Asphalt Technology News

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NCAT COMPLETES A NATIONAL STUDY ON SEGREGATION IN HMA PAVEMENTS

The National Center for Asphalt Technology (NCAT) has just completed a National Cooperative Highway Research Program (NCHRP) Project: NCHRP 9-11, "Segregation in Hot Mix Asphalt Pavements." Dr. Mary Stroup-Gardiner was the principal investigator on this project.

Segregation has historically been defined to mean localized areas of coarse materials in some areas and fine materials in others in the finished mat. Coarse aggregate-rich regions typically have high air voids and low asphalt contents which can accelerate moisture and durability related pavement distresses such as pothole formation and raveling. Previous research has shown that very coarsely segregated materials also have substantially reduced tensile strengths and fatigue life. Fines-rich materials commonly have low voids with high asphalt contents which can lead to localized depressions (permanent deformation) and flushing.

Traditionally, visually identified areas of non-uniform surface texture have been interpreted as segregated

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ROSAN$_v$ laser system mounted on the bumper of a vehicle for surface texture measurements to identify segregation in HMA pavements. Sand patch method was used for evaluating surface texture for comparison.

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ASPHALT TECHNOLOGY NEWS (Library of Congress Catalog No. ISSN 1083-687X) is published by the National Center for Asphalt Technology (NCAT) of Auburn University. Its purpose is to facilitate the exchange and dissemination of information in hot mix asphalt technology, trends, developments and concerns. Opinions expressed in this publication by contributors and editors, the mention of brand names, the inclusion of research results, and the interpretation of those results do not imply endorsement or reflect the official positions or policies of NCAT or Auburn University.

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mix. The subjective nature of this evaluation has consistently made it difficult to reach a consensus between agency inspectors and contractors as to what is and is not segregation. Upon testing in these suspect areas, some results show a substantial change in gradation but no difference in others. Further investigation has also shown that the majority of the sections with no significant change in gradation consistently had high air voids (more than 10 percent).

Both segregation and low density can significantly increase the occurrence of localized pavement distresses. Therefore, a non-uniform surface texture may be indicative of compositional and/or volumetric non-uniformities which can lead to accelerated pavement distresses. A methodology for measuring segregation needs to be developed so that the total percent of non-uniformity in the mat can be estimated. Only then can a reliable, statistically viable specification for detecting and measuring segregation be developed.

Hot mix asphalt (HMA) segregation is a common reoccurring problem throughout the United States, and a number of studies have been conducted to identify its causes. However, little work has been done to systematically develop:

- Definitions of segregation
- Procedures to detect segregation
- Evaluations of the effect of segregation on mixture properties and pavement performance

The objectives of this research were to develop procedures for defining, detecting, and measuring segregation and to evaluate its effects on HMA pavement performance. Non-destructive technologies capable of evaluating the characteristics of the entire mat during construction were considered the most desirable methods. The best candidate technologies would produce measurements strongly correlated with changes in key performance-related mixture properties. This would allow for the development of sound, statistically-based specifications which could be linked to the anticipated costs associated with the loss of pavement life due to segregation.

Three non-destructive methods have been used in the past. These include: 1) visual identification, 2) sand patch testing, and 3) nuclear density gauges.

Historically, visual identification of non-uniform surface texture has been used to locate segregation. This is a subjective approach which can lead to disagreements between agency and contractor representatives. Visual observations are better able to identify segregation in mixtures with large maximum size aggregate and coarser (below the maximum density line) gradation. It is difficult to visually identify segregation for mixtures with smaller size aggregates and finer gradations.

The sand patch test has been used to quantify visual observations of differences in the surface macrotexture. The ASTM E965 test method indicates that the precision of the test method is approximately 1 percent of the measured depth in millimeters and the between operator variation is about 2 percent.

Good agreement was consistently reported between visual observations of non-uniform textured areas and the sand patch test results for measuring surface macrotexture. An examination of the data from areas visually considered acceptable and confirmed by testing of the cores indicates that if a maximum limit of 0.30 mm was placed on macrotexture, 88 percent of the areas with either voids greater than 10 percent or segregated mix would be identified. However, it should be noted that limits on surface texture will be mix-specific. That is, an SMA (stone matrix asphalt) should have a higher mean surface texture than a fine, dense-graded mix. Limits will most likely have to be defined as differences in texture between uniform and non-uniform areas.

Attempts have been made to use rolling density gauges to identify segregated areas by profiling the

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NCAT DEVELOPS SSD DEVICE FOR DETERMINING BULK SPECIFIC GRAVITY OF FINE AGGREGATES

Bulk specific gravity of the fine aggregate is used in hot mix asphalt (HMA) volumetric mix design (including Superpave) to determine the amount of asphalt binder absorbed by the aggregate and the percentage of the voids in the mineral aggregate (VMA). The current test method (AASHTO T84) uses a cone method to establish the saturated surface dry (SSD) condition of the sample, which is necessary to conduct the test. This method does not work satisfactorily for fine aggregates which are very angular and have rough surface texture, and, therefore, do not slump readily when in SSD condition.

A research project was undertaken by NCAT with the cooperation of the Federal Highway Administration to develop an automated equipment and method of establishing the SSD condition of the fine aggregate. The wet sample of the fine aggregate is placed in a rotating drum and is subjected to a steady flow of warm air. The temperature gradient of the incoming and outgoing air and the relative humidity of the outgoing air is monitored to establish the SSD condition.

