

ASPHALT TECHNOLOGY NEWS

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NCAT HOLDS PAVEMENT TEST TRACK CONFERENCE

The National Center for Asphalt Technology (NCAT) held its Pavement Test Track Conference on November 15-16, 2005 to present the findings from Phase II of the NCAT test track. Engineers from 25 states attended the conference.

Ray Brown, NCAT director; Don Vaughn, director of the Alabama Department of Transportation (DOT); and Larry Benefield, dean of the Samuel Ginn College of Engineering at Auburn University, welcomed the conference delegates. Marshall Thompson, professor emeritus at University of Illinois at Champaign, was the keynote speaker at the conference.

Buzz Powell, test track manager and David Timm, assistant professor, provided a general overview of the test track. Four technical sessions were held during the two-day conference.

The session on performance comparison was moderated by Dave Newcomb and presentations were made by Ray Brown and Randy West from NCAT. Session 2 on implementation of findings was moderated by Gary Brunson and presentations were made by engineers who have sponsored work at the test track: Mike Doran of Tennessee DOT, Dale

Williams of Missouri DOT, Merrill Zwanka of South Carolina DOT, and James Williams of Mississippi DOT. The third session on mechanistic pavement analysis was moderated by Chuck Van Deusen and presentations were made by Dave Timm and his graduate students, Angela Priest and Immanuel Selvaraj. The final session on tire-pavement noise was moderated by John Bukowski, Federal Highway Administration (FHWA) and presentations were made by Don Watson and Doug Hanson from NCAT and Mark Swanlund from FHWA.

Test track tours were arranged for the conference delegates to allow them to observe the physical condition of the pavement test sections and to learn about test track loading and testing operations.

The NCAT test track was built
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Aerial view of the NCAT Test Track

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NCAT Holds Test Track Conference

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to develop and evaluate better ways to design and construct hot mix asphalt (HMA) pavements. The track has been in service since 2000. A number of findings have been already been identified and implemented by individual states and other findings are being developed as work continues. The ongoing research at the track continues to provide valuable information regarding pavement materials and



Loading of the NCAT test track sections



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

mixtures, construction procedures and structural pavement design.

The test track research up to this date can be divided into two cycles of tests. The first cycle (Phase I) began in 2000 with loading of forty-six test sections. The only variable among the sections in the first cycle of tests was the properties of the mixtures in the top four inches. This cycle of tests was completed in 2002 after ten million equivalent single 18-thousand pound axle loads (ESALs) had been applied to the sections. This traffic level is representative of 20 years of traffic on many rural Interstate highways.

The second cycle (Phase II) of tests began in 2003 when parts of the test track were reconstructed. Eight sections were removed full depth and reconstructed to provide different thicknesses of HMA. Some of the structural sections used modified asphalt binder and others used unmodified asphalt binder in adjacent sections. Fourteen sections were milled and overlaid with a new mix to be evaluated. The remaining sections were left in place to evaluate the effect of two more years of traffic (another ten million ESALs) and the effect of an additional two years of exposure on durability.

The following is a summary of test track findings and their implementation based on the feedback from the various sponsors.

- **Fine-graded versus coarse-graded mixtures**

Superpave requirements when introduced encouraged the use of coarse-graded mixtures especially for high volume roadways. However, research at WesTrack later indicated that fine-graded

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Venue of Test Track Conference: Hotel and Conference Center at Grand National, Opelika, Ala.



Larry Benefield, dean of engineering at Auburn University, welcomes conference delegates

mixtures performed significantly better than coarse-graded mixtures in rutting and fatigue performance. Some coarse-graded mixtures have also experienced permeability problems especially when the pavement density is slightly lower than the usual specification requirements.

Due to these problems, many states have had concerns about which type of mixture (coarse-graded or fine-graded) to use. Thus, several states were interested in evaluating these two aggregate gradings. The results of several side-by-side comparisons at the track have shown that the amount of rutting expected is approximately the same for coarse-graded and fine-graded mixes.

Based on work at the test track, the Alabama DOT

has changed their specifications to require that fine-graded mixes be used on their high-volume roadways. The track showed that these mixes would provide good resistance to rutting and would also minimize the permeability problem.

Based on work at the track, North Carolina has revised their specifications to allow more fine-graded mixtures to be used. The contractor is now given the option to use either fine-graded or coarse-graded mixes and the decision is usually fine-graded mixtures since they are more workable and easy to compact.

When Florida adopted Superpave, fine-graded mixtures were allowed on lower volume roads (less than 10 million design ESALs) but coarse-graded mixtures were required for higher levels of traffic. As a result of work at the track and work at their own accelerated loading facility, the Florida DOT now allows fine-graded mixtures to be used on all traffic level projects.

• Effect of binder grade on rutting

Superpave guidelines recommend that the high temperature PG grade be bumped for higher-traffic volume roadways to minimize rutting. One of the purposes of the first cycle at the track was to look at the effect of bumping the high-temperature grade. Several comparison sections were built with the binder grade as the only variable. The results from the first cycle of testing indicated that on average, there was more than a 50 percent reduction in permanent deformation when the high temperature grade was bumped from PG 64 to PG 76. This is a two-grade bump, which is typical of many projects on high-volume roadways. This information is helpful in performing life cycle cost analysis for modified versus unmodified asphalt

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A view of the conference delegates



Don Vaughn, director of the Alabama Department of Transportation, welcomes conference delegates



Marshall Thompson, professor emeritus at University of Illinois at Champaign, delivers the keynote address

binders. As a result of this information some states have increased the number of projects where grade bumping is specified.

