

# ASPHALT TECHNOLOGY NEWS

A Publication of the National Center for Asphalt Technology, Auburn University

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## PRACTICAL RESEARCH PROJECTS UNDERWAY AT NCAT

Since its inception in 1986, the National Center for Asphalt Technology (NCAT) has been engaged in conducting practical research which can be applied to practice by the hot mix asphalt (HMA) industry. Over the years, the number of NCAT research projects has increased steadily. Projects have been sponsored by the NAPA Research and Education



*Loading of the NCAT Test Track with tractor/trailers*

Foundation, NAPA, Asphalt Paving Alliance, Strategic Highway Research Program, National Cooperative Highway Research Program (NCHRP), the Federal Highway Administration, the South-east Superpave Center, the Alabama Department of Transportation, and other state highway departments of transportation.

The following is a brief description of several research projects underway at NCAT:

- **NCAT Test Track**

The NCAT Test Track is the largest research project underway at NCAT. The 1.7-mile oval test track was completed in August 2000 and loading began in September. Its construction, loading, and performance has been described in the past issues of the Asphalt Technology News (see previous issues on the NCAT web site).

The Test Track, consisting of 26 test sections on the tangents and 20 test sections on the curves, will be subjected to 10 million ESALs over a period of two years. About 8.3 million ESALs have been applied by the end of August this year.

The following are specific mix attributes whose rutting (permanent deformation) performance will be compared on the Test Track.

- Coarse-graded, fine-graded and through the restricted zone gradation of Superpave mixes
- Neat versus modified asphalt binder at optimum asphalt binder at optimum asphalt content as well as optimum plus 0.5 percent
- Stone matrix asphalt (SMA) versus Superpave mix using granite aggregate
- 12.5 mm versus 9.5 mm nominal maximum size Superpave designed

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mixes

The mixtures have been tested by various laboratory performance tests which will be correlated with actual field performance to determine the best test method(s) for predicting rutting performance. The rut depth developed so far in the test sections ranges from 0.5 to 6.2 mm.

It is expected that the Test Track will be subjected to the target of 10 million ESALs in November this year. The final research results will be presented at the National Transportation Symposium to be held on November 13 and 14 this year at Auburn University Hotel and Dixon Conference Center (see announcement elsewhere in this newsletter).

- **NCHRP 9-9(1) Verification of the Gyration Levels in the  $N_{design}$  Table**

The objective of this study is to verify the revised  $N_{design}$  gyrations levels by comparing field densification of in-service pavements with the densification of samples of the same mix tested in the Superpave gyratory compactor. According to the test plan 40 HMA paving projects from various regions around the country have been visited, samples taken, and tested in the field. NCAT has a mobile (trailer) testing laboratory which



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**E. Ray Brown, Director**  
**Prithvi (Ken) Kandhal, Associate Director Emeritus/ Editor**  
**James S. Killian III, Associate Editor, College of Engineering**

has been used for such projects. For each project, samples are taken initially for laboratory compaction and determination of initial in-place air voids. In-place core samples continue to be taken at three months, six months, one year, and two years to evaluate densification under traffic.

- **NCHRP 9-27 Relationships of In-Place Voids, Lift Thickness and Permeability**

The objectives of this study are: (a) determine the in-place air voids needed to achieve an essentially impermeable and durable pavement, (b) determine the minimum lift thickness needed for desirable pavement density levels to be achievable, and thus impermeable pavements, and (c) recommend improvements to AASHTO T166 to achieve a more precise, uniform, and accurate determination of bulk specific gravity for compacted HMA mixtures.

- **NCHRP 9-17 Accelerated Laboratory Rutting Tests**

The objectives of this study are: (a) evaluate the Asphalt Pavement Analyzer to determine its suitability as a general method of predicting rutting potential and (b) compare its effectiveness with other loaded wheel testers and the simple HMA strength test being developed in another NCHRP project.

- **NCHRP Idea 73 Project**

The objective of this project is to develop a prototype infrared sensor bar (mounted on the paver), the GPS system and the data acquisitions software so that the temperature of the mat just behind the screed is obtained and recorded in real time.

- **Analysis of Perpetual HMA Pavement Concept**

The objective of this project is to formulate a national method for the structural design of perpetual HMA pavements. Current work is assessing the mechanistic response of perpetual-type pavements. The end result of this research will be a design program that will consider materials, traffic, and reliability level in the design of perpetual pavements.

- **Corelok Round Robin**

It is very difficult to obtain an accurate measurement of the bulk specific gravity ( $G_{mb}$ ) of compacted HMA mixtures which comprise coarse-graded mixtures, SMA mixtures, and open-graded friction course mixtures. It is a major concern facing the HMA industry, because  $G_{mb}$  measurements are the basis for volumetric calculations during the mix design and construction. Preliminary studies by NCAT have indicated the



*NCAT's mobile testing laboratory is used for testing in the field*

Corelok vacuum-sealing device to be promising for measuring the  $G_{mb}$  of compacted coarse mixtures. However, it is important to establish the repeatability and reproducibility of this device through a round robin study.

- **Refinement and Validation of a New-Generation Open-Graded Friction Course Mix Design Procedure**

This is a pooled-fund study being conducted in cooperation with 13 participating states across the country. The objective of this study is to refine and validate a new-generation OGFC mix design procedure developed by NCAT (see NCAT Report 00-01).

- **Bulk Specific Gravity of Fine Aggregate**

The bulk specific gravity value is used in calculating the voids in the mineral aggregate (VMA) and the fine aggregate angularity. The current method of determining the bulk specific gravity of fine aggregate (AASHTO T84 or ASTM C128) uses a cone and tamp to determine the saturated surface dry (SSD) condition of the fine aggregate. This method does not work well when determining the SSD condition of angular or rough textured fine aggregates because they do not readily slump. NCAT developed a prototype test equipment to establish the SSD condition based on relative humidity of the outgoing air when a wet fine aggregate is placed in a rotating drum and is subjected to drying by warm air blown into the drum. Three companies are now engaged in building a commercial version to determine the bulk specific gravity using different approaches. Their final test equipment will be evaluated by NCAT.

- **Development of a Workability Device for HMA Mixtures**

Prior to Superpave, the mixing and compaction temperatures of dense-graded HMA mixtures were established based on neat asphalt binder viscosity.