Two prototypes devices were constructed. The test results obtained with the second prototype device (Figures 1 and 2) are very encouraging. Further improvements to be made to the second prototype device to improve the repeatability and reproducibility of the test, have been identified.

Some equipment manufacturers have seen the NCAT's second prototype SSD device and have shown interest in building its commercial version which will be evaluated by NCAT.

Two options are available for manufacturing the SSD device. In the first option, the sample can be taken out of the drum immediately on reaching the SSD condition to measure its SSD mass, SSD volume, and dry mass. The second option is possible if the SSD device has the capability of measuring the mass of the aggregate when desired without taking it out of the drum. In that case, after the SSD mass is recorded the sample can be dried further in the drum to constant mass which is also recorded. These two measurements can be used to calculate the percentage of water absorption by the fine aggregate. The percentage of water absorption and the apparent specific gravity of the fine aggregate can be used to compute its bulk specific gravity. Since the apparent specific gravity determination does not use the SSD condition it is reasonably repeatable and reproducible.

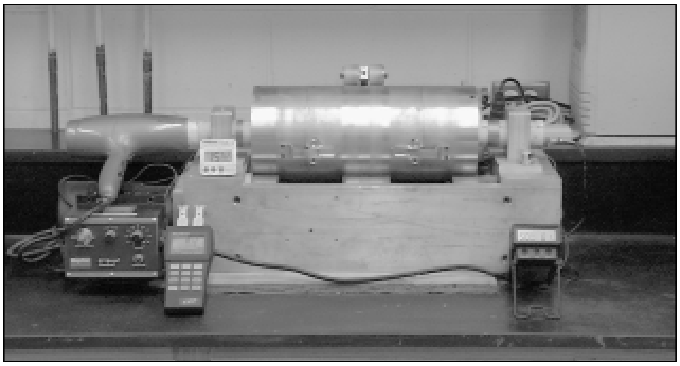

Figure 1. Second prototype of the NCAT SSD device

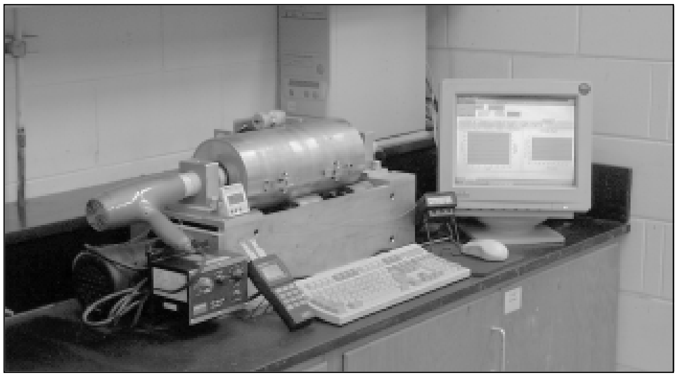

Figure 2. Second prototype of the NCAT SSD device with data acquisition system

WORKSHOPS ON HMA MIX DESIGN INCLUDING SUPERPAVE

Workshops on hot mix asphalt mix designs including Superpave will be held at NCAT on January 24-27, 2000; February 14-17, 2000; and March 20-23, 2000. These workshops consist of two and a half days of intensive lecture, demonstration, and hands-on training on HMA mix design procedures. Upon completion the participants will be able to conduct the HMA mix designs in their laboratories.

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(**NCAT segregation study**, *Continued from page 2)*

longitudinal density of the mat. The assumption is that segregation will be seen as low density. However, concentrations of different aggregate types can have a significant effect on the nuclear density gauge testing variability. If variability is increased, it may become difficult to distinguish changes in density due to segregation.

Two primary types of segregation were identified: gradation segregation and temperature segregation. Gradation segregation is the most commonly seen type and can occur as the result of aggregate stockpiling and handling, mix production, mix storage, truck loading practices, construction practices, and equipment adjustments. Temperature segregation was identified as occurring as the result of differential cooling of portions of the mix on the surface of the mix in the haul truck, along the sides of the truck bed, and in the wings of the paver. Temperature segregation causes non-uniform air voids in the compacted mat.

A general definition of segregation was formulated in this study which encompasses all types:

> "Segregation is a lack of homogeneity in the hot mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es)."

"Constituents" should be interpreted to mean asphalt cement, aggregates, additives, and air voids.

Laboratory testing of both field cores and laboratory-prepared samples resulted in the development of definitions of levels of segregation based on expected changes in key mixture properties:

Areas with *no segregation*, assuming that proper mix design and compaction is attained, will have acceptable air voids, greater than 90 percent of the anticipated mix stiffness, and the asphalt content within 0.3 percent of the job mix formula, and no statistical difference in the percent passing any of the coarse sieve sizes.

Areas with *low level segregation* will have a mix stiffness of between about 70 and 90 percent of the non-segregated areas and increased air voids of between 0 and about 4 percent. If gradation segregation is present, at least one sieve size will be at least 5 percent coarser and there will be a corresponding decrease in asphalt content between 0.3 and 0.75 percent.

Areas with *medium level segregation* will have a mix stiffness of between about 30 and 70 percent of the non-segregated areas and increased air voids of between 2 and 6 percent. If gradation segregation is present, at least two sieve sizes will be at least 10 percent coarser and there will be a corresponding decreased asphalt content between 0.75 and 1.3 percent.