As a result of this work, Florida has specified the use of PG 76-22 in the top structural layer for traffic level D (10 to 30 million ESALS) and in the top two structural layers for traffic level E (> 30 million ESALS).

• Performance of SMA mixtures

Stone matrix asphalt (SMA) mixtures have been used in the US for almost 15 years with very good results. Since SMA was adopted in the US, one of the requirements has been to use only crushed stone. Some states only have natural sands and gravels within their state so they have to import aggregates from other states, which often makes SMA too expensive to use.



Ray Brown, NCAT Director, provides an overview of test track findings



Randy West, NCAT assistant director, discusses coarse versus fine graded mixtures

In effect, this prevents some states from using SMA even though this type of mixture has provided very good performance.

Evaluations were conducted at the track using crushed gravel in an SMA mixture and it was determined that the SMA mixture had less cracking than a similar mixture designed using Superpave requirements. Both sections provided good resistance to rutting.

As a result of this finding, Mississippi has now begun placing gravel SMA mixtures using locally available materials in an effort to improve the performance of their HMA mixtures. James Williams of Mississippi DOT asserted this during his presentation at the conference. This finding has also led Tennessee to place its first section of SMA containing crushed gravel aggregate.

Georgia invests heavily in SMA mixes for heavy-traffic applications. They sponsored comparison sections of SMA and Superpave to support a life cycle cost comparison. While both sections have exhibited good rutting resistance (less than 2 mm with no statistical difference between the two), the Superpave section has increased in macro texture since the time of construction, which is indicative of the loss of fines associated with weathering. It has also begun to exhibit centerline cracking. In contrast, the higher binder content SMA section has exhibited only a slight change in macro texture and it does not appear to be at risk for cracking. According to the presentations made by Mike Doran of Tennessee DOT and Dale Williams of Missouri DOT at the Conference, limestone SMA mixtures have performed really well.

• Improved performance through increased asphalt content

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In general, it is desirable to use as much asphalt binder as possible in a mix without causing rutting or bleeding. Based on results from the test track, Alabama has determined that more asphalt binder can be added to their Superpave mixtures without causing problems, especially when polymer-modified asphalt binders are used. This higher asphalt content results in improved durability leading to a longer pavement life. The procedure to get more asphalt binder in the mixture has been to reduce the number of gyrations required during mix design.

• Validation of accelerated loading facilities

Two sponsors of the track work, Florida and Indiana, also utilize their own accelerated loading facilities. It is important that the performance measured using these accelerated loading devices is similar to that expected on the roadway. The NCAT test track offers an opportunity to calibrate the other accelerated loading devices to what would be expected on the roadway.

Indiana's participation included work to validate the testing performed with Purdue's automated accelerated pavement test (APT) device. It has been found that the relative differences in rutting between various test sections measured at the Purdue facility were similar to the differences observed at the NCAT track, which validated the use of their APT for conducting local rutting comparison studies at reduced cost.

The Florida DOT has also validated their heavy vehicle simulator (HVS) with test sections at the track. The comparison of results between the track and the HVS has been very good.

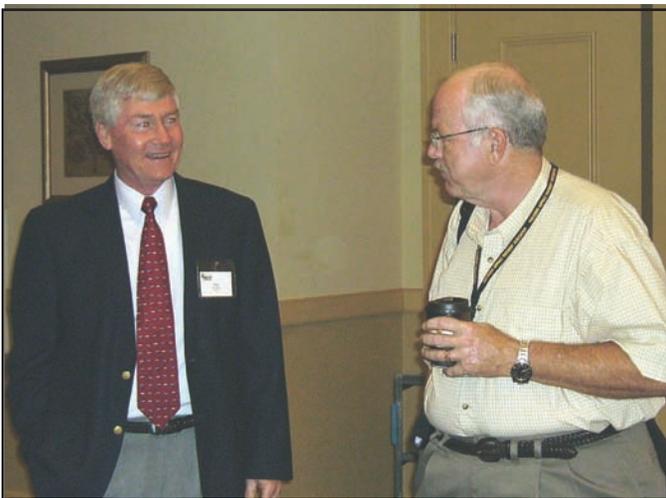


Dave Timm, assistant professor, explains the design of structural test sections

• Effect of aggregate properties on performance

Aggregate tests generally do not correlate well with performance. Most aggregate specifications used by states have been derived over time with limited data. One property, Los Angeles (LA) Abrasion, has been used to classify aggregate quality for many years. Some aggregate sources have been excluded from use in South Carolina because they have a LA abrasion loss that exceeds the state's specification requirements. One of these sources of aggregates was used in an HMA mixture and placed on the track for evaluation. No significant production problems were encountered during the construction of this

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Ray Brown, NCAT director and Jack Weigel, chairman of NCAT Applications Steering Committee, discuss the findings of the test track



Buzz Powell, test track manager, provides an overview of the track



*Engineers from New Zealand visited NCAT in March. L to R:
Andrew Harvey, Jeff Waters and Maurice Hume*

section, no significant macro texture changes were observed, and rutting performance was similar to that of other sections with acceptable materials. Based on the results of these tests, Merrill Zwanka of South Carolina DOT mentioned at the conference that South Carolina has changed their specifications to allow the use of an aggregate source with relatively higher LA abrasion loss.

Mississippi and Tennessee constructed sections to look at blending limestone with gravel mixes to determine the effects on performance and skid

resistance. Both states have now verified that they can make mixes containing all local crushed gravel that will provide satisfactory performance. Friction tests on the test track sections also provided valuable data, which Mississippi used to increase the amount of limestone allowed in surface mixtures from 30 to 50 percent.