However, things have changed now. Relatively coarser gradations in Superpave, use of gap-graded stone matrix asphalt, and use of polymer-modified asphalt binder do not allow one to rely on the neat binder viscosity to establish the mixing temperature. There is a need to develop a device to quantify the workability of HMA mixtures and establish the mixing temperature based on a threshold workability value. NCAT has developed a prototype workability device which is sensitive to mix gradation, aggregate type, binder grade, and modifiers. The evaluation of this device is continuing.

- **Development of Mix Design Criteria for 4.75 mm Nominal Maximum Aggregate Size (NMAS) Mixes**

The objective of this study is to develop mix design criteria for 4.75 mm NMAS mixes, such as gradation controls (including dust-to-asphalt ratio) and volumetric property requirements such as air voids, VMA, and VFA. There is a scope for smaller NMAS mixes which can be used for low-volume roads and streets and parking lots.

- **Measurements of Noise in HMA Pavements**

Traffic noise is a serious problem. In many areas of the United States, large noise barrier walls are being constructed at the cost of up to one million dollars per roadway mile. In the case of automobiles traveling at high speeds, the pavement noise from tire/pavement interaction is the dominant noise source. Therefore, if quiet pavement surfaces can be developed a significant reduction in roadside noise can be achieved. However, there is a need for accurately measuring the noise characteristics of various road surfaces. NCAT in cooperation with the Arizona Department of Transportation and the California Department of Transportation has built a prototype noise measuring device mounted on a trailer, which will be used to test different pavement surfaces' noise generation characteristics.

- **Review of Performance of SMA and Superpave Projects**

A few years ago NCAT had evaluated the field performance of several SMA and Superpave projects throughout the United States. At that time most of the projects were relatively new. The purpose of this project is to reevaluate the pavements after they have been in service for several more years so that long-term pavement performance can be determined. A total of 11 SMA projects and 18 Superpave projects located in five states—Colorado, Indiana, Wisconsin, Virginia, and Maryland—have been visited to evaluate their long-term

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performance.

- **Study of Gyration Angle in Superpave Gyrotory Compactors**

The objective of this project sponsored by the Alabama Department of Transportation is to measure the internal angle of all Superpave gyrotory compactors (SGC) in the state of Alabama using the FHWA's Dynamic Angle Validation (DAV) kit. The DAV device is placed inside of the SGC mold with loose HMA mix. It measures the angle of gyration seen by the sample during actual compaction, unlike measurement of the gyration angle externally. This will allow the development of a relationship between sample density and internal angle of gyration. To date all 121 SGC of different makes have been tested and data analysis is underway.

- **Refinement of Ignition Method for Mixtures Containing Certain Dolomitic Aggregates**

Asphalt content of HMA samples tested in the ignition oven is determined from the difference between the initial mass of the HMA sample and the mass of residual aggregate corrected for aggregate loss (calibration factor). The ignition test is continued until a constant sample mass is achieved. However, certain dolomitic aggregates continue to lose mass at an excessive rate even after all of the asphalt binder is burnt off and, therefore, do not reach an end point. It is difficult to use the ignition test when the HMA consists of such aggregates. Alabama, Indiana, Iowa, Missouri, and Ontario have all experienced problems with this phenomenon. This project is investigating potential solutions to reduce aggregate loss during testing of mixtures containing such aggregates.

- **Evaluation of Infrared Ignition Oven for Asphalt Content**

The conventional ignition oven was developed by NCAT in the mid 1990s and is now used worldwide. An ignition oven based on infrared mode of heating has been developed by a manufacturer. This project was undertaken to evaluate the infrared ignition oven in comparison to the conventional ignition oven.

- **Evaluation of Lateral Pressure Indicator to Predict HMA Mixture Performance**

Lateral pressure indicator (LPI) was recently developed as a means of evaluating the resistance to permanent deformation of an HMA mixture. The LPI consists of an SGC compaction mold with two square holes cut out on opposite sides of the mold. A steel plate slightly smaller than the hole rests against the HMA



*Chuck VanDeusen (right), chairman of NCAT Applications Steering Committee, and Ray Brown, NCAT director, reviewing the meeting agenda. The committee met in July.*

mix during compaction. The steel plate is attached to a load cell that measures the lateral force during compaction. By dividing the lateral force by the area of the plate, the lateral pressure can be determined.

The resistance to permanent deformation of an HMA mixture is related to the cohesion and internal frictional resistance of the mixture. It is hypothesized that the lateral pressure indicates the overall strength of the HMA mixture being compacted. For example, a rounded aggregate mix may generate a greater lateral pressure compared to a crushed aggregate mix.

This project will study a variety of mix variables (such as aggregate type, gradation, binder grade, and asphalt content) to evaluate the potential of LPI for measuring the HMA mix strength.

- **Superpave Center Research Projects**

Several research projects sponsored by the states supporting the Southeast Superpave Center are also in progress. For example, one project is evaluating the effectiveness of different tack coat materials (the first step was to develop a bond test) and application rates, and another project is collecting Micro-Deval abrasion test data for aggregate sources on a regional basis.

On completion of practical research projects, NCAT researchers prepare a draft final report which is reviewed by the members of the NCAT Applications Steering Committee. The final report is then published and is also posted on the NCAT web site <[www.eng.auburn.edu/center/ncat](http://www.eng.auburn.edu/center/ncat)>. These practical research reports can be downloaded free of charge from the NCAT web site by the HMA industry, government agencies, and academia throughout the world. At the present time 78 research reports are available on the NCAT web site.

## BRIAN PROWELL APPOINTED NCAT ASSISTANT DIRECTOR

Brian Prowell was recently appointed as assistant director of NCAT. He received his B.S. from Penn State in 1990, M.S. from Virginia Tech in 1992, and is currently working toward his Ph.D. at Auburn University. Prior to joining NCAT, Mr. Prowell worked as a senior research scientist for Virginia Transportation Research Council (VTRC).



*Brian Prowell*

Prowell has conducted research on aggregate properties, asphalt content determination, pavement density and permeability, performance graded (PG) binders, recycling, rut testing, SMA, Superpave mix design, and testing variability. Brian developed a state-of-the-art binder laboratory for VTRC and oversaw Virginia DOT's PG binder testing program. He was the lead implementation engineer for Superpave in Virginia. He also performed troubleshooting and forensic testing for Virginia DOT.

Brian Prowell is a member of the Association of Asphalt Paving Technologists, ASTM Committee D04, and TRB committee A2D02. He is a registered professional engineer in Virginia.