Areas with *high level segregation* will have a mix stiffness of less than 30 percent of the non-segregated areas and increased air voids of more than 4 percent. If gradation segregation is present, at least three sieve sizes will be at least 15 percent coarser and there will be a corresponding decreased asphalt content of greater than 1.3 percent. Cores will have a tendency to fall apart upon coring or cutting.

The following two non-destructive technologies were recommended to detect and measure various levels of segregation.

1. Infrared Thermography

This technology can be used to detect and measure each level of segregation, however it cannot distinguish between gradation and temperature segregation types. Infrared thermography is an excellent inspection tool for identifying anomalous areas which require additional conventional testing. This technology can be used to survey each lot. Any lot with several repeated, but not necessarily cyclically occurring, areas having a temperature differential of between 10 and 16°C will likely have evidence of low levels of segregation. Any lot with several repeated, but not necessarily cyclically occurring, areas having a temperature differential of between 17 and 21°C will likely have characteristics associated with a medium level of segregation. Areas with temperature differentials greater than 21°C will likely have high level of segregation. If a definition of the type of segregation is desired, cores have to be taken from each of the temperature regions and tested to determine changes in air voids, asphalt content and aggregate gradations.

At this time, this technology can be used as an inspection tool to identify areas with large temperature

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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 "Research in Progress." It is updated frequently based on the information received from the Departments of Transportation and other sources.

NCAT STUDIES ACCELERATED LABORATORY RUTTING TESTS

The National Center for Asphalt Technology (NCAT) has undertaken a National Cooperative Highway Research Program (NCHRP) Project "Accelerated Laboratory Rutting Tests: Asphalt Pavement Analyzer." Prithvi (Ken) Kandhal, associate director of NCAT, is the principal investigator.

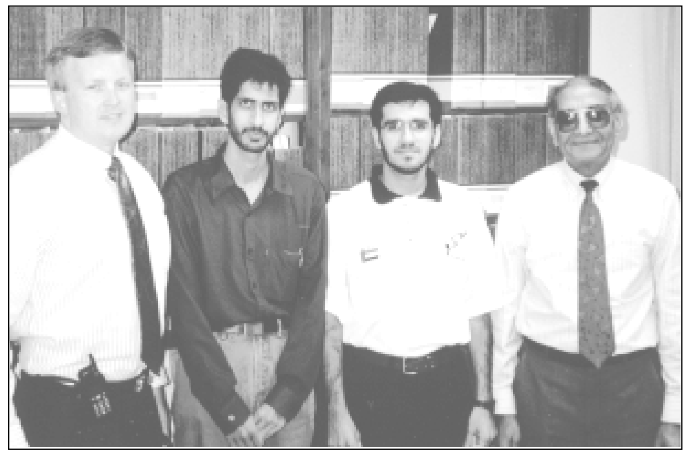
Increased truck traffic, heavier axle loads, higher tire pressures, and increasing use of super-single tires are among the factors contributing to the demand for rut-resistant hot mix asphalt (HMA). The problem of premature rutting of HMA pavements can be addressed through proper mix design, production, and construction. The Marshall and Hveem design methods, which have historically been used for HMA mix design, do not reliably predict rutting under increased traffic loads. The Strategic Highway Research Program (SHRP) has provided new tests to estimate rutting potential; however, the tests are time-consuming and not intended for quality control and quality assurance (QC/QA). Accelerated laboratory tests to predict rutting are needed for HMA design as well as for QC/QA purposes during HMA production and pavement construction.

The Asphalt Pavement Analyzer (APA), formerly known as the Georgia Loaded Wheel Tester, offers promise as a practical method to evaluate HMA rutting potential in mix design and QC/QA applications. However, the APA test does not yield a fundamental material characterization, so the relationship of its test results to actual field performance may depend heavily on local factors (e.g., aggregate properties and mix design type) and specific project characteristics (e.g., traffic level and traffic speed). Other methods and equipment, including other types of loaded wheel testers as well as simple strength tests (under development) may also prove suitable for evaluating the rutting potential of HMA.

This project was undertaken with the following objectives: (1) to evaluate the Asphalt Pavement Analyzer and determine its suitability as a general method of predicting rutting potential, and for use in field quality control and quality assurance operations, and (2) to compare the effectiveness of the Asphalt Pavement Analyzer with that of other loaded wheel testers and a simple strength test (under development in NCHRP 9-19 "Superpave Support and Performance Models Management").

HMA mixtures that have known field performance from accelerated pavement testers (such as accelerated loading facilities) and full-scale field studies (such as MnRoad) will be selected for testing by the APA. Various APA testing parameters (variables) such as sample configuration, air voids content in sample, hose diameter, and test temperature will be used in a full factorial experiment. The combination of testing parameters which gives APA rut depths closest to and highly correlated with the field rut depths, will be recommended to fine tune the APA testing protocol. The modified test procedure (in AASHTO-format) will be further validated by correlating the laboratory rut depths with the measured rut depths of at least 10 additional HMA mixes from an independent set of field pavement test sections.

This $350,000, 27-month research project was begun by NCAT in May this year and will be completed in July 2001.



Dubai government engineers S.A. Mohamed and M.H. Al Abboudi (second and third from left) visited NCAT in September

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ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the Spring 1999 Asphalt Forum.