Work on Phase III (2006-2008) of the NCAT test track will begin soon. Construction of test sections is expected to be completed by August this year and loading is scheduled to begin in November. The following are the expected outcomes from Phase III, which will be completed by the end of year 2008:

- Characterize seasonal properties and pavement responses for pavement design
- Link pavement response (stress, strain) to structural deterioration (cracking, rutting)
- Validate and calibrate mechanistic-empirical models
- Rapid assessment of materials options
 - Polymer modified versus unmodified binders
 - Virgin versus RAP mixtures
 - New mix types versus current mixtures
- Build more economical, longer lasting pavement structures.



Don Watson, NCAT engineer, demonstrates the use of noise trailer at the test track

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.

Mississippi (James Williams III, Mississippi DOT)

The Mississippi Department of Transportation is planning to construct an open graded friction course (OGFC) test section this summer. The OGFC was previously tried by the State in the 1970s with poor results. However, with the use of fibers and polymer modified binders a more durable and safer OGFC wearing course is expected. The OGFC will be a gravel/limestone mixture with a PG 76-22 asphalt binder. Construction techniques and permeability will be monitored during and after completion of the project.

Mississippi's first SMA pavement is continuing to perform very well. The SMA pavement was constructed in the summer of 2004.

Nevada (Darin Tedford, Nevada DOT)

The Nevada DOT is still experimenting with the implementation of Superpave mix designs. We plan to execute three Superpave-designed paving contracts in 2006.

Rhode Island (Francis Manning, Rhode Island DOT)

Which other states are using chemically-modified crumb rubber asphalt binder?

Which physical and/or chemical tests are used by other states for Superpave PG "plus" asphalt binders?

Does the warm asphalt technology have some application in constructing chip seals and sealing cracks?

Tennessee (Gary Head, Tennessee DOT)

The Tennessee DOT placed its first open-graded friction course (OGFC) in middle Tennessee last year. It was placed next to a Novachip section so that we may monitor road spray, durability, and noise on both test sections.

Has any agency observed that a modified asphalt binder could potentially mask the results of moisture susceptibility test in terms of tensile strength ratio (TSR)? For example, could a modified asphalt binder PG 76-22 give a higher, passing TSR value than a PG 64-22 in the same mix that is prone to stripping?

Texas (Dale Rand, Texas DOT)

We are evaluating different approaches to allow more asphalt binder in our mixtures. We are also examining some test procedures to evaluate the tensile strength and cracking resistance of HMA mixtures.

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.ncat.us>). Click on "Information" at the top of the page, then "Research in Progress." It is updated frequently based on the information received from the Departments of Transportation and other sources.

NCAT's Asphalt Technology Course (January 30 - February 3, 2006)



Back, L-R: Brian Schultz, Bryce Simons, Bill Strum, Peter Fleming, Jason Hessling, and Pete George
Front, L-R: Don Watson (Instructor), Mike Knight, Jamie Sharp, Dan Cooper, and Pam Turner (Instructor)

ASPHALT FORUM RESPONSES

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

In the past some highway agencies were allowing either fine-graded or coarse-graded Superpave mixtures and some were allowing both. What is the current practice in your agency and why? (**Prithvi “Ken” Kandhal, National Center for Asphalt Technology**)

Colorado (Ro Guevara, Colorado DOT)

We allow both. Since the Colorado DOT has an end result specification we will accept mix designs that meet our specifications.

Florida (Gregory Sholar, Florida DOT)

The Florida DOT (FDOT) used to allow only coarse-graded mixtures for roadways with 10 million ESALs or greater due to their perceived nature of minimizing rutting better than the fine-graded mixtures. Based on test results from the NCAT test track and the FDOT's accelerated testing program using a heavy vehicle simulator, the FDOT started allowing fine-graded mixtures for roadways with 10 million ESALs or greater starting in July 2005. Also at that time, the FDOT started requiring PG 76-22 asphalt binder in the top two structural layers of any mixture type for roadways with traffic over 30 million ESALs, and PG 76-22 asphalt binder in the top structural layer of any mixture type for roadways with traffic over 10 million ESALs. (**Editor:** Please read the summary of the Florida DOT's paper on this topic given in “Putting Research into Practice” column of this issue.)

Kansas (Cliff Hobson, Kansas DOT)

The Kansas DOT now uses fine-graded Superpave mixtures, primarily due to permeability issues. The original coarse-graded Superpave mixtures were generally too permeable and led to early failures from water intrusion.

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

The Kentucky Transportation Cabinet allows both coarse-graded and fine-graded Superpave mixtures. However, contractors in Kentucky choose to produce coarse-graded Superpave mixtures almost exclusively. We are very pleased with the rut resistance of coarse-graded mixes, but pavement permeability is an ongoing concern in some areas of the state. In an effort to reduce the permeability of our pavements, we are now utilizing some fine-graded mixtures and hope to maintain the same level of rut resistance with these finer blends.

Mississippi (James Williams III, Mississippi DOT)

Currently for medium- and high-type mixtures, the combined aggregate gradation of the job mix formula, when plotted on the 0.45 power chart, is required to fall entirely below the maximum density line on all sieves smaller than the No. 4 sieve. This specification is in place to ensure the mixture has adequate rutting resistance. However, medium- and high-type mixtures containing fine aggregates with a fine aggregate angularity (FAA) of 44.0 or higher may be designed above the maximum density line.

Missouri (Joe Schroer, Missouri DOT)

Missouri allows both coarse- and fine-graded Superpave mixtures. We wanted to see how the Superpave specifications would perform as written. We have not had any failures at this point.