## INTERNATIONAL SYMPOSIUM ON LONG-LASTING ASPHALT PAVEMENTS

An international symposium on Design and Construction of Long-Lasting Asphalt Pavements will be held in Auburn, Alabama June 7-9, 2004. The International Society for Asphalt Pavements (ISAP) is the primary sponsor of this specialty conference. The National Center for Asphalt Technology (NCAT) will

host the conference in Auburn, Alabama (100 miles southwest of Atlanta, Georgia). The conference is also co-sponsored by the Federal Highway Administration, the National Asphalt Pavement Association, and the Alabama DOT.

The objective of this conference will be to address materials, mix design, and construction procedures to ensure long-lasting (perpetual) asphalt pavements. Topics will include: perpetual pavement design, materials and mix design, quality control/quality assurance, construction issues, contracting methods, and other related subjects.

Abstracts (300 words or less) of potential papers can be sent to Dr. E. Ray Brown by email at <rbrown@eng.auburn.edu> and must be received by June 1, 2003.

For additional information concerning the conference, contact Ms. Carol Tapley at <ctapley@eng.auburn.edu> or call (334) 844-6228.

## PERPETUAL PAVEMENT TASK GROUP MEETS AT NCAT

The first meeting of the Perpetual HMA Pavement Task Group was held at NCAT on July 11 this year. Ten members who represented industry, government, and academia attended it.

There was general agreement that there is sufficient anecdotal evidence supporting perpetual HMA pavements. There is a need to address the following issues:

- Impact of perpetual pavements on life cycle cost analysis
- Impact of perpetual pavements on user delay costs
- More data supporting the limiting strain criteria
- Development of construction guidelines

David Timm and Andrew Brooks gave an overview of the current perpetual pavement research at NCAT.

They presented preliminary results regarding stress analysis of perpetual pavements. The results showed the need to evaluate each layer (course) of the perpetual pavement, rather than only considering the bottom-most layer. A prototype of the structural design program is expected early next year.

The next meeting of the task group is tentatively scheduled for December this year.



*Attendees of the meeting of the Task Group on Perpetual Pavement*

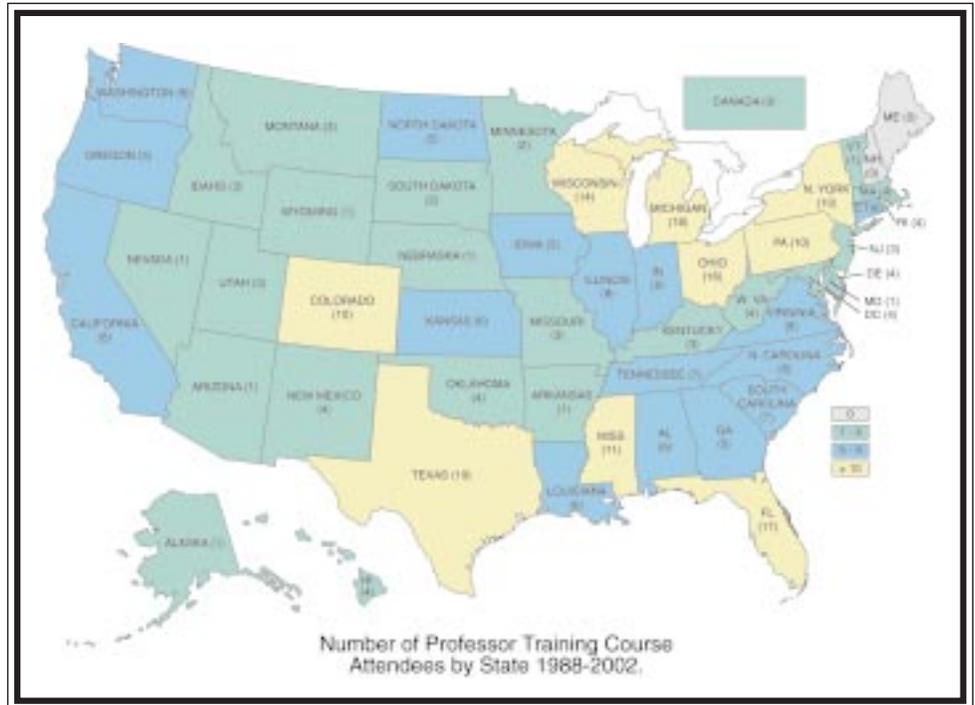
## PROFESSOR TRAINING COURSE IN ASPHALT TECHNOLOGY

Shortly after its inception, the National Center for Asphalt Technology began a program specifically designed to educate college level instructors and professors in the fundamentals of hot mix asphalt (HMA) technology. Known as the Professor Training Course, this training program encourages and facilitates the educators to include HMA technology in civil engineering curriculum of their colleges and universities, and teach this technology effectively to the incoming engineers. This course has also helped the professors in conducting asphalt-related research at the state and national levels.

The Professor Training Course has been offered once each summer since 1988. Including the summer of 2002, 299 participants have attended this course during the last 14 years. The geographical distribution of attendees covers 48 states and Canada, as shown on the U.S. map. Over 80 percent of the attendees

were from four-year state-supported universities. Attendees from U.S. educational institutions do not pay any fee for the course. Their travel and living expenses are offset through funds raised by the NAPA Hotmixers and some state asphalt pavement associations. The cost to conduct the course is paid by the NAPA Research and Education Foundation.

The Professor Training Course is the only program of its kind in the nation and has been a great success.



### NCAT's Asphalt Technology Course, March 11-15, 2002



**Front Row, L-R:** Mike McAndrews, Ray Porter, Rick Richter, Dennis Dickey, Shanda Jensen

**Back Row, L-R:** Jim Hewston, Joe LaHeist, Dave Bolden, Scott Weege, Jason Jurgenson, Brian Prowell (instructor)

## PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of the Association of Asphalt Paving Technologists (AAPT) held in Colorado Springs, Colorado 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 papers are given, with names of authors in parentheses, followed by a brief summary.

### 1. ISSUES PERTAINING TO THE PERMEABILITY CHARACTERISTICS OF COARSE-GRADED SUPERPAVE MIXES (Cooley, Prowell, and Brown)

Studies conducted by the Florida Department of Transportation have indicated that coarse-graded Superpave mixtures can be excessively permeable to water at in-place air voids less than 8 percent. Numerous factors including the lift thickness can affect the permeability of HMA. This study was undertaken to evaluate the relationships between in-place air voids, lift thickness, and permeability. As highway agencies begin to include permeability specifications, mix designers need tools that can be used during the mix design process to evaluate the permeability characteristics of a given aggregate structure.