Are any states experiencing winter maintenance problems (freeze-thaw damage, difficulty removing ice, permeability concerns, etc.) with the 19-mm Superpave mixes that are allowed to remain over the winter? Is anyone having winter maintenance problems with the 12.5-mm mixes? Do states have policies to prevent the use of "coarse-graded" Superpave mixes that will be left over the winter prior to placing the wearing surface in the spring? (Dale Peabody, Maine DOT)

Kentucky (Allen Myers, Kentucky Department of Highways)

Kentucky's specification requires the contractor to "perform all further work necessary to protect and maintain the uncompleted work during the winter months." This requirement is not, however, always enforced. Kentucky utilizes 19-mm Superpave mixtures that would be subject to this specification. We also utilize 12.5-mm mixes, often as the final riding surface. Kentucky's Superpave mixes are exclusively coarse-graded. We are very concerned about the permeability of these mixtures and the damage incurred each winter.

We do not have premature rutting problems any more with the Superpave mix and PG binder. However, we are concerned with the fatigue problem that might result from coarse-graded mixes and stiff binder. We have purchased an Asphalt Pavement Analyzer to evaluate the fatigue characteristics of our HMA mixes. (Murari Pradhan, Utah DOT)

Connecticut (Keith Lane, Connecticut DOT)

We have not experienced any fatigue problems with the coarse-graded Superpave mixtures in our state.

Indiana (Khaled Galal, Indiana DOT)

In general, Indiana's pavements are considered thick pavements and do not usually exhibit fatigue problems.

Ohio (Dave Powers, Ohio DOT)

We restrict the coarseness of Superpave gradation in all cases due to failures with overly coarse mixes.

A number of different gyratory compactors are used in the Superpave design process. These will invariably have some differences in performance. How is this taken into account when you have a set number of gyrations? (John Bethune, Australian Asphalt Pavement Association)

Editor

The Federal Highway Administration (FHWA) has established a protocol for evaluating and approving any new brand of the Superpave gyratory compactor. The evaluation is conducted by one of the Superpave centers to ensure that all compactors impart similar compactive effort to HMA specimens at various gyration levels.

The meeting of Asphalt Pavement Analyzer User Group was held in Auburn in September.

ASPHALT FORUM

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

Alabama (Randy Mountcastle, Alabama DOT)

Review of a recent research report indicates that the restricted zone is probably not necessary for limestone and granite mixes. What are the other states doing with the restricted zone?

Connecticut (Keith R. Lane, Connecticut DOT)

Has anyone recently noticed a change in HMA pavement characteristics after placement? We have experienced problems with HMA remaining soft for several days after paving.

Florida (Gale Page, Florida DOT)

A recent study by our department has shown that one-hour aging of the HMA mix at the plant during production will more accurately represent the conditions occurring at the roadway, especially for mixes containing absorptive aggregates. Has any other state examined this issue?

Iowa (Michael Heitzman, Iowa DOT)

The Iowa DOT Bituminous Team is developing a one-day training program on Superpave for practicing engineers. Currently, available programs focus on mix design technicians and general engineers. This training package is geared towards engineers who must apply Superpave concepts in design, construction, and maintenance. Four presentations were given in the Spring of 1999 to Iowa DOT central office and field staff. The program is under final development for ten sessions this winter. Copies of the training package should be available by the end of the year.

Maine (Dale Peabody, Maine DOT)

Maine is proposing the use of a 4.75 mm Superpave mix for use as a thin leveling course on overlay projects. Do any other agencies have experience with this? What VMA and VFA criteria would be appropriate for this type of mix?

Michigan (Mike Frankhouse, Michigan DOT)

The Michigan Department of Transportation intends to sample and test HMA mixture at the project site for acceptance. What experience do other states have with this procedure and will this process be used for all projects?

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**
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The benefits of using polymers with PG binders is well documented. Are other states relying on specifying PG binders only or are polymer modifications specified concurrently with PG binders to assure polymerization?

Missouri (Jim Campbell, Missouri DOT)

Superpave will be Missouri's standard mixture for the 2000 construction year for heavy, medium and light duty roads with 3500 ADT and greater. Percent Within Limits (PWL) will be fully implemented to determine pay factors for the 2000 construction year.

Oklahoma (Kenneth Hobson, Oklahoma DOT)

We have adopted the change in the N_{design} table as recommended by the Mixture Expert Task Group. We believe this will help. We are just starting to do permeability testing because we realize the possibility of permeability problems. Density in the field is a significant factor as it has always been. We are purchasing an Asphalt Pavement Analyzer (APA) and hope to identify potential problem mixes. Our binder specification changes may help some. They should provide a more consistent material in any case.

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SPECIFICATION CORNER

Alabama - The Alabama DOT's QC/QA specification has been revised to discontinue using split samples. Independent samples will be used for testing by the contractor and the DOT.

Arkansas - The Supplemental Specification for Superpave was revised this year in accordance with the latest AASHTO specification MP2-99 and TP4-99. Therefore, only four compaction levels for N_{design} (50, 75, 100, and 125 gyrations) will be used for Superpave volumetric mix designs.

Florida - The Florida DOT will be adopting changes proposed by AASHTO for MP2, PP2, PP28, and TP4. The DOT is now using a new flexible wall permeameter manufactured by Karol-Warner. The new specification limit for permeability will be 125 x 10^{-5} cm/s. The DOT has lowered the in-place minimum density requirement for coarse-graded Superpave mixes from 94.0 to 93.5 percent Gmm for 100 percent pay.

