help address cracking problems for many airfield pavements.
- Since the SMA mixes had 1.5 to 2 percent higher asphalt content, durability of SMA should be much greater than conventional mixes.

Based on the results of this study, a draft FAA technical advisory circular on SMA for airfields was developed. A presentation covering the research results and a basic overview of SMA design and construction issues will also be developed to inform airfield managers, military officials and design consultants. The full report (Number 04-04) can be downloaded at www.aapt.us.



NCHRP 9-38: Endurance Limit of HMA Mixtures to Prevent Fatigue Cracking in Flexible Pavements (Prowell, Brown, Daniel, Bhattacharjee, Von Quintus, Carpenter, Shen, Anderson, Swamy and Maghsoodloo)

Fatigue cracking has long been a major concern in the design and construction of hot mix asphalt (HMA) pavements. Thickness of the HMA is a fundamental consideration in designing pavements to resist fatigue cracking. If the HMA pavement structure is too thin, the pavement will fail under repeated loading, producing familiar alligator cracking. This bottom-up fatigue cracking is primarily caused by tensile strain at the bottom of the HMA.

Several strategies have been used to prevent fatigue cracking and produce long-life pavements, including the following:

- *Polymer-modified asphalt binder.* Laboratory testing has shown that fatigue performance of polymer-modified mixes is greater than unmodified mixes.

Fatigue characteristics also seem to be dependent on the base asphalt binder used for modification.

- *Rich bottom layer.* Increased asphalt content and increased compaction produce a strain-resistant bottom layer with lower air voids, which also improves moisture resistance. The underlying unbound layers must be sufficiently stiff to allow for the increased compaction necessary for a rich bottom layer.
- *High-modulus base.* A stiff binder is used to produce a high-modulus base mix. Increased stiffness can result in lower strains and increased fatigue life, which in turn produces a more economical pavement. This technique has been used successfully in Europe.

Lab tests are generally not an accurate predictor of fatigue life in the field. Since in-service pavements tend to have longer fatigue lives than what is predicted by lab tests, a shift factor, which can be significant, must be applied. Due to time constraints, lab tests are typically conducted at higher stress/strain levels than what a pavement actually experiences in the field. Performance at lower stress/strain levels is then extrapolated from the lab test data. Thus, there is very little understanding of the actual performance expected at the lower stress/strain levels representative of field conditions.

Research indicates that there might be a level of strain below which fatigue damage does not occur in a pavement structure. This strain level is called the endurance limit. If a pavement structure is designed so that the endurance limit is not exceeded, then that pavement should resist bottom-up fatigue cracking and provide a very long life. This also means that additional pavement thickness, greater than what is required to keep strains below the endurance limit, would not provide additional fatigue life.

The Study

The primary objectives of this study were twofold:

1. Determine if there is an endurance limit for HMA mixes and measure its value for a representative range of mixes, including mixes containing polymer-modified asphalt.
2. Make recommendations for incorporating the endurance limit into mechanistic pavement design methods.

First, the endurance limit was defined in practical, working terms as the strain level that results in a 40-year pavement life. A reasonable maximum number of loading cycles in a 40-year period was determined to be 500 million through highway capacity calculations. Based on recommendations

from SHRP, a shift factor of 10 between lab and field performance was then used to determine a limit of 50-million cycles for laboratory beam fatigue testing. Thus, a mix which provided at least 50-million cycles of fatigue life in the lab would correspond to a pavement that could withstand 500-million load repetitions (a 40-year life) in the field at the corresponding strain level.

Previous research suggests that the endurance limit is roughly 70 micro-strain in the lab and up to about 200 micro-strain in the field. However, laboratory beam fatigue testing is typically conducted between 250 and 750 micro-strain. Since very little fatigue testing has been done at low strain levels, this study was designed to characterize the relationship between strain and number of cycles to failure at very low strain. The two principal means of testing were flexural beam fatigue testing and uniaxial tension testing.