New Hampshire (Alan Perkins, New Hampshire DOT)

We allow both coarse- and fine-graded mixtures. However, we encourage designing on the fine side to obtain higher asphalt contents in our mixtures. We believe this approach will extend the life of our pavements by delaying damage resulting from the environment.

New Mexico (John Tenison, New Mexico DOT)

New Mexico allows both types of gradations due to our extremely dry climate. To date, our experience with this decision, based on 12 years of field performance and over 15 million tons of HMA placed, has been very positive. We have not observed any field evidence of premature cracking, stripping, or rutting of our properly designed HMA pavements.

Texas (Dale Rand, Texas DOT)

The current practice in Texas DOT is that we allow both coarse- and fine-graded Superpave mixes. We had some workability problems with some of the coarse mixes but we still like the stone on stone contact that provides good skeleton for rutting resistance.

Virginia (Bill Maupin Jr., Virginia Transportation Research Council)

The Virginia mix design gradation ranges tend to be on the fine side of the maximum density line for the larger sieve sizes and straddle the maximum density line for the smaller sieves. A permeability requirement was implemented last

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SPECIFICATION CORNER

Colorado - Temperature segregation specification, HMA test result verification, and dispute resolution specification will be implemented for information only this year.

Connecticut - Various items of HMA specifications are being revised for use in pilot projects in 2006-07. Some items are as follows:

- PWL specifications (volumetric properties) for HMA
- Calibration procedure for nuclear density gauges by correlating with core density
- Notched-wedge-joint method for constructing longitudinal joints with and without hot-poured rubberized asphalt tack coat
- New density requirements for the cold side (unconfined edge of the first paved lane) of longitudinal joints
- Mandate the use of ignition oven for asphalt content determination
- Mandating that all Superpave consensus properties and specific gravities be determined by AMRL approved laboratories for mix designs and JMF changes

Kentucky - As part of a major revision to their Standard Specifications in 2000, the Kentucky Transportation Cabinet (KYTC) replaced several Kentucky “in-house” methods with national AASHTO or ASTM standards. The adoption of AASHTO T 84 as a replacement for a similar Kentucky fine aggregate specific gravity method created some unanticipated concerns. The provisional surface test was used for manufactured sands that did not slump properly in the cone test. The provisional surface test utilizes a nonabsorbent mat and determines surface moisture by an observed vapor trail. This mechanism contributed to significant variability between operators and unacceptable delays in the asphalt mix design approval process.

In response to these concerns, KYTC has generated a modified version of AASHTO T 84. This Kentucky method achieves better consistency by washing the material over a No. 200 sieve, drying, soaking and then bringing it to a saturated surface dry (SSD) condition by use of the cone. In addition, a vibrating pad is employed to remove trapped air from the sample in the pycnometer. This method limits the options provided in AASHTO T 84, specifies the equipment involved and better defines the SSD condition. As a result, more consistency is experienced between operators and the resulting specific gravity values more closely approximate those of the parent material.

Missouri - Hot mix asphalt specifications have been revised to allow 5 percent asphalt roofing shingles. Shingles from manufacturing waste or tear-offs can be used. Tear-offs

allow 3 percent other foreign material limiting wood to 1.5 percent or one-half of the OFM. Since asphalt binder in shingles is stiff, a softer PG 58-28 asphalt binder is required in the recycled HMA. Missouri is taking part in a Minnesota study to determine if Missouri’s standard PG grade, PG 64-22, would be acceptable in recycled mix.

Nevada - The Nevada DOT has adopted Superpave PG Binder Specifications for use when specifying unmodified binders.

New Hampshire - All HMA mix designs will be developed using the Superpave method since it was determined to be better than the Marshall method.

New Mexico - The New Mexico DOT will be changing the asphalt binder that is used in open-graded friction course from a PAC-20 to allow a PG 70-28 plus asphalt binder or a PG 70-28R plus, terminal-blended asphalt rubber binder.

Tennessee - The Tennessee DOT will issue a new Specification Book this spring. Some significant changes related to HMA are as follows:

- Mix designs can be developed either with Marshall method or Superpave gyratory compactor using 65 gyrations and APA performance testing (Section 407).
- Revised specifications indicate how antistripping agents can be introduced at both the asphalt plant and supplier’s terminal (Section 407).
- New specifications have been developed for microsurfacing (Section 414).
- Tensile strength ratio (TSR) has been revised from 75 to 80 percent in the moisture susceptibility test.
- Specifications have been developed for both stone matrix asphalt (SMA) and open-graded friction course (OGFC).

The following URL can be used to access the new Specifications Book and read more on the above topics: <http://www.tdot.state.tn.us/construction/specs.htm>.

Texas - The Texas DOT has just implemented new HMA specifications. Both the Texas DOT and the industry are evaluating the new specifications and have conducted several training seminars around the state to cover the new specifications.

Ontario - The table of macro-texture ratios in segregation specification SP 103F38 has been removed since it was based on Marshall mixes, which are no longer used. A new table based on test data from Superpave mixes will be developed.

PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of the Transportation Research Board held in Washington, DC in January. We are reporting observations and conclusions from them which may be of value to field engineers. These comments are obtained mostly from research projects with a limited scope; before application to practice we recommend that you read the entire paper to determine its limitations. Titles of the paper are given, with names of authors in parentheses, followed by a brief summary.