Twenty-three on-going HMA construction projects were visited and field permeability tests conducted. Field permeability tests were conducted at 15 randomly determined sites for each project using the NCAT permeability device. Cores were taken at each of the 15 locations to determine pavement density using AASHTO T166. In addition, for some of the projects, the cores were tested with the Corelok device and a laboratory permeameter. The laboratory permeameter is essentially the second generation of the device developed by the Florida DOT and is commercially available.

The common thread between all 23 projects was that mix from each project was designed using Superpave protocols and that the gradations of each mix passed below the maximum density line at the 2.36 mm (No. 8) sieve. For the purposes of this study, coarse-graded Superpave gradations were defined as gradations passing below the Superpave defined maximum density line at the 2.36 mm (No. 8) sieve.

Four different nominal maximum aggregate sizes

(NMASs) were investigated: 9.5, 12.5, 19.0, and 25.0 mm. Design compactive efforts ( $N_{\text{design}}$ ) ranged from a low of 65 to a high of 125 gyrations with a Superpave gyratory compactor.

Based upon the data accumulated in this study and the analyses of the data, the following conclusions were drawn:

- Permeability, whether field or laboratory, is related to the density of coarse-graded Superpave mixes.
- Coarse-graded Superpave mixes having nominal maximum aggregate sizes of 9.5 and 12.5 mm have similar permeability characteristics.
- The nominal maximum aggregate size of the mix affects the permeability characteristics of a pavement. Mixes having larger nominal maximum aggregate sizes have more potential for high permeability than mixes of smaller nominal maximum aggregate sizes, at the same air void level.
- At permeability values within the typically specified region for a pavement, the field and laboratory permeability test methods provide approximately similar results.
- There is a relationship between in-place density, lift thickness, and permeability. As density increases, permeability decreases. As lift thickness increases, permeability decreases.

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### A SHORT COURSE IN ASPHALT TECHNOLOGY

This training course has been developed by NCAT for practicing engineers who are involved with hot mix asphalt (HMA). The purpose of this one-week intensive course, which will be held on February 3-7, 2003 and March 3-7, 2003, is to provide a general understanding of all phases of HMA technology. Upon completion, the participant will be able to make knowledgeable decisions related to HMA pavements and communicate effectively with asphalt specialists when the need arises. NCAT will accept applications from practicing engineers from both private and public sectors in the United States and abroad. This includes personnel from the FHWA, state DOTs, FAA, Corps of Engineers, Air Force, Navy, county engineers, city engineers, consulting engineers, and contractors. Please call (334) 844-6228 ext. 110 or visit our web site at <http://www.eng.auburn.edu/center/ncat> (Click on "Education" at the top of the page, then click on "Upcoming Training Courses") for a brochure or information.

## SUPERPAVE MIX DESIGN WORKSHOP

Superpave mix design workshop will be held at NCAT on February 18-21, 2003. 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.

Please call (334) 844-NCAT (6228) or visit our web site at <<http://www.eng.auburn.edu/center/ncat>> (Click on "Education" at the top of the page, then click on "Upcoming Training Courses") for a brochure or information.

- A reasonable relationship was determined between water absorption during AASHTO T-166 and water permeable voids from Corelok testing and permeability results (both field and laboratory). This may be used as a quick screening test to identify pavements that may be permeable.
- Some reasonable relationships were found between the permeability of laboratory compacted samples and field permeability. These relationships suggest that a mix designer may be able to evaluate the permeability potential of a mix during mix design. Also, a mix designer may be able to compare the permeability potential of different mix designs for a given project.

## 2. SUPERPAVE FOR LOW-VOLUME ROADS AND BASE MIXTURES (Prowell and Haddock)

During the Strategic Highway Research Program (SHRP) little research was conducted for low-volume surface mixtures or base mixtures. The  $N_{\text{design}}$  gyrations were developed based on tests of roads subjected to medium or heavy traffic and extrapolated for low-volume roads. Some studies have shown the recommended design gyrations of the Superpave gyratory compactor (SGC) may be too high for low-volume roads.

The Virginia Department of Transportation (VDOT) has been satisfied with the performance of existing Marshall designed SM-1 (a sand mixture for resurfacing low-volume subdivision roadways) and BM-2 (25 mm NMA base) mixtures. Typically, 50 blows were applied to a 4-inch diameter specimen for designing the mixtures for low-volume roads and the optimum asphalt content was selected at 6 percent air voids (a majority of states select at 4 percent air voids).

In considering the change over from Marshall to

Superpave design method, there were concerns that the compactive effort in the Superpave may be too high for these mixtures, resulting in lower asphalt contents which in turn may result in poor durability. There were also concerns about drastic changes in gradation, which may result from liberal gradation controls in Superpave.

The purpose of this study was to evaluate VDOT's existing subdivision and base mixtures using the Superpave mix design system and determine the necessary criteria under Superpave to continue to receive comparable Marshall designed mixtures.

Production samples of four SM-1 mixture designs and eight BM-2 mixture designs were collected. The samples were compacted and tested using both Marshall and Superpave criteria. Various SGC compaction levels were used, including stopping at both  $N_{\text{design}}$  and  $N_{\text{max}}$ . Beam specimens of all mixtures were also tested for rutting using the Asphalt Pavement Analyzer (APA).

While the conclusions and recommendations made as follows are applicable to Virginia, they may provide guidance to other states that have similar materials or use similar methodologies to evaluate mixtures with good performance histories.

- SM-1 mixture for subdivision roads may be designed within the Superpave gradation bands for a 9.5-mm mixture. However, the Superpave 9.5 mm gradation bands allow unacceptably coarse mixtures for subdivisions. Changing the minimum requirement for the percent passing the 2.36-mm (#8) sieve from 32 to 47 percent would produce an acceptable mixture.
- SM-1 samples compacted to  $N_{\text{design}} = 68$  gyrations produced similar design binder contents to a 50-blow Marshall with the optimum binder content selected at 6 percent VTM. It is recommended to use  $N_{\text{design}} = 65$ .
- Superpave VFA criteria, for less than 1 million ESALs, appear to be too restrictive for production of SM-1 mixtures. Superpave  $N_{\text{initial}}$  and  $N_{\text{max}}$  criteria appear to be appropriate for SM-1.

## DOWNLOAD NCAT RESEARCH REPORTS AT NO COST

Over 75 NCAT research reports are now available as PDF (portable document format) files which can be easily downloaded at no cost from our web site. You will need the Adobe Acrobat Reader, which can also be downloaded free from our homepage, to open these files. Visit our web site at <http://www.eng.auburn.edu/center/ncat> and click on **NCAT Publications**. Previous editions of **Asphalt Technology News** are also available from our homepage.