The primary material properties influencing fatigue life are binder content, binder stiffness and air void content. For this study, a 19.0 mm granite mix was tested with both PG 67-22 and SBS-modified PG 76-22 binder. Samples were prepared with each binder at optimum asphalt content (target air voids of 7.0 ± 0.5 percent) and optimum plus 0.7 percent asphalt content (target air voids of 3.3 ± 0.5 percent). During Phase II of the study, samples were also tested with PG 58-22 and PG 64-22 binder.

Beam fatigue testing was performed according to AASHTO T321 in a constant strain mode. Testing was conducted at progressively lower strain levels between 800 and 50 micro-strain. Tests were terminated either at failure (a reduction in stiffness of 50 percent) or at 50 million cycles. Once fatigue life at a given strain level exceeded 50 million cycles, a lower strain level was not tested. During Phase II of the study, a limited round-robin study was conducted between five labs to provide an estimate of variability for beam fatigue testing.

For samples that did not reach failure, an extrapolation procedure was needed to estimate the number of loading cycles corresponding to 50 percent of initial stiffness. Using data from the samples that had fatigue lives between 20- and 50-million cycles, the accuracy of five extrapolation methods was evaluated: exponential model, logarithmic model, single-stage Weibull function, three-stage Weibull function and ratio of dissipated energy change (RDEC). The single- and three-stage Weibull functions were selected for extrapolating fatigue tests that did not fail within 50 million cycles.

Based on these results, an AASHTO Standard Practice for Predicting the Endurance Limit of Hot Mix Asphalt for Long-Life Pavement Design was developed. This draft procedure involves collecting beam fatigue data at both 800 and 400 micro-strain. A log-log extrapolation of the

initial data is then used to predict the endurance limit, and testing is repeated at the predicted strain level to confirm the endurance limit. Since the tests at the predicted endurance limit should not fail, the tests are conducted to a minimum of 12 million cycles and the failure point is extrapolated. The recommended extrapolation method for low-strain fatigue tests is the single-stage Weibull function, which appeared to be the most conservative and also had the least variability in the mini-round-robin study. Terminating low-strain tests at 12-million cycles is much more expedient than testing to 50-million cycles, which requires approximately two months per sample.

Uniaxial tension testing also provided a promising technique for endurance limit determination. While the results were obtained more rapidly than beam fatigue test results, the data analysis was also more complicated. Further study is needed to reconcile differences between beam fatigue and uniaxial fatigue results.

Conclusions

Data from the study supports the existence of an endurance limit for each of the mixes tested. As presented in the proposed AASHTO standard, the lower limit of the 95 percent confidence interval for a fatigue life of 50-million cycles is reasonably close to the endurance limit. This 95 percent prediction limit varied from 75 to 200 micro-strain for the mixes tested. Mixes with stiffer high-temperature binder grades and optimum plus asphalt contents (such as in rich bottom mixes) showed higher endurance limit values.

The instrumented structural sections from the 2003 NCAT Test Track provided an opportunity to evaluate the shift factor between lab and field performance. Eight sections of varying thickness were constructed using the same 19.0 mm base mix that was used in this study. Both PG 67-22 and SBS-modified PG 76-22 binders were used. Fatigue transfer functions were developed and used to calculate shift factors based on measured strain in the field. The calculated shift factors ranged from 4.2 to 75.8.

Finally, the effect of incorporating the endurance limit into mechanistic pavement design methods was analyzed. The following conclusions were drawn:

- Using the endurance limits measured in this study, the thicknesses determined for perpetual (long-life) pavements were consistent with thicknesses observed in previous studies of in-service pavements
- Required pavement thickness determined using the Mechanistic-Empirical Pavement Design Guide (MEPDG) and PerRoad was sensitive to the endurance limit



Strategies for Design and Construction of High-Reflectance Asphalt Pavements (Tran, Powell, Marks, West, and Kvasnak)

Government agencies and private businesses alike are focusing on green construction practices to meet the requirements of the Leadership in Energy and Environmental Design (LEED) certification system. Using cool pavement strategies is an important part of achieving LEED certification for new construction. These strategies aim to reduce the absorption and retention of solar heat, making pavement surface temperatures cooler.