1. EVALUATION OF COARSE AND FINE GRADED SUPERPAVE MIXTURES UNDER ACCELERATED PAVEMENT TESTING (Choubane, Gokhale, Sholar and Moseley)

The aggregate gradation specifications in the Superpave mix design procedure (MP2-03) include a primary control sieve (PCS) point that lies along the maximum density line. Gradations that pass above the PCS point are commonly called fine-graded mixtures, whereas those passing below are called coarse-graded mixtures. As part of the initial field implementation of Superpave, it was thought that coarse-graded mixtures would provide a more robust aggregate structure and therefore better rutting performance. Therefore, many state highway agencies, including Florida, started specifying coarse-graded mixtures on all high volume roads (those that have a 20-year design traffic level equal to or higher than 10 million Equivalent Single Axle Loads (ESALs)). However, there have been significant challenges regarding the use of coarse-graded mixtures both in Florida and

nationally. For instance, obtaining density on the roadway has proved to be a consistent problem for coarse-graded mixtures. These mixes required a higher level of density to reduce the water permeability to an acceptable level. To achieve such a level of in-place density, a high number of passes is required with a vibratory roller, which has resulted in excessive breakdown of aggregate. This breakdown of aggregate can result in significant loss in pavement life. Many contractors, therefore, prefer the use of fine-graded mixtures, as they are relatively easier to construct and manage from a quality control standpoint. Many states have also historically observed good performance from some of their fine-graded mixtures. Furthermore, full-scale experiments at WesTrack showed that coarse-graded Superpave mixtures rutted significantly more than the fine-graded mixtures. Various research projects have also suggested that fine-graded mixtures perform at least as well as coarse-graded mixtures in terms of rutting performance.

The primary objective of this study was to evaluate the appropriateness of the recommendation that only coarse-graded mixtures be used in heavy traffic conditions. A comparative rutting performance of coarse-and fine-graded Superpave mixtures was thus investigated under an Accelerated Pavement Testing (APT) program.

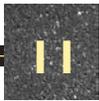
The APT testing site in Florida consists of eight linear test tracks with each test track measuring approximately 150 feet long (45 m) by 12 feet wide (3.6 m). The accelerated loading is performed using a Heavy Vehicle Simulator (HVS) in which wheel loads were applied on all test sections through a 12 inch wide super-single tire loaded to 9,000 pounds (40 kN) at a speed of 8 mph (12 km/h). The load was applied in a unidirectional mode with a 4 inch (100 mm) wheel wander with the tire pressure maintained at approximately 115 psi (790 kPa). All tests were conducted at a controlled temperature of 50°C, at a depth of 2 inches (50 mm) from the pavement surface. A total of 90,000 HVS loaded wheel passes were applied on each of the test sections.

An unmodified asphalt binder conforming to PG 67-22 was used for both the coarse and fine-graded mixtures, which had 12.5 mm nominal maximum aggregate size. A lime rock base course was provided underneath both mixtures. Both mixtures were laid in two lifts of 2 inches (50 mm) each. The coarse and the fine-graded mixtures tested in this study utilized a combination of granite aggregate from Georgia and local sand. The percentages of material passing the 2.36 mm sieve size were 32 and 48, respectively, for the coarse-graded mixture and the fine-graded mixture. The target laboratory air void content was 4.0 percent for both mixtures at N_{design} of 100 gyrations.

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At the APT test site, rutting measurements were obtained periodically, using a laser-based profiling device mounted on the underside of the wheel carriage of the HVS. Based on the rut depths measured at the APT site it was concluded that the fine-graded mixtures performed as well or slightly better than the coarse-graded mixtures in terms of rutting performance.

Rutting performance of the coarse-and fine-graded mixtures was also analyzed in the laboratory with the Asphalt Pavement Analyzer (APA). The results of APA testing indicated that the amount of rutting in either type of mixture was nearly the same. The average APA rut depths were slightly higher for the coarse-graded mixture, but not at a level that would indicate significantly inferior rutting performance compared to the fine-graded mixture. The APA results thus correlated well with the HVS results in terms of rutting performance.

The National Center for Asphalt Technology (NCAT), located in Auburn, Ala., operates a full-scale test track utilizing multiple heavily loaded tractor-trailers that apply ten million ESALs of loading over a two-year time period. The Florida DOT (FDOT) purchased two test sections in the year 2000 to study the performance of coarse-graded and fine-graded mixtures. Limestone aggregates and reclaimed asphalt pavement were shipped from southeast Florida to the test track for construction of the two test sections. The two mixtures utilized the same aggregate components but in slightly different percentages to obtain the coarse and fine-gradations. Each mixture was designed to meet Superpave criteria for a 12.5 mm traffic level D mixture (10-30 million ESALs). The two sections were trafficked for two years and then left in place to be trafficked again for two more years as part of NCAT's second experiment. The second experiment was completed in December 2005. After 17 million of the scheduled 20 million ESALs had been applied to the two sections, the fine-graded mixture had rutted 3.8 mm and the coarse-graded mixture had rutted 5.2 mm, further demonstrating that fine-graded mixtures can perform as well as or better than coarse-graded mixtures with respect to rutting.

The present study was performed with the primary objective of evaluating the rutting performance of coarse and fine-graded mixtures. The results of this research and experience at the NCAT test track have shown that fine-graded mixtures can perform at least as well as coarse-graded mixtures with respect to rutting. In response to these results and observing similar trends elsewhere in the United States, the FDOT has made several changes to the July 2005 edition of the Superpave specification. The FDOT will now allow fine-graded mixtures for traffic level D and E mixtures and will require PG76-22 modified binder in the top structural layer of traffic level D mixtures and in both structural layers for traffic level E mixtures. The adoption of these changes should improve the quality of hot mix asphalt and reduce production and constructability issues associated with coarse-graded mixtures.