Indiana - Increased emphasis will be placed on HMA pavement density. AASHTO recommended changes to Superpave will be implemented next year.

Illinois - The Illinois DOT will begin to request warranties for full-depth asphalt pavements and asphalt overlays of pavements in the year 2000. Warranties will limit the amount of cracking, roughness, potholes, shoving, bleeding, raveling, and rutting that will be acceptable over the warranty period. Early projects will have warranty lengths of seven years.

The DOT is currently in the process of developing an End Result Specification (ERS) based on Percent Within Limits for density, asphalt content, and air voids. The new specification will be used and evaluated on a demonstration project in the year 2000.

Iowa - Working towards full implementation of Superpave, the Iowa DOT is halfway through a two-year effort to consolidate the basic hot mix asphalt paving specification language with QC/QA requirements and Superpave provisions. The new specification will make it easier for inspectors and contractors to determine the requirements for a project. The consolidated text removes all references to Marshall mix design. All state projects in 2000 will use the Superpave mix design process.

Kansas - During 1996-97 about 99 students (state, contractor, and consultant) completed either the Superpave Field or Superpave Field/Design course. During 1997-98 about 145 students completed the training. During the fourth year (1999) 161 students were trained.

Kentucky - Kentucky's "standard specifications" are being revised for a new publication to be effective January 1, 2000. In the asphalt area, the possible location of random density cores will be revised to allow coring within 75 mm (three inches) of the longitudinal joint between driving lanes. This change will hopefully result in a denser, and a longer lasting, longitudinal joint.

Maine - In conjunction with other New England states, PG 64-28 has been specified to replace 64-22 as the primary asphalt binder grade. This will hopefully provide better resistance to thermal cracking, and by specifying the same grade on a regional basis, will reduce the need for liquid suppliers to provide numerous binder grades.

Contractors now have an option of using either the nuclear or core sample method for in-place density acceptance. This change was made due to difficulties experienced last year obtaining accurate nuclear density results.

The micro-deval test is being offered as an alternative to the Washington degradation test for aggregate toughness. Contractors must specify on the mix design which test they wish the department to use to evaluate their material. The micro-deval abrasion loss cannot exceed 18 percent.

Two pilot projects have been awarded which have provisions for using the contractor's quality control test results along with Maine DOT's acceptance tests to determine pay factors.

Michigan - Next year, HMA samples will be obtained behind the paver for testing on several projects. Both contractors and the Michigan Department of Transportation will gain experience with these sampling procedures and evaluate mixture production variations between the HMA plant and project site. A new QC/QA specification is being developed to accommodate the change to sampling from the project site with the intention that all projects constructed in the future will use this sampling process.

Missouri - The Missouri DOT added a density requirement for longitudinal joints. In the past raveling has been a problem at these locations. The new specification will require the contractor to meet a required density no less than 2.0 percent below the specified density within 50 mm (6 inches) of a

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(**Specification**, *Continued from page 8)*

longitudinal joint.

The DOT has also modified the Superpave specifications. A tolerance of ±1.5 percent on the minus 200 (0.075 mm) gradation will be allowed, where before it was ±1.0 percent. The density requirements have been changed from 92 to 95 percent to 92 to 96 percent of Gmm. Finally, the dust/asphalt range has been changed from 0.6-1.2 to 0.6-1.6 based on AASHTO recommendations.

Oklahoma - Binder specifications were revised in September this year. There was a perception that the binders caused HMA mixes to be dry, dull, and lifeless. The mixes were failing retained tensile strength tests (Oklahoma uses a test method similar to AASHTO T283) both during the design and field production. Six Superpave projects will be let in November this year. Oklahoma DOT may require the use of material transfer vehicle on large projects soon.

Ohio - The Superpave specification was updated from last year's version based on experience and national recommended changes. A new warranty specification was developed for fully designed pavements based on recent legislation.

South Carolina - The following four revisions were made to the Supplemental Specifications this year:

- Steel slag in hot mix asphalt courses: Steel slag has always been allowed in the South Carolina DOT mixes, with some limitations. This specification deals with the curing and testing for expansion of the steel slag.
- Crushed Glass: This specification allows crushed glass to be used in asphalt aggregate base and binder mixtures. Glass is limited to no more than 15 percent by weight and must have 100 percent passing the 9.5 mm sieve. All applicable EPA limits must be met before introducing glass into any asphalt mixture.
- Asphalt job mix formula designs: "All Marshall and Superpave asphalt mix designs shall be designed by the contractor…" The addition of Superpave mix designs was added to this Supplemental Specification.
- Blending hydrated lime with aggregates: The addition of SC-T-78, "Method of Verification of Hydrated Lime Weighing Systems for Hot Mix Asphalt" was added to the Supplemental Specification. This specification allows the contractor the option to verify the weighing system with check weights and digitally display a real time check in the control room.

A QC/QA specification will be implemented in January next year. This specification will utilize the Percent Within Limits (PWL) method for calculating the lot pay factors. To date, three pilot projects have been completed, with several to be completed by the end of this year.