Cool pavement strategies include:

- Shading pavement surfaces with vegetation or other landscape features
- Using porous surface layers, which increase evaporation and air circulation
- Increasing solar reflectivity of the pavement surface

The LEED requirement for solar reflectivity is a solar reflectance index (SRI) of at least 29 percent. SRI represents the surface temperature of a material relative to that of standard white (SRI=100) and standard black (SRI=0) surfaces. Calculation of the SRI is based on the solar reflectance (albedo) and thermal emissivity of a pavement surface. Solar reflectance correlates with color; for example, lighter colors have higher reflectance. Emissivity is a measure of the ability to radiate absorbed heat. A surface with higher reflectance and/or emissivity will have a higher SRI value.

In general, asphalt pavements have low SRI values when first constructed, but the SRI increases over time due



StreetBond coating

to weathering of the binder and increasing exposure of aggregate. In contrast, Portland cement concrete (PCC) pavements have higher SRI values initially, but the SRI decreases over time.

The Study

For this study, the following eight technologies were considered as potential high-reflectance pavement surfaces.

1. Surface gritting using light-colored aggregate
2. Chip seals with light-colored aggregate
3. Sand seals (also known as scrub seals) with light-colored aggregate
4. Shot blasting – provided by Blastrac®
5. Synthetic binder with light-colored aggregate – a natural color of CS-Phalt™ provided by Toda America, Inc.
6. Light-colored surface paint – two shades of StreetBond™ provided by Integrated Paving Concepts, Inc.
7. Micro-surfacing using light-colored materials –E-Krete® provided by PolyCon Manufacturing, Inc.
8. Grouting of open-graded mix with cementitious materials – Densiphalt® produced by Euco Densi, LLC



Shot blasting

Test sections (12-foot square) were constructed to evaluate technologies one through seven. Solar reflectance measurements using a pyrometer were taken at varying times of day over a two-month period. Due to the varying



E-Krete



Chip seals and sand seals

position and angle of the sun, this allowed solar reflectance measurements of different areas within each test section. Cores were also sent to the PRI Construction Materials Technologies Laboratory for testing of solar reflectance and thermal emissivity. SRI values were then calculated according to ASTM E 1980. Data from an existing surface was provided for evaluation of the eighth technology.

Conclusions:

The following conclusions and recommendations were drawn from the results of this study:

- Six of the eight technologies exhibited SRI values of 29 or higher. These include light-colored paint (StreetBond™ by Integrated Paving Concepts), micro-surfacing with light-colored materials (E-Krete® by PolyCon), synthetic binder with light-colored aggregate (CS-Phalt™ by Toda America), Densiphalt® by Euco Densi, chip seals and sand seals using light-colored aggregate.



Synthetic binder

- Another technology, surface gritting using light-colored aggregate, probably would have exhibited SRI values greater than 29 if the aggregate had adhered properly to the asphalt mat. Further investigation of the construction process is needed to make sure the uncoated or lightly-coated aggregate will sufficiently adhere to the mat.
- Solar reflectance values differ based on test method (lab or field), particularly if the surface being tested is rough or irregular. Consequently, calculated SRI values differ (up to 11 percent in this study). The LEED certification system currently allows solar reflectance measurement using either test method.
- Cost comparisons should be made on a case-by-case basis, because construction costs can vary significantly based on project scope, size and location.
- Technology-specific recommendations:
 - StreetBond™ coating and E-Krete® micro-surfacing are applied in a thin layer and do not improve pavement structural capacity. These materials can be used over general-purpose parking lot pavements.
 - Light-colored synthetic binders such as CS-Phalt™ are used in constructing an overlay or a new pavement. The production and paving equipment must be cleaned in advance to preserve the light color of the mix.
 - Densiphalt® can be used to protect against fuel spills and also offers resistance to abrasion and rutting.
 - The durability of sand seals and chip seals in parking lot conditions has not been verified.