2. EVALUATION OF SUPERPAVE MIX DESIGN FOR LOW VOLUME ROADS IN NEW JERSEY (Vitillo, Bennert, and Smith)

Low-volume roads make up approximately 70 percent of New Jersey's centerline miles. Most of these roads belong to counties and municipalities and have lower Equivalent Single Axle Loads (ESALs) levels than those found on the state highways and Interstate system. Most of the asphalt mixtures for these low volume roads were designed with the Marshall mix design method. Many of the Marshall designed mixes have performed well with minimal rutting or cracking after more than ten years of service. Based on a survey of Local Aid Engineers, four well-performing Marshall mixtures, from four different suppliers and from different regions of the state, were selected to be evaluated under the Superpave HMA Design system.

The Superpave HMA design system currently uses four levels of design traffic loadings or ESALs (less than 0.3 million, 0.3 to 3 million, 3 to 30 million, and greater than 30 million) to specify the level of gyratory compaction for the design specimens. The vast majority of the Superpave investigations and implementation have concentrated on the high-design traffic levels, which are greater than 3 million ESALs. Very little work has been done on Superpave mixtures in the design traffic levels below 0.3 million. A fundamental question to be answered by this research was: "Can Superpave-designed mixes replace the proven Marshall mixtures for these low traffic volume roadways?"

The objective of this study was to compare the composition (gradations and binder content), volumetric parameters, rutting, fatigue, permeability, and average asphalt binder film thickness of the new Superpave mixtures with those of the proven Marshall mixtures developed for low volume roads.

The original Marshall mixtures used an AC-20 (viscosity-graded) binder. The PG 64-22 binder, which is the current standard in New Jersey, has similar properties to the AC-20 previously used. All four mixtures in this study used the same PG 64-22 binder. The aggregates used in this project were obtained from the suppliers of the original Marshall mixtures. The original Marshall mixtures were New Jersey I-5 HMA mixes. They were evaluated as Superpave 9.5 mm nominal size mixes. The aggregate gradations of the original Marshall mixtures were plotted on a FHWA 0.45 power chart to check the gradation for compliance with the Superpave requirements. All four gradations met the requirements of the Superpave 9.5 mm mixture control points. Three mixtures were considered fine-graded mixes because their gradation passes above the maximum density line. One mixture D was considered a dense mix because its gradation passes along the maximum density line.

Marshall Specimens were compacted with 50 blows on each side of the specimen. Superpave specimens were compacted using
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[$N_{\text{initial}} = 6$, $N_{\text{design}} = 50$, and $N_{\text{max}} = 75$] gyrations as specified for the design ESALs of less than 0.3 million. The volumetric properties of these samples at the Superpave specified 4.0 percent air voids were compared to those of the Marshall specified 4.5 percent air voids of the compacted samples.

This study utilized two performance measures, HMA rutting and fatigue, and two durability properties, permeability and average binder film thickness, to compare the Marshall and the Superpave designed mixtures for the low-volume road condition. The gyratory samples were tested in the Asphalt Pavement Analyzer at 64°C. The fatigue tests were run on Marshall and Superpave mixture samples cut from beams produced by a vibratory compactor.

Permeability tests were performed to assess the mixtures' ability to limit the passage of air and water through the material. The 150-mm diameter gyratory samples were compacted to 7.0 ± 1.0 percent air voids. The samples were then tested using the Florida DOT method FM5-565 (Falling Head Test) in the falling head permeameter. The average permeability for all Marshall and Superpave mixtures was observed to be low indicating little potential for stripping and oxidation of the binder leading to good durability. The results of the permeability testing for the mixes also compared well with those found in the literature with similar gradation and air void contents.

The following conclusions were drawn from this research study, which was developed to address the needs of county and municipal agencies in transitioning from the Marshall mixture methodology to the Superpave mixture design system for use on low volume roads.

- The evaluation of Superpave for low-volume roads has provided a positive assessment of the use of Superpave for these facilities. The analyses show that the suppliers and the local agencies will have an easy transition implementing Superpave on the county and municipal road systems. In fact, based on the gradation and volumetric properties of well-performing Marshall mixtures, New Jersey has been using Superpave-like mixtures for some time.
- The aggregate blends used for well-performing NJ I-5 Marshall mixtures fit within the Superpave gradation control points and tend to be fine-graded mixtures. The volumetric properties of the Marshall and Superpave mixtures were also similar. In two cases, the Marshall mixtures obtained a higher optimum asphalt binder content, while in the other two cases the Superpave mixtures obtained a higher optimum asphalt binder content.
- In comparing the test results from the Asphalt Pavement Analyzer, the Marshall and Superpave mixtures had similar rutting performance.

- In comparing the test results from the Flexural Beam Fatigue device, the Marshall and Superpave mixtures also had similar fatigue performance.
- The Marshall and Superpave mixtures had similar falling head permeability values and moderate binder film thickness. This provides a level of proof that the Superpave mixtures will have durability comparable to the NJ I-5 Marshall mixes for these low-volume applications.

3. LABORATORY EVALUATION OF LONG-TERM EFFECTIVENESS OF ANTISTRIPPING ADDITIVES (Lu and Harvey)

This paper is focused on evaluating the long-term effectiveness of antistripping additives under prolonged moisture conditioning situations. The evolution of moisture effect with time and the equivalency of different conditioning procedures were also studied.