Tennessee - The Tennessee DOT developed new Superpave specifications to be used in this year's Superpave projects (a total of 20). The NCAT recommendations for gyration levels and compacting to N_{design} were included in the new specification. A deviation from the mainstream Superpave was made in reducing the Fine Aggregate Angularity (FAA) minimums to 43 in all mixes designed for traffic over three million ESALs. Natural sand was limited to a maximum of 20 percent except where the FAA was more than 44 (25 percent maximum) or FAA was more than 45 (30 percent maximum). Tennessee does not observe the restricted zone, because other criteria are used to limit "fine dirty" sands. Tennessee has historically used the "effective" specific gravity, and in this year's specification, limits were set for VMA calculated by effective specific gravity of aggregates. For each mix, the minimum VMA was increased by 1 percent to reflect the usage of effective specific gravity, and a range of 4.5 percent was allowed above the minimum VMA. The minimum percent passing the 2.36-mm sieve was also increased 5 percent for each mix to prevent very coarse mixes. Tennessee DOT pay factors are based on asphalt content and gradation. In Superpave projects, a 1.03 pay factor was introduced for exceptional quality control based on asphalt content and gradation. The specification committee believed that these changes would encourage the production of a more consistent mix in which density could be achieved, and undesirable permeability would be prevented.

Texas - The following specification changes are of interest:

- The Texas DOT has changed the friction requirements for HMA surface courses. Aggregates have been classified based on a combination of soundness, polish value, and acid insoluble residue rather than polish value alone.
- Micro-deval test is being evaluated for measuring aggregate toughness and soundness.
- An upper limit on stiffness (viscosity) is being considered for PG asphalt binders.
- Specifications are being evaluated for material transfer vehicle.

Utah - The Utah DOT has converted its specification format to the Construction Specifications Institute (CSI) from the AASHTO five-part specification format for all construction related work including hot mix asphalt. Currently, UDOT personnel are being trained on the CSI format and plan to implement it next year.

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PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of the Association of Asphalt Paving Technologists (AAPT) held in Chicago in March. We are reporting observations and conclusions from these papers which may be of value to field engineers. These comments are obtained mostly from research projects with a limited scope; before application to practice we recommend that you read the entire paper to determine its limitations. Titles of the papers are given, with names of authors in parentheses, followed by a brief summary.

1. SUPERPAVE CONSTRUCTION ISSUES AND EARLY PERFORMANCE EVALUATION (Brown, Decker, Mallick, and Bukowski)

Many states have begun to construct a large number of Superpave mixes and by the year 2000 it is expected that most states will have adopted the Superpave technology as standard practice. This report outlines construction issues that have been identified by contractors working with Superpave mixes. The report also provides results of a national performance survey of Superpave mixes conducted by NCAT. The survey was conducted in eight states (Arizona, Colorado, Florida, Indiana, Maryland, New York, Virginia, and Wisconsin). The performance to date has been generally good but most pavements inspected were only one to two years old.

The survey concerning construction issues was focused on contractors with experience in the design, production and placement of Superpave designed Hot Mix Asphalt (HMA). The objective of the telephone survey was to develop a broad overview of Superpave successes and problems from a contractor's perspective. The survey results are presented by topic as follows:

Materials. Forty percent of the asphalt binders in the survey were modified. Seventy percent said they saw no differences in the binder compared to conventional viscosity-graded materials. Sixty percent of respondents indicated they did not use anti-strip additives. Of those who did, use of liquid and lime was evenly split.

Twenty-five percent of interviewees needed to use a higher binder content compared to Marshall/Hveem designed mixtures while 40 percent used less binder, and 3 percent used the same percentage. Of those using a lower asphalt content, the survey showed that they were generally up to one half percent lower. The range for the increase in asphalt content was from one half to one percent higher.

All respondents indicated that the compaction temperature was established by the binder suppliers. Several of the interviewees expressed a need for a test procedure which would permit a practical determination of mixture compaction temperature.

Ninety-five percent of the respondents indicated that usual aggregate suppliers were able to provide the materials needed to produce Superpave designed mixtures. Changes which were required in aggregate products included using washed materials, including more manufactured sand, and increasing the number of aggregate sizes used.

Eighty percent of the respondents indicated that the blend of aggregates was coarser than Marshall/Hveem designed mixtures. That same 80 percent were designing their aggregate blend to fall below the restricted zone.

Sixty percent of the interviewees indicated that they had no problems designing around the restricted zone. As would be expected, mixes designed on the fine side of the restricted zone more easily met VMA requirements.

Those whose blend could go through the restricted zone were required to satisfy a performance test requirement such as a rut test.

Eighty-five percent had to reduce the natural sand in the mix with 40 percent having to eliminate natural sand altogether.

Mix Design. Generally, 12.5 and 19 mm mixes were the principal ones used - again no surprise as these roughly relate to 1/2" and 3/4" mixes previously used. Sixty percent of the Superpave mix tonnage placed was in a surface course application. Eighty percent of the companies reported owning at least one Superpave gyratory compactor (SGC).

Half of the respondents indicated a significant struggle to achieve volumetric properties in the mix design. The main problems were low and/or inconsistent voids, a need for more cubical aggregates, and a need for more manufactured sand.

Despite these problems, 85 percent of the mixes met all criteria of Superpave. In order to achieve VMA and avoid the restricted zone, it was suggested to blend aggregate to go above the maximum density line to about the 4.75/2.36 mm sieve, then let the blend cross the line and go below the restricted zone.