Real Time Voids Production Control System Using a Rapid Result Volumetric Test Method

By guest writer: Greg Brouse, Eastern Industries, Inc., Winfield, Pa.

Our industry constantly strives to improve product durability by improving methods of producing, placing and analyzing hot mix asphalt (HMA). The Strategic Highway Research Program (SHRP) was instrumental in researching, developing and introducing many improvements. The Real Time Voids (RTV) system is a byproduct of such work. RTV is a method of quickly determining compacted mixture (G_{mb}) air voids from calculations comparing the specimen weight to its measured gross volume.

Volumetric principles used for many years are still the foundation for building asphalt pavements. In design, production and placement, the void structure is the most critical factor in evaluating the mix. Although every ingredient and parameter has value, all relate to volumetrics in one way or another. RTV utilizes those proven principles to control the mix almost continuously during production. Air voids are calculated at the completion of laboratory compaction using the gyratory height and diameter measurements with the specimen weight. The result is a dependable air void content in eight to 10 minutes from the time of sampling. No additional equipment is needed and very little extra time is required.

The volumetric properties we use to evaluate HMA designs are critical in assuring that the mixture properties are favorable to durability. Volumetric properties can also reveal mix sensitivity to changes in aggregate characteristics or asphalt content. For example, a particular mixture with plenty of voids in the mineral aggregate (VMA) may show minimal changes in air voids when subjected to changes in the amount of material passing the #200 sieve (P200). On the other hand, another mix might demonstrate unacceptable air voids with very little variation in the P200. Regardless of what particular mix component might be responsible for a change in volumetrics, inconsistent air voids during production can make a mix nearly unusable when trying to achieve acceptable field compaction. A change in volumetrics can also indicate that other parameters such as asphalt content or P200 may be approaching acceptance limits.

Here are the basics of how RTV works. A mixture sample is taken from either a truck or prior to the mix silo and immediately compacted to the design number of gyrations (N_{des}). The RTV is calculated using the specimen weight and the height from the gyratory compactor and the maximum specific gravity and relative density adjustment factor from the standard quality control (QC) tests. The following equations are used to calculate RTV.

$$RTV = \frac{Gmm' - Gmb(adj)}{Gmm'} \times 100$$

$$Gmb(adj) = Gmb(gyr) \times AF$$

$$Gmb(gyr) = \frac{Mm \times 4 \times 1000}{\pi d^2 h_x}$$

$$AF = \frac{Gmb'(T166)}{Gmb'(gyr)}$$

Where: <i>RTV</i>	= Real Time Voids
<i>Gmm'</i>	= Gmm from running average of QC tests
<i>Gmb(adj)</i>	= Adjusted Gmb of the RTV specimen
<i>Gmb(gyr)</i>	= Calculated Gmb using gyratory weight and volume
<i>AF</i>	= Relative density adjustment factor
<i>Mm</i>	= Mass of the mix in the gyratory mold (g)
<i>d</i>	= Diameter of the gyratory mold (150 mm)
<i>h_x</i>	= Height of the compacted mix in the gyratory mold (mm)
<i>Gmb'(T166)</i>	= Gmb measured by T 166 from the QC running average
<i>Gmb'(gyr)</i>	= Gmb using gyratory values from the QC running average

The initial values for theoretical maximum specific gravity (Gmm') and the adjustment factor (AF) are based on data from the approved mix design. These values should be changed throughout the production process using a running average of the QC test results. While it is recognized that these values continually change during production, using values from past measurements is a necessary deviation from the standard practice to accomplish the rapid RTV results.