Hydrated lime and liquid antistripping agents are often used as additives in HMA mixes to improve their resistance to moisture damage. Most laboratory studies have evaluated the effectiveness of these additives based upon a short-period intensive moisture conditioning procedure – usually a freeze-thaw cycle. Whether this short-term conditioning sufficiently simulates the actual field conditions is unknown. Recent field sampling of dry cores of asphalt mixes in California revealed that moisture widely exists in asphalt pavements throughout the year leading to questions about the performance of asphalt mixes exposed to moisture for a long period, and the effectiveness of antistripping additives after long-term conditioning. Research was conducted in the laboratory to answer these questions, by use of two test methods – the indirect tensile strength ratio test and the flexural beam fatigue test. A moisture-sensitive mix was treated with the hydrated lime and two liquid antistripping agents, vacuum saturated and conditioned in a humid environment for a period up to one year. Mix properties were measured and analyzed every four months.

The control (untreated) mix chosen for the experiment consists of a granite aggregate and an AR-4000 asphalt binder, with a 19-mm nominal mix gradation as per Caltrans standard specifications. The aggregate used has very poor compatibility with asphalt binder. Hydrated lime and two liquid antistripping agents (A and B) were included as the antistripping additives. Hydrated lime was added to dampened aggregate during mixing, at a ratio of 1.4 percent (by dry mass of aggregates). The two liquid antistripping agents were anonymous proprietary products. These agents were added to asphalt binder at a ratio of 0.75 percent (by mass of asphalt binder). The optimum binder content, determined by the Hveem mix design procedure, was 5.0 percent for both untreated and treated mixes.

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Two test methods were used to examine the long-term effectiveness of antistripping additives: indirect tensile strength ratio (TSR) test and flexural beam fatigue test. The TSR test examines the strength loss of asphalt mixes due to moisture, whereas the flexural beam fatigue test examines the moisture effect on the fatigue response of asphalt mixes.

Hveem specimens with the size of 101 mm in diameter and 63.5 mm in height were used in the TSR test. Specimens were compacted to an air-void content around 6.5 percent by a kneading compactor. The factors included in this experiment are as follows:

- Three treatment cases: nil, hydrated lime, and liquid antistripping agent A
- Four conditioning periods: zero month, four months, eight months, and twelve months. Zero month means that specimens were tested shortly after moisture was introduced by vacuum
- Three conditioning procedures: Dry, 25°C, and CTM371. Dry means that moisture was not introduced and specimens were stored in air until testing. 25°C means that specimens were first partially saturated under a vacuum of 381 mm-Hg for three minutes and then stored in a humid room at 25°C and 100 percent relative humidity until testing. CTM371 means that after the conditioning procedure as used in “25°C”, specimens were further conditioned following the procedure in the California CTM 371 test, that is, a freeze-thaw cycle consisting of 16 hours at -18°C and 24 hours at 60°C

To evaluate the moisture effect on fatigue response of asphalt mixes, the four-point bending flexural beam fatigue test, as developed in the SHRP project, was selected for this study. The test was performed in the same way as the conventional fatigue test

in a controlled-strain mode, which is relatively simple to operate and better simulates the field conditions where the deformation of HMA layers is partly constrained by the underlying structures. This is closer to the case for thin HMA layers overlaid on old pavements, which is a major practice on current U.S. highways. The same factor levels as in the TSR test were included in the flexural beam fatigue test with two exceptions – the CTM371 conditioning procedure was not included and another liquid antistripping agent (liquid B) was added.

The following conclusions were obtained from this study:

- Both hydrated lime and liquid antistripping agents can improve the moisture resistance of the control mix used in the experiment. Mix properties – including indirect tensile strength, flexural stiffness and fatigue life – are least affected by moisture for the mix treated with hydrated lime, most affected by moisture for the untreated mix, and moderately affected by moisture for the mixes treated with liquid antistripping agents. Different liquid antistripping agents have different effectiveness. Liquid antistripping agents do not significantly change the mix properties in dry conditions. Hydrated lime does not significantly change the indirect tensile strength or fatigue response, but significantly increases the flexural stiffness in dry conditions.
- For a conditioning period as long as one year in the laboratory, both hydrated lime and liquid antistripping agents are effective in improving the moisture resistance of asphalt mixes. The effectiveness of hydrated lime does not decrease but, in some cases, increases with the conditioning time, while the effectiveness of the liquid antistripping agents may change with time.
- There is a pretty good equivalency between the two conditioning procedures – CTM 371 and long-term moisture conditioning at a room temperature. This equivalency provides support for using the CTM 371 conditioning procedure in the laboratory to test the moisture sensitivity of asphalt mixes.
- Moisture damage develops with time on a nonlinear scale. At a mild temperature (25°C), the damage evolves significantly in the first four months and then levels off. For the untreated mix, moisture damage develops slowly after four months. However, for treated mixes, moisture damage tends to stop developing after four months.
- When moisture exists in mixes for a short period, neither indirect tensile strength nor the flexural initial stiffness can discriminate between mixes with and without treatments. However, the fatigue life can show sufficiently the difference between untreated and treated mixes. It is more discriminative to use the fatigue life ratio as the index of moisture sensitivity.

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Ten engineers from Europe visited NCAT in March for technical exchange of asphalt technology. The group, which was led by Egbert Beuving, technical director of the European Asphalt Pavement Association, is seen here with NCAT staff.

- This study validated the effectiveness of antistripping additives for at least one year, by use of severe conditioning in the laboratory. This conditioning included a higher moisture content than would be typical in the field and long-term storage in a humid, temperature-controlled room. The traffic effect, as experienced in the field, was simulated to some extent by the repeated loading in the fatigue test. Based on the reduction trend of the results and the more severe-than-field conditioning, it is likely that the additives would remain effective for more than one year in the field. However, field data collection and analysis is necessary to confirm this point.