- Superpave fines to effective binder content criteria appear to be too restrictive for an SM-1 type mixture. Fines are desired to reduce VMA and increase binder stiffness. Increase the maximum fines to effective binder ratio to 1.3.
- Based on Asphalt Pavement Analyzer testing, VDOT's SM-1 mixtures appear to be rut resistant, generally meeting VDOT's requirements for 3-10 million ESALs. Therefore, SM-1 mixtures may historically have been under-asphalted. Additional binder would improve durability. Rutting should not be a problem under such low traffic conditions.
- VDOT's BM-2 NMA mixtures were historically designed on the fine side of the Superpave 25.0 mm NMA maximum density line. Some BM-2 mixtures actually qualify as Superpave 19.0 mm mixtures.
- Use  $N_{design} = 65$  for base mixtures which will produce mixtures comparable to Marshall mixtures.

[Editor: Please review "Asphalt Forum" and "Specification Corner" in this newsletter; some states are using  $N_{design} = 50$  for low-volume roads.]

### 3. INVESTIGATION OF THE RESTRICTED ZONE IN THE SUPERPAVE AGGREGATE GRADATION SPECIFICATION (Kandhal and Cooley, Jr.)

The recommended aggregate specification for Superpave hot mix asphalt (HMA) mixtures includes a restricted zone which lies along the maximum density gradation between the intermediate size (either 4.75 or 2.36 mm, depending on the nominal maximum size of the aggregate) and the 300  $\mu$ m size. The restricted zone forms a band through which gradations were recommended not to pass. The restricted zone requirement was adopted in Superpave to help reduce the incidence of tender or rut-prone HMA mixes.

According to many asphalt paving technologists, compliance with the restricted zone criteria may not be desirable or necessary to produce paving mixes that give good performance. Some highway agencies and suppliers can provide examples of aggregate gradations that pass through the restricted zone, but produce paving mixes that have historically performed well.

This research project was undertaken to evaluate the effect of the Superpave restricted zone on permanent deformation of dense-graded HMA mixtures. Its primary objective was to determine under what conditions, if any, compliance with the restricted zone requirement is necessary when all the other Superpave requirements such as fine aggregate angularity (FAA) and volumetric mix criteria are met for the specific project.

The following factors were evaluated: two coarse

aggregates, ten fine aggregates (ranging in fine aggregate angularity from 38.6 to 50.3), two nominal maximum aggregate size mixes (9.5 and 19.0 mm), five aggregate gradations, and three compactive efforts ( $N_{design} = 75, 100, \text{ and } 125$ ). Of the five gradations used, three violate the restricted zone and two fall outside of the restricted zone (control) as follows:

- Control gradation above restricted zone (ARZ)
- Control gradation below restricted zone (BRZ)
- Violating gradation straight through restricted zone (TRZ)
- Violating gradation humped through restricted zone (HRZ)
- Violating gradation crossing over through restricted zone (CRZ)

Permanent deformation characteristics of mixes meeting Superpave volumetric requirements were evaluated by two different types of tests: empirical and fundamental. For the empirical test, the Asphalt Pavement Analyzer was used. The Superpave shear tester and a repeated load confined creep test were utilized as fundamental tests. Test results from the three mechanical tests were analyzed statistically to evaluate the effect of the five gradations on permanent deformation of the HMA mixtures.

The following conclusions were drawn and recommendations made from this research project.

- Mixes meeting Superpave and FAA requirements with gradations that violated the restricted zone performed similarly to or better than the mixes having gradations passing outside the restricted zone.
- The restricted zone requirement is redundant for

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## NATIONAL TRANSPORTATION SYMPOSIUM

The National Center for Asphalt Technology invites you to attend and participate in a National Transportation Symposium to be held on November 13 and 14, 2002 at Auburn University Hotel and Dixon Conference Center. This two-day symposium will feature research results (concept to performance) from the first loading cycle at the 1.7-mile NCAT Test Track—the most advanced and comprehensive facility of its kind in the world.

The program will begin at 1 pm on November 13 (Wednesday) and end at noon on November 14 (Thursday). Registration fee is \$50 per person. Please call Carol Tapley at (334) 844-6228 or email <ctapley@eng.auburn.edu> for registration and details.

## RESEARCH IN PROGRESS

We have discontinued the publication of this column in this newsletter because it can now be accessed on NCAT's homepage (<http://www.eng.auburn.edu/center/ncat>). 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.

mixes meeting all Superpave volumetric parameters and the required fine aggregate angularity (FAA). References to the restricted zone as either requirement or a guideline should be deleted from the AASHTO specifications and practice for Superpave volumetric design for HMA regardless of NMAS or traffic level.

- Although not germane to the primary objective of this project, the following observations were made:
  - Coarse aggregate type has a significant effect on VMA of mixes. Coarse, angular granite aggregate generally produced higher VMA than the coarse, crushed gravel aggregate.
  - Coarse aggregate type has a significant effect on the  $%G_{mm}@N_{ini}$  values. However, fine aggregate type and gradation type appear to have a more significant effect.
  - ARZ and CRZ gradations tend to provide higher VMA values while the TRZ gradation provided the lowest VMA values.
  - The TRZ gradations generally provide the lowest VMA values for both the 9.5 and 19.0 mm NMAS mixes. This suggests that the maximum density line drawn according to the Superpave guidelines (connecting the origin of the 0.45 power chart to the 100 percent passing the maximum aggregate size) is reasonably located on the gradation chart.
  - Relatively finer gradation mixes (such as ARZ and HRZ) tend to have higher  $%G_{mm}@N_{ini}$  values compared to TRZ, CRZ, and BRZ mixes.
  - High FAA values do not necessarily produce high VMA in mixes although there was a general trend of increasing VMA values for increasing FAA.
  - Higher FAA values generally produced lower  $%G_{mm}@N_{ini}$  values. None of the mixes having a FAA value lower than 45 met the

$%G_{mm}@N_{ini}$  requirements of 89 percent and lower for the mixes prepared at  $N_{design}=100$  and 125. This indicates high FAA values contribute to a stiffer fine aggregate/asphalt component in HMA at initial compaction levels.