Monitoring RTV values allows the plant technician to quickly examine material consistency throughout production. One thing is certain: if there is a change in the air voids, there is a reason for it. We need to be confident in setting action limits to modify or stop production until control can be reestablished. When we determine that there is a change in mixture voids, we can make adjustments based on experience and plant history long before conventional QC testing for gradation and asphalt content are complete.

Our first use of the refined RTV system was in 2005 on an Interstate highway project. In an effort to assure that the mix would perform well, we targeted a minimum air void action limit of 3.5 percent controlled by RTV. The project went very well, and no extra personnel were needed to provide this control.

In 2007, our company participated in a project that introduced International Standards Organization (ISO) quality assurance practices to highway construction. We

partnered with Pennsylvania DOT to do a process capability study of production and placement techniques on two of the mainline pavement items. As part of a large data collection program, RTV was included to compare with other parameters.

Figure 1. shows some interesting trends from the study. A total of 120 RTV specimens were compacted during 4,291 tons of production, which is an average of about one specimen per 35 tons of material. Note how comparable the RTV test results (blue) are to the actual air voids measured from AASHTO T166 (green) in the first 22 tests. The lengthy specimen preparation for AASHTO T166 and T209 testing to determine the compacted air voids at this high frequency was stopped when the results showed that the RTV values compared reasonably well with the T 166 results. In addition, see how the P200 content (pink) appears to have notable correlation to the RTV. As the P200 decreases, the voids increase.

Figure 2. shows similar trends in the process capability study of the 19 mm binder course. Again, note how comparable the RTV test results (blue) are to the actual air void tests measured using AASHTO T166 (green). Again, a correlation appears to exist between the P200 content (pink) and the RTV. As the P200 decreases, the voids increase.

Certainly, similar comparisons between changes in air voids and changes in other characteristics of the HMA can occur; but regardless of why the air voids are changing, it is surely safe to assume production should not continue until control is established. There is a wealth of information yet to be evaluated in the 2007 process studies, but we

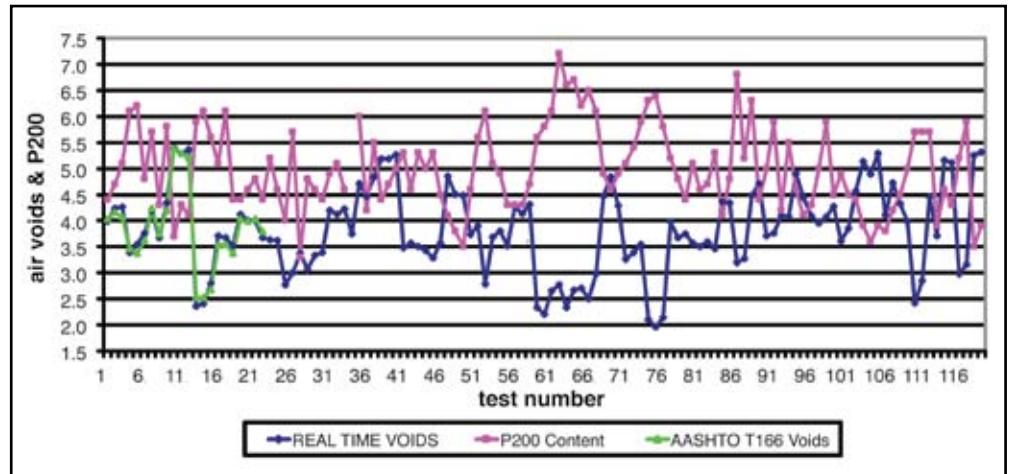


Figure 1. 9.5 mm mix production control chart comparing RTV to percent passing No. 200 sieve

have determined that there is sufficient evidence to support using the RTV system for production control purposes. In the 2007 study alone, production was halted based on the RTV results, and corrections to the plant were made prior to resuming production. Substandard materials were identified and stopped by the producer before they left the plant.