Plant Operations. Seventy percent of the respondents indicated the Superpave mix was produced using a drum mix plant, almost all of which had a baghouse. Sixty percent of the interviewees indicated additional cold feed bins were necessary to handle Superpave mixture requirements. The total number of bins reported ranged from six to eight.

Fifty percent of the interviewees reported that mix temperatures had to be increased from 5-8°C for the

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(**PRACTICE**, continued from page 10)

Superpave designed mixes. This may be due to a combination of increased use of modifiers and a stiffer mixture.

Paving Operations. All interviewees indicated that they experienced no difference between Superpave and Marshall/Hveem designed mixtures relative to hauling the product and getting the materials through the paver. Eighty-five percent of the survey participants indicated that handwork was more difficult. Overall, 85 percent saw no problems with the paving operations when handling Superpave designed mixtures.

Compaction. Fifty percent of the respondents indicated more effort was required for compaction. Sixty percent had to add up to three additional rollers to the paving train. Sixty percent said they saw no difference in pick up of the mix, but 30 percent quit using pneumatic rollers. Two thirds of the interviewees noted tenderness in the mix, indicating that understanding specific temperature zones was critical. Seventy percent said that specified density was harder to achieve due to the increase in coarse aggregate content and the lift thickness to particle size issue. 85 percent of the contractors indicated that density was consistently achieved. Forty percent of the contractors said the Superpave mixes cool faster than Marshall/ Hveem designed mixtures.

Quality Control. All respondents indicated use of the theoretical maximum density test ("Rice" test) in the QC process. Seventy-five percent of the contractors were running the test once or twice a day.

Forty-five percent of the interviewees were using the NCAT ignition test procedure for determining asphalt content and 30 percent were using a nuclear gauge for asphalt content determination. The remainder were using a solvent extraction or recordation method for determining the asphalt content.

None of the respondents indicated any change in bleeding, fat spots, or checking of the Superpave designed mix compared to conventional materials. Seventy percent reported the same surface texture with the remainder indicating a coarser texture.

The following are the results of the survey of Superpave mix performance in eight states. Only coarse graded mixes were evaluated.

Since most of the Superpave projects were relatively new the age of the pavements inspected were low. The age varied from new pavements up to six years old. Most of the pavements inspected were one to two years old.

A total of 44 pavements were inspected to determine rutting, cracking, segregation, surface texture, and quality of longitudinal joints.

Most of the Superpave mixes were providing excellent performance. They had good texture and good longitudinal joints. Some of the mixes were also providing good performance in critical loading areas such as intersections.

Rutting. Most of these pavements were very young at the time of inspection, and while rutting may become a problem in the future, at the time of inspection it was not a problem. Only one of the 44 projects had rutting greater than 4 mm, and this was localized. Most of the mixes look relatively dry, and it is expected that they will continue to resist rutting.

Longitudinal Joint. Many of the joints observed were excellent but there were many joints that were open. It appears that for some projects additional effort is needed to ensure a good tight joint.

Cracking. Most of the observed cracking was reflective and was not caused as a result of the quality of the Superpave mix. However, these mixtures often appear dry and are porous if not properly compacted. This porous condition can result in an increase in cracking due to more rapid oxidation and loss of bond between the asphalt and aggregates.

Surface Condition. Superpave mixes have more coarse aggregate and therefore provide a different surface texture. When not properly compacted these mixtures can be very open on the surface. When the texture is open the mix tends to be permeable and will hold water.

Segregation. The inspection indicated that segregation can be a problem with Superpave mixes just as with conventional mixes. Segregation may be more difficult to see due to the coarse texture of the mix.

Permeability. One of the biggest problems observed with Superpave was permeability. Coarse graded mixes become permeable at a lower void level than fine graded mixes. Research has shown that Superpave mixes become permeable at about six percent air voids. On some projects the entire area appeared to be permeable. If these permeability problems occur on a project it is expected that the life of the mix will be significantly reduced. The high permeability is likely to cause disintegration of the mix over an extended period of time.

2. EFFECT OF THE IGNITION METHOD ON AGGREGATE PROPERTIES (Hall and Williams)

This study was undertaken by the University of Arkansas to evaluate the effect of the ignition method (used for determining asphalt content of HMA mixes) on aggregate properties: gradation and bulk specific gravity. Aggregates from four HMA plants in Arkansas were sampled, representing most of the aggregate types currently used for HMA in Arkansas. Mixes consisting of a predominantly limestone based blend, a predominantly crushed gravel (silica) based blend, and

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(**NCAT segregation study**, *Continued from page 4)*

differential for further tests.

2. ROSAN$_v$ Surface Texture Measurements

This technology can be used to detect and measure each level of gradation segregation which alters the surface texture characteristics of the pavement. It cannot be used to detect any of the types of temperature segregation.

Ratios of the texture in segregated area to that in non-segregated areas were set based on statistically different key mixture properties. Texture ratios between 0.75 and 1.15 indicate no segregation, between 1.16 and 1.56 are associated with a low level of segregation, and between 1.57 and 2.09 with medium segregation. Ratios above 2.09 indicate high levels of segregation. These ratios agree reasonably well with those recommended by the Ontario Ministry of Transportation based on sand patch method.

A practical approach for using a spreadsheet program to analyze the raw ROSAN$_v$ laser data was developed to help reduce the amount of time and subjectivity of the analysis. The end result of this methodology is an estimate of the percentage of the longitudinal path with each level of segregation. This technology and analysis approach is ready to be immediately implemented by state agencies. The test method has been developed in AASHTO format, and appropriate specifications have been recommended.