- None of the mixes failed the  $%G_{mm}@N_{maximum}$  requirement of 98 percent maximum. In the future, the validity of this requirement should be examined.
- Numerous mix designs in this study exceeded the maximum VFA requirement of 75 percent. The Superpave requirement of 65.0 to 75.0 percent for VFA effectively limits the VMA of 9.5 mm NMAS mixes to a narrow range. Both VMA and VFA requirements for 9.5 mm NMAS Superpave mix design need to be evaluated.
- The potential of mixes failing due to excessive VMA (more than 2 percent above the minimum specified value) increases with a lower design compactive effort, angular coarse aggregate content, and high FAA values.
- Both the Asphalt Pavement Analyzer and the repeated load confined creep test were reasonably sensitive to the gradation of mixes. The repeated shear at constant height test conducted with the Superpave shear tester was not found to be as sensitive to changes in gradation.

## 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. It will be held on June 17-26 next year. The course has been updated to include Superpave binder and mix technology, and stone matrix asphalt (SMA). Some financial assistance in attending this course is possible. Please call NCAT at (334) 844-NCAT for brochure or information or visit our web site at <http://www.eng.auburn.edu/center/ncat>.

## 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.*

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### **Florida (Greg Sholar, Florida DOT)**

Have any states used the CoreLok for  $G_{mm}$  or  $G_{sb}$  testing using medium to highly absorptive aggregates? If so, please comment on the accuracy obtained.

### **Georgia (Peter Wu, Georgia DOT)**

(a) Is any state DOT currently using AASHTO TP 8–Beam Fatigue Apparatus to evaluate mixture fatigue property—as part of the hot mix asphalt design process? If so, what testing mode—constant stress or constant strain—is used? What is the specification requirement for fatigue life?

(b) Is any state DOT using reclaimed asphalt pavement (RAP) in stone matrix asphalt (SMA)? If so, what is the maximum percentage of RAP allowable in SMA?

### **Kentucky (Allen H. Myers, Kentucky Transportation Cabinet)**

(a) For those states that have implemented or plan to implement a rut specification utilizing the Asphalt Pavement Analyzer, how are you incorporating the revised test parameters resulting from the NCHRP 9-17 project?

(b) Which states plan to implement the Direct-Tension Tester and AASHTO MP 1a for PG binder testing? Are any changes anticipated in the asphalt binders normally supplied to your state as a result of this test?

(c) What is the experience of other states with reheating “cold” asphalt mixture samples and compacting them in the gyratory compactor? How does the bulk specific gravity of the reheated mix compare to that of the original sample compacted while the mix was still hot?

### **New York (Zoeb Zavery, New York State DOT)**

New York State DOT will use 50 gyration Superpave mixtures for low volume roadways. This decision was made based on limited data collected by evaluating the 50 blow Marshall designed mixtures compacted in the

gyratory compactor using 50 gyrations and the removal of the restricted zone for gradation. The comparison was made on the air voids and in most cases, the air voids of the compacted specimens were about the same. With the removal of the restricted zone, it allowed the use of good performing Marshall mixtures to be used under the Superpave system. The 50-gyration mixes used to date are performing satisfactorily.

The coarse aggregate angularity requirement for \$30 million ESAL design level is 100/100 for fractured faces. This requirement excludes some gravel aggregates from use for this design level. Is any state not following this requirement? If not, are there any long-term pavement performance concerns?

### **Tennessee (Greg Duncan, Tennessee DOT)**

The Tennessee DOT is pursuing a specification change in smoothness/roughness acceptance criteria. Please respond with relevant information as to how your state changed from Mays Meter or other testing equipment to Road Profilers. How did you implement the change for longer projects that extended beyond the change date? How did you correlate the equipment to obtain relatively the same level of smoothness? Australia (John Bethune, Australian Asphalt Pavement Association)

The following three publications have been issued recently:

1. Austroads Framework for Specifying Asphalt
2. Light Duty Asphalt Pavements—Design, Specification, and Construction
3. Selection and Design of Flexible Pavements

### JOIN US

We at NCAT hope you enjoy this issue of **Asphalt Technology News**. It is provided free of charge. If you wish to be added to our mailing list, please send your business card or your name and mailing address to:

**Prithvi (Ken) Kandhal**  
Associate Director Emeritus, NCAT  
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## ASPHALT FORUM RESPONSES

*The following responses have been received to questions raised in the Spring 2002 Asphalt Forum.*

*Has any state purchased the new FHWA device for measuring the internal angle of gyratory compactors? If so, how is it being implemented? What are the preliminary results? (Allen Myers, Kentucky Transportation Cabinet)*

### **Nebraska (Laird Weishahn, Nebraska Dept. of Roads)**

We have not purchased the internal angle measuring device yet. However, we found differences in gyratory compactors when checked with an early model of this device.

### **New York (Zoeb Zavery, New York State DOT)**

We have purchased four units to collect data by checking the internal angles of the gyratory compactors at ten state laboratories and at the HMA production facilities statewide. The New York DOT, with the cooperation of the industry, is hoping to collect as much data as possible during this construction season. At this stage, our goal is to determine how many compactors meet the specified angle requirement. Once the data is collected and analyzed, a joint decision will be made between the industry and the department on how to implement the use of the FHWA device.

### **Utah (Murari Pradhan, Utah DOT)**

The Utah Department of Transportation has purchased one internal angle measuring device. It has been used to check the calibration of the gyratory compactors in central, regional, and field laboratories.

### **Washington (Dennis Duffy, Washington DOT)**

The Washington DOT has purchased one device which is being evaluated at the present time.

*For relatively new coarse-graded HMA pavements placed on extremely steep grades, has any state experienced excessive permeability, even to the degree that water seeps from the pavement down the grade for several days after the last substantial precipitation? If this concern exists, is it worse for treatments involving new HMA base and surface versus just an overlay? What corrective actions have been attempted? (Allen Myers, Kentucky Transportation Cabinet)*

### **New York (Zoeb Zavery, New York State DOT)**

The New York State DOT has experienced this type of problem, particularly in the early days of Superpave and in the areas of segregation or low densities. The problem was in both overlays as well as new construction. But this problem also existed with our heavy duty mixes, which were 75 blow Marshall designed mixtures. In either case, the problem gradually disappears after the pavement has been in service for a year or so. We believe the traffic and sanding the roadways in the winter helps in closing the voids.

### **Ohio (Dave Powers, Ohio DOT)**

The Ohio DOT has encountered excessive permeability in coarse-graded Superpave surface mixtures similar to that reported by Florida DOT a few years ago. Coarse-graded Superpave mixes have significantly higher permeability compared to fine-graded mixes. We do not have any experience with Superpave designed base mixtures.