This technique is not that new. Many experienced engineers and technicians have known that lab compaction is a quality indicator during production. RTV is nothing more than an application of that idea – taking a test and turning it into a reliable process control tool. The Superpave system uses this same concept to calculate specimen densities throughout the compaction spectrum (N_{ini} to N_{max}).

RTV focuses on plant production, with the understanding that no matter how hard we try, the very best in delivery and placement practices can do no more than mirror the consistency with which the mixture is produced. Only after we achieve confident real-time control of production can we even begin to overcome the challenges in achieving true optimum roadway compaction.

Using the RTV system may change the future of HMA quality control and could be a building block for a complete control system that will analyze all mixture properties and eventually lead to uniform placement and densification control as well.

Gregory Brouse is a process and quality control manager for Eastern Industries, Inc. in Winfield, Pa., a subsidiary of the New Enterprise Lime and Stone Company. He has over 34 years of experience in production and control of HMA and has been instrumental in trying to bridge the gap between specifications and practicality in the state of Pennsylvania.

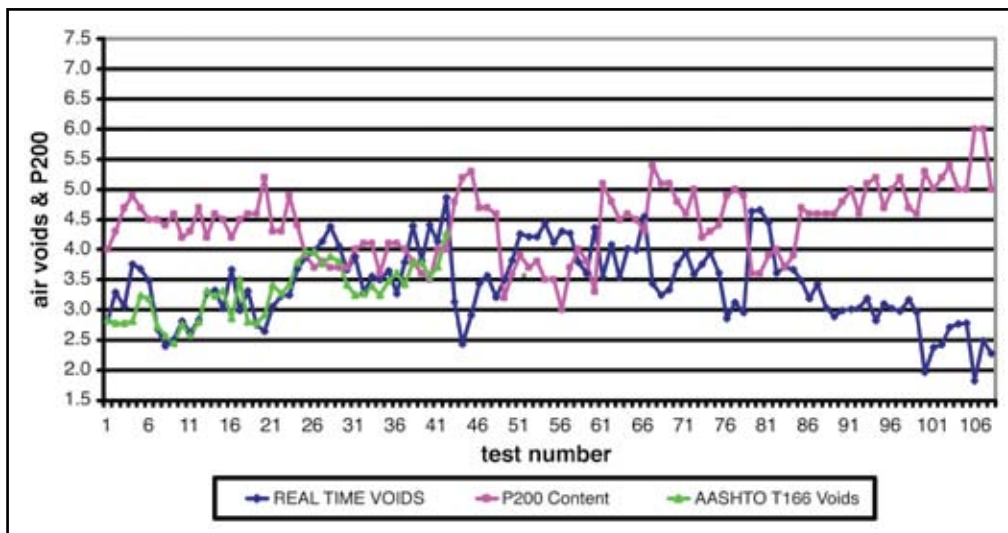


Figure 2. 19 mm mix production control chart comparing RTV to percent passing No. 200 sieve

NCAT Training Opportunities

NCAT offers a variety of training opportunities to fit your needs and workshops can be conducted at your facilities. By scheduling a workshop on-site, agencies and contractors can make the most efficient use of their training budget while complying with imposed travel restrictions. Workshops can also be custom-tailored to fit the technical needs of your personnel.

For example, NCAT recently held a Superpave Mix Design course for Utah DOT at their lab facilities in Salt Lake City, for 12 of their bituminous personnel. The workshop materials were custom-tailored to include UDOT specifications and test procedures. A workshop certification exam was given at the conclusion of the course. Similar workshops have been given at Georgia DOT, Louisiana DOT and at a private testing lab facility in Vancouver, Canada.

Dates and Location:

These courses can be conducted on-site at an agency or contractor's facilities, at a time suitable for your convenience.

Let NCAT help you with your training needs: To obtain more information on training, visit our website: www.ncat.us or call Linda Kerr at 334.844.7308 or Don Watson at 334.844.7306.