(**Specification Corner**, *Continued from page 9)*

Vermont - Superpave mix design gradations are allowed to enter the “restricted zone” by a maximum of 1 percent during production. Gradation was not allowed into restricted zone in the past. This is to help with compaction of Superpave mixes. In-place compaction requirements have been increased by 1 percent of Gmm (94-95 percent Gmm) on Superpave projects to reduce the permeability of Superpave pavements.

Australia - Austroads, in consultation with industry, has issued a specification which outlines the requirements for multigrade binders for use in both sprayed seal and asphalt applications and applies to refined products free of polymer modifiers used in polymer modified binders (PMBs).Where such polymer modifiers are present, the specification framework given in APRG18 - Specification for Polymer Modified Binders, will be used. This is an interim specification which will be subject to review as further information and experience with the performance of multigrade binders is obtained. The multigrade binders specifications are based on extensive field validation work in Europe and Australia during the past decade.

The multigrade classification system adopted is based on the range of properties expected at both high and low service temperatures. The C600/170 grade developed for sealing and asphalt applications has 60 degree C properties similar to Class 600 (35 pen) and low temperature properties similar to Class 170 (90 pen). The harder asphalt grade C1000/320 has properties significantly harder than Class 600 while maintaining low temperature properties similar to a Class 320 (65 pen). Multigrade binders have been developed to provide improved deformation resistance at high service temperatures while retaining a desirable level of flexibility at low temperatures.

Ontario, Canada - Refinement has been made on specification for using the contractor’s quality control (QC) test results for acceptance of hot mix. The implementation of a new specification on segregation for visually detecting mix is continuing. A penalty of \$15/m^2 is being implemented for medium segregated patches. Consensus recompaction temperatures will be enforced this year for hot mix acceptance testing. Compaction and recompaction temperatures for recycled mixes have been revised based on preliminary results of a study of recycled mixes containing PG asphalt binders.

(**Putting Research**, *Continued from page 11)*

a blend containing appreciable amounts of both limestone and crushed gravel, were represented in the mixtures evaluated. Maximum nominal size of mixes ranged from 12.5 to 25.0 mm.

An aggregate correction factor is needed in the ignition method. It can be determined in one of two ways. In the first, an HMA specimen of ‘known’ asphalt content is ignited and the oven-derived asphalt content is recorded, the difference in the measured asphalt content, and the known asphalt content is taken to be the aggregate correction factor. The second method ignites a ‘blank’ aggregate specimen (without asphalt binder); the recorded ‘percent weight loss’ is used directly as the correction factor. Both methods have been included in testing specifications and, therefore, both were used in this study for comparison.

A PG 64-22 asphalt binder was used in all HMA mixtures. A specimen size of approximately 2000 grams was used in the ignition oven.

The gradation of aggregate blends used in ignition oven specimens were determined by “washed” sieve analysis prior to mixing with the asphalt binder. After the ignition test, cooled aggregates were again subjected to a washed sieve analysis. The bulk specific

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gravity of the coarse aggregate (plus 4.75 mm) in the blend was determined before and after being subjected to the ignition method.

The following significant conclusions were drawn from this study:

- The ignition method provides estimates of asphalt binder content with similar accuracy as other binder content determination methods such as solvent extraction and nuclear asphalt content.
- The aggregate correction factor used in the ignition method should be determined using HMA specimens with "known" binder content, rather than "blank" aggregate specimens for obtaining better results on asphalt contents. The average asphalt content error was reduced by more than 50 percent in some cases by using calibration factors from HMA specimens.
- For typical Arkansas limestone and crushed gravel aggregates, the aggregate correction factor cannot be estimated based on aggregate type alone; a correction factor should be established for each aggregate blend individually.
- For the Arkansas aggregates tested, the gradation of the HMA aggregate blend does not change significantly after being subjected to the ignition method.
- Based on the work performed in this study, it is recommended that the ignition method for determining the binder content of HMA be adopted in Arkansas as an alternative to the currently specified nuclear method.
- For the Arkansas aggregates tested, only slight changes in the bulk specific gravity of the coarse aggregate in HMA aggregate blend were measured after the aggregate has been subjected to the ignition method; in many cases these changes may be explained by variability in the testing procedure as well as changes due to ignition testing. In all cases, the bulk specific gravity decreased on ignition, the difference ranged from 0.005 to 0.066.

3.CONSOLIDATION OF THE N_{design} COMPACTION MATRIX AND EVALUATION OF GYRATORY COMPACTION REQUIREMENTS

(Brown and Buchanan)

The Superpave mixture design specification, AASHTO PP28, provides a 7 x 4 N_{design} matrix for the gyratory compaction of HMA specimens. The matrix consists of seven levels of traffic ranging from less than 0.3 million equivalent single axle loads (ESALs) to greater than 100 million ESALs. Four levels of temperature are considered ranging from less than 39°C to 43-44°C.

Many individuals and organizations have stated that the number of compaction levels should be reduced from the 28, as exists today, to three to five levels. Some have also expressed the desire to possibly have low, medium, and high traffic compaction levels. Past research has shown that in many cases significant differences do not exist in mixture design parameters between some of the currently specified compaction levels which differ by one or two gyrations.

An examination of the current $N_{maximum}$