### **Oklahoma (Kenneth Hobson, Oklahoma DOT)**

In Oklahoma, one project exhibited this behavior but primarily along longitudinal joints. The seepage was more significant along superelevations and sags in the vertical curve. Though not a Superpave mix design, it was a coarse-graded mix design for both top and bottom lifts. Another project using the same type mix designs exhibited seepage behavior as well. A third project is a Superpave project. Catastrophic bottom lift stripping failures are propagating towards the top lifts. A preliminary forensic investigation found no significant permeability problems as indicated by laboratory permeability tests for the top three lifts. The bottom lifts (25 mm NMA mix) had large open voids. Several bottom lifts could not be tested due to stripping. A prime coat was used on the subgrade. The top lift (12.5 mm NMA mix) delaminated in the coring process. This project is still under investigation. The second project has yet to be investigated. One field engineer is concerned that our mixtures in the top lift are too coarse.

For the one project in Oklahoma with this problem that was investigated, the project had both new and overlaid pavement sections.

After forensic testing, which included both lab and field permeability testing, Asphalt Pavement Analyzer

(APA) rut testing, moisture sensitivity testing, nuclear density, core density and gradation/extraction testing and analysis, it was recommended that a seal coat be applied. Pavement moisture levels should be checked before applying the seal coat. The pavement had an average density of 92 percent of theoretical maximum density. *(Editor: In some cases, application of seal coat can aggravate the stripping problem by sealing the moisture in the pavement.)*

#### **Utah (Murari Pradhan, Utah DOT)**

The Utah DOT experienced similar permeability problems with coarse-graded 19 mm NMA maintenance mixtures when placed in thin (40 mm) lift. The problem has been addressed mostly by the use of 12.5 mm mixes and better construction practices.

*Do any states perform Superpave aggregate consensus-property testing on field materials at the asphalt mixing plant? If so, what requirements are applied? The same values as in the laboratory mix design? How is the aggregate sample obtained (stockpile, extraction, ignition oven, etc.)?* **(Allen Myers, Kentucky Transportation Cabinet)**

#### **Iowa (Michael Heitzman, Iowa DOT)**

In Iowa, aggregate consensus properties are not a part of the routine QC/QA testing on field production material. However, if the mixture requires a significant proportion change (after JMF approval), the coarse aggregate angularity (CAA) and the fine aggregate angularity (FAA) values are reviewed (and measured, if necessary) to ensure that the combined aggregate satisfies the specification minimums.

#### **Nebraska (Laird Weishahn, Nebraska Dept. of Roads)**

Nebraska requires that FAA numbers be generated on one sample every day, both cold feed and ignition oven samples. When the ignition sample result is within specification, the cold feed sample is not required. The field values requirements are the same as the laboratory mix design.

#### **New York (Zoeb Zavery, New York State DOT)**

New York does not perform the aggregate consensus property testing on a routine basis during production. However, if performance problems are encountered, then the department may require the testing to be performed by the producer. In that case, the same values as in the design will be used on the aggregate sample

from the stockpiles.

#### **Oklahoma (Kenneth Hobson, Oklahoma DOT)**

The Oklahoma DOT samples aggregate from the belt at the HMA plant, which is tested in the field resident engineer's laboratory for sand equivalent value. The belt sample must meet the sand equivalent requirement as in laboratory mix design.

#### **Washington (Dennis Duffy, Washington DOT)**

Washington does conduct aggregate tests at the asphalt plant and the same specifications apply as for the mix design.

*Some HMA producers would like to use 100 mm diameter samples to monitor their production of surface course mixes. They believe it takes too long to cool the 150 mm diameter samples and it hinders their ability to control the process during production. Does any state allow the use of 100 mm samples for surface courses to monitor production?* **(Zoeb Zavery, New York DOT)**

#### **Nebraska (Laird Weishahn, Nebraska Dept. of Roads)**

We require 150 mm samples only and controls are based on volumetric and aggregate consensus properties. We have found that complete test results can be obtained in 2 to 2 + hours. A sample is required for every 750 ton subplot. We have found that when production approaches 450 to 500 tons per hour the technician(s) have difficulty keeping up. Our subplot size was influenced by the length of time needed to run a complete QC test and average plant production rates. We do require contractor field laboratories to be air conditioned.

#### **Ohio (Dave Powers, Ohio DOT)**

I understand the Colorado DOT allows 100 mm diameter specimens.

#### **Oklahoma (Kenneth Hobson, Oklahoma DOT)**

It would be acceptable in Oklahoma to allow quality control (QC) tests using 100 mm diameter specimens. These test results would not be accepted for quality assurance (QA) or acceptance of the final product. An offset or correction would be needed to correlate the QC results using 100 mm specimens to the QA results using 150 mm specimens. The 100 mm specimens should be compacted with a Superpave gyratory compactor to reduce variability in test results. A Marshall or Hveem compactor could be used but higher variability would be expected. It takes nearly three hours

*(continued on page 14)*

for a 150 mm diameter specimen to cool. For QC purposes, this can be excessive. A better alternate may be to allow for a correction or offset based on quicker cooling periods such as assuming the specimen is at room temperature even though internally it is not. At

the Superpave 2000 seminar held in Denver, Colorado, it was reported that a change in bulk specific gravity for hot to partly hot was 0.0004. For hot to cold the change was 0.015. QC results would differ more with absorptive aggregates.

## SPECIFICATION CORNER

**California** - Special provision specifications have been developed for the use of slag aggregate in hot mix asphalt (HMA) and asphalt-rubber seal coats.

Pilot projects are underway for evaluating microsurfacing and bonded HMA wearing courses. The microsurfacing is being used both as a surface treatment and rut filler. The bonded wearing courses (<25mm) consist of a gap-graded HMA placed over an application of polymer-modified asphalt emulsion membrane. These wearing courses are being used over structurally sound pavements and are anticipated to last eight to ten years.

The California Quality Control/Quality Assurance (QC/QA) Specification will be used on all HMA projects with at least 10,000 tons placed in a single, relatively continuous process.

**Florida** - Payments to the contractors are now based on percent within limits (PWL) approach since July of this year. Contractors' test results are used to calculate PWL. The department will verify contractors' test results at a reduced frequency.

**Iowa** - A provisional HMA QC/QA specification has been developed for projects with less than 5,000 tons of HMA. It involves reduced sampling and testing. The effectiveness of this specification will be monitored for one to two years before formal approval.