4. CHARACTERIZATION OF AGGREGATE RESISTANCE TO DEGRADATION IN STONE MATRIX ASPHALT MIXTURES (Gatchalian, Masad, and Chowdhury)

Stone matrix asphalt (SMA) mixtures rely on stone-on-stone contacts among particles to resist applied forces and permanent deformation. Aggregates in SMA should resist degradation (fracture and abrasion) under high stresses at the contact points. The main objectives of this study were to characterize the

resistance of aggregates to degradation (abrasion and fracture) in SMA mixtures, and recommend test methods to measure aggregate properties related to their resistance. These objectives were achieved through the following tasks:

- Design SMA mixtures using different aggregate sources
- Measure aggregate physical properties such as abrasion resistance
- Quantify aggregate degradation due to compaction using different conventional and advanced methods such as X-ray computed tomography
- Quantify aggregate degradation due to repeated dynamic loading
- Recommend an approach for the selection of aggregates in SMA.

Six coarse aggregates that were used in this study were selected to represent various types of mineralogy and to exhibit different shape characteristics. One 12.5 mm SMA mixture design using trap rock was obtained from the Texas Department of Transportation. The researchers replaced the coarse aggregate fraction of the original mixture design essentially keeping the same gradation in order to produce several mixture designs. In this study, the term coarse aggregates refers to particles larger than the 2.36 mm sieve. A total of six mixture designs were produced using the same gradation but different coarse aggregates. The fine

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aggregate fraction (particles smaller than 2.36 mm) was obtained from the same source for all six mixtures. Limestone screenings, filler (fly ash), and hydrated lime comprised the fine aggregate fraction. This allowed a more direct examination of the SMA performance in relationship to coarse aggregate degradation.

In addition, 0.3 percent cellulose fiber by weight of total mixture and 1.0 percent hydrated lime were used in all mixtures. The mix design developed by the Texas Department of Transportation originally used a PG 76-22 asphalt binder, but in this study a softer asphalt binder PG 64-22 was used to further emphasize the influence and interaction of coarse aggregates in SMA. The asphalt content of each mixture was monitored to ensure that mixtures had 4.0 percent air voids at 100 gyrations.

The Micro-Deval Abrasion test was performed on the coarse aggregates following AASHTO TP58. This test induces abrasion on coarse aggregates by revolving them in the presence of steel spheres and water.

Recent advancements in aggregate shape measurement technology have led to a new methodology to classify aggregate characteristics. This methodology utilizes the Aggregate Imaging System (AIMS) to directly measure and analyze aggregate characteristics (texture, angularity and shape). AIMS was used to measure the angularity, texture, and shape of coarse aggregates before and after the Micro-Deval test in order to compute the change in physical characteristics of the aggregates due to the induced abrasion.

Because the performance of SMA depends on aggregate quality and stone-on-stone contact, the breakdown of aggregate during compaction was also examined. In this study, the HMA specimens were compacted using the Superpave gyratory compactor (SGC). For each of the six mixture designs, two specimens compacted to 100 gyrations and two specimens compacted to 250 gyrations were used in the analysis. In this study, the changes in aggregate gradation of specimens compacted at 250 gyrations were compared with those of specimens compacted at 100 gyrations and uncompacted loose mixtures. Aggregate gradation was determined using mechanical aggregate size analysis and imaging techniques.

The ignition oven was used to extract the asphalt binder and provide an aggregate sample. Gradation analysis was used to analyze the pair of 100 gyrated samples to the pair of 250 gyrated samples. Non-compacted mixtures that were put into the ignition oven were also used in the comparison. The purpose of these mixtures was to determine any change in gradation due to the aggregates exposure to extreme heat from the ignition oven. This comparison will show the aggregate breakdown resulting from the two compaction levels.

The following conclusions were drawn from this study:

- The measurement of weight loss in the Micro-Deval combined with the change in gradation due to

compaction can be a valuable procedure to evaluate the resistance of aggregates to degradation. Even if aggregates do not meet the allowable weight loss requirements in the Micro-Deval, they can still be used if the change in gradation due to compaction is minimized to acceptable limits. On the other hand, aggregates that exhibit small weight loss should be evaluated for possible degradation in the mix and should be avoided if proven to be susceptible to breakage.

- AIMS can be used to supplement the Micro-Deval results. A decrease in sphericity indicates that the aggregate has the potential to experience particle breakage. AIMS results can also be used to set minimum values for loss of texture in order for the mix to have the necessary surface friction between particles.

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year, which has promoted the use of finer mixes.

Ontario (Kai Tam, Ontario Ministry of Transportation)

Ontario currently uses Superpave 12.5, 19, 25, and 37.5mm size mixtures and has recently added Superpave 9.5 mm size mix on some trial contracts. Despite the range of mixes that we allow, most of our mixes have consisted of Superpave 19 mm and Superpave 12.5 mm. We do not indicate in our specifications any preference for coarse- or fine-graded mixtures. However, we are beginning to investigate using fine-graded Superpave 12.5 mm mixtures, especially for bridge decks.

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Back, L-R: Gary DeWitt, Rodney Nelson, Patrick Morgan, Pete Holter, Don Watson (Instructor), Bob Myers, Christopher Breth, Jeremy Jablonski, Jonathan Heese, Tim Olson, Aaron Monks, and Patrick O'Donnell. **Front, L-R:** Fen Ye, Immanuel Selvaraj, Mike Jaacks, Tim Holmes, Elizabeth Barnes, Jimmy Aguilar, Tom Kaczmarowski, John Flatt, Lisa Klotz, Michael Vigil, Nick Antoniadis, and Brett Haggerty. *Not Pictured: Jason Selvage*



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