2009 Superpave Mix Design Course Participants



A Superpave Mix Design Workshop was held at the NCAT facilities in Auburn, Alabama, on March 23-26, 2009. Participants came from five states across the country, as well as the Sultanate of Oman.

New Faces at NCAT



Dr. Alessandra Bianchini joined NCAT as a lead research engineer in January 2008. She earned her master's degree in civil engineering from the University of Udine (Italy) in 1998. Her subsequent work at Aviano Air Force Base in Italy included the design and oversight of airfield maintenance projects. In 2007, she earned her doctoral degree from New

Mexico State University, where her doctoral dissertation research focused on pavement performance prediction using a neural network approach. While working on her doctorate degree, she also taught an undergraduate class on pavement analysis and design. Alessandra is a registered professional engineer in New Mexico. At NCAT, her research includes tire/pavement noise analysis, pavement texture characteristics and pavement performance.



Blaine Guidry joined NCAT in September 2008 as an assistant research engineer with primary responsibilities being assisting with test track operations. Blaine received his bachelor's degree in civil engineering from Auburn University in 2004. Prior to joining NCAT, he worked as an assistant aggregate engineer with the Alabama

Department of Transportation Materials and Tests Bureau in Montgomery.



Dr. Jaeseung Kim joined NCAT as a lead research engineer in October 2008. His education includes a bachelor's degree in civil engineering from Myongji University in South Korea in 1999, as well as master's and doctoral degrees from the University of Florida in 2002 and 2005, respectively. His doctoral dissertation research concentrated

on the concept of energy dissipation related to asphalt pavement cracking. He also taught several materials and pavement analysis courses at the University of Florida. After completing his doctorate, he worked as an engineer with the Florida DOT. At NCAT, his research includes laboratory performance testing and fundamental engineering properties of asphalt materials, as well as thermal analyses of pavements.



Grant Julian is an assistant research engineer. Although Grant began working as a full-time employee at NCAT in January 2008, he was very familiar with NCAT because he has worked as a co-op student since 2003. Grant received his bachelor's degree in civil engineering from Auburn University in 2007. He is currently working on a master's degree, and

his master's thesis research will focus on bond strength of asphalt pavement layers. His specialties include mix design and field testing. He also manages the mobile lab, which was used to conduct on-site testing for various warm-mix projects in Texas and Nebraska last summer.



Adam Taylor is also a new assistant research engineer, joining NCAT as a full-time employee in July 2008. He obtained both bachelor's and master's degrees in civil engineering from Auburn University in 2006 and 2008, respectively. His master's thesis research concentrated on the mechanistic characterization of unbound materials. Adam also

worked as a co-op student at NCAT while pursuing his undergraduate degree. Currently he is involved with performance testing and aggregate specific gravity testing as well as research on the effects of mixture additives.



Dr. Richard Willis recently joined NCAT as a post-doctoral fellow. He received a bachelor of science degree from Freed-Hardeman University in 2002, a bachelor's degree in civil engineering from Auburn University in 2004, as well as a master's and doctorate from Auburn in 2005 and 2008, respectively. Richard's master's thesis was on statistical

analysis of HMA quality assurance data, and his doctoral dissertation was on field-based measurement and analysis of pavement strains to determine fatigue thresholds. Richard has taught civil engineering materials labs for several semesters and has been the coordinator for the Consortium of Accelerated Pavement Testers. His current focus is on design and lab performance testing of asphalt mixtures for the next cycle of the test track.



The winner of the Smooth Rider custom chopper, raffled off by the National Asphalt Pavement Association's Associate Members, was Brennan Brothers Contracting in Old Bridge, New Jersey. The drawing was held at the 2009 World of Asphalt Show and Conference in March 2009. Mike Brennan with Brennan Brothers is shown with the bike (upper-right photo). Proceeds from the sale of the raffle tickets for this motorcycle went to benefit the equipment needs for the National Center for Asphalt Technology.

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