A provisional specification has also been developed for job mix formula (JMF) approval based on test strip production HMA. It gives the contractor more flexibility and responsibility and eliminates a step in the HMA approval process. The effectiveness of this specification will be monitored for one to two years before formal approval.

**Kansas** - The Kansas DOT no longer requires the gradation of HMA mixes to stay out of the "restricted zone" or "forbidden zone." As long as the HMA volumetrics are met, the contractor can propose an aggregate gradation through the zone.

**Kentucky** - Pilot projects involving a new specification for the density of HMA pavements at or near the

longitudinal construction joint are being let. Some features of this specification include:

- Two roadway cores per 1000 tons within  $3.0 \pm 0.5$  inches of the joint;
- 100-percent pay for core density results of 89.0 to 90.9 percent of the theoretical maximum density; and
- 105-percent pay for core density results of 91.0 to 96.0 percent of the theoretical maximum density.

Based on the results and experience from this year's projects, it is planned to revise this joint density specification as needed and implement it on all applicable projects sometime in 2003.

Beginning next year it is planned to test the intermediate dynamic shear of Kentucky's normally specified asphalt binders (PG 64-22, PG 70-22, and PG 76-22) at 25EC. This temperature was selected based on PG 64-22, the recommended binder for Kentucky climate.

**Maine** - Twelve HMA projects were advertised this year with the 2002 Ride Quality Specification. Numerous HMA overlay projects were advertised this year with Superpave mixes designed at 50 gyrations to improve durability.

**Nebraska** - The following specification changes will be implemented next year:

- When modified binders are used, the HMA contractor must inform the DOT about the type of modifier being used, the compaction and mixing temperatures recommended, and how they are determined.
- If a liquid anti-strip agent is used, it must be added to the binder by the binder supplier and the resulting binder must meet binder specifications.
- The contractor must report to the Engineer any changes in HMA mixture properties that could result from changes in mixture components such as aggregate, modifier, and anti-strip agent.

These changes are being made to hold the HMA contractor (who is the prime contractor) accountable for binder issues as well.

**Nevada** - The Nevada Department of Transportation has

developed a new specification for polymer-modified asphalt for use in Las Vegas and the surrounding county. The specified PG76-22NV binder includes some modifications to the original PG specification, and the addition of a cold temperature ductility test.

According to the department the benefits from the use of polymer-modified asphalts greatly outweigh the increase in cost. Nevada has been using modified asphalt (AC-20P) for over 10 years in the northern part of the state with great success. However, the AC-20P did not perform satisfactorily in the hotter desert climate of the south, being too susceptible to permanent deformation. It is believed PG76-22NV binder will meet the temperature and traffic demands of the southern regions of the state.

This new binder was used in four projects this year and it is planned to use it in future projects as well. Preliminary test results from the Asphalt Pavement Analyzer and the Thermal Stress Restrained Specimen Test show this material should perform well.

**New Hampshire** - The restricted zone was deleted this year for Superpave mix designs. The maximum allowable percentage of RAP in recycled mixtures, without modifying the binder grade, was increased from 10 to 15 percent. A minimum asphalt content is being considered for wearing courses designed with Superpave. Implementation of QC/QA specification is being pursued for all projects; currently it is used on about 35 percent of projects.

**New Jersey** - Effective September this year, the HMA contractors can use an oversized, heavyweight (10.5 oz/sq. ft.) tarp that will lay on top of the HMA in the truck in lieu of tie-downs. However, all trucks must be equipped with airfoil to deflect air over the top of the truck.

**Ohio** - An incentive density specification was implemented this year; previously it had been a disincentive only. Incentive smoothness specification is already being used on high volume roads; it is now being tried on low volume roads.

**Oklahoma** - The following specification changes are being considered for next year:

- APA rut specification
- Laboratory permeability specification for mix designs
- Use of material transfer vehicle (MTV) with segregation specification
- Micro-Deval abrasion (AASHTO TP 58)

specification for aggregates

The preceding specifications have been used on special projects in the past.

**South Carolina** - The South Carolina DOT is presently in the process of revising their QC/QA percent within limits (PWL) specifications to more closely resemble the variability experienced in the state. This revision will address the issues dealing with VMA, low tonnage lots, and completion of a lot on a daily basis. It is expected to incorporate the revised specification in contracts next year.

The department is continuing the evaluation of 4.75 mm HMA mixtures and is considering placing a test section on the NCAT test track next year.

**Tennessee** - The Tennessee DOT has awarded two “contractor maintained asphalt pavement” projects and plans to let two more projects this year. The term of the maintenance agreement is five years. Route selection and current condition of the pavements seem to be the biggest contractor concerns. The specification limits rutting, cracking, segregation, and rideability. Generally state routes with around 5000 ADT have been selected for such projects.

**Utah** - A supplemental binder specification with the following requirements was implemented this year:

- A minimum  $G^*$  of 1.3 is required for all binders having an algebraic difference (between high and low temperatures) of 92 or greater.
- A maximum phase angle of 71 degrees is specified for algebraic difference of 98.
- A maximum phase angle of 74 degrees is specified for algebraic difference of 92.
- A minimum direct tension failure strain of 1.5 percent and failure stress of 4 MPa is specified for algebraic difference of 92 or greater.

The toughness and tenacity requirements of 75 and 50 lb-in, respectively, when tested by ASTM D5801, have been maintained.

**Ontario, Canada** - Ontario’s provincial standard specifications for HMA materials and construction are continually being updated to improve the consistency between municipal and provincial specifications/practices.

The newly developed special provision for stone matrix asphalt (SMA) will be used on all future contracts.

The special provision for lane edge (joint) compaction has been refined to clarify testing locations and include payment strategy.

## NCAT's Professor Training Course, June 18-27, 2002



**Standing L-R:** Ray Brown (instructor), Chiu Liu, Mo Shahin, Danny Richardson, Randall Akiona, George Mertitt, Steve Meunch, Hesham Maghoub, Edward Wiredu, Abraham Navarro, James Hoskin, Tim Vollar (instructor), Nabil Suleiman, Gary Wenczel, Mujahid Akram, Allen Cooley (instructor), Stephen Mensah, Jason Moore, Graham Hurley (instructor).

**Seated L-R:** Greg Williams, Don Watson (instructor), Ron Meade, Hani Titi, Harry Cooke, Guangwei Chen, Jorge Prozzi, Ashok Gurjar, Ricardo Archilla, Hassan Salem, Joe Ivy, Junxia Wu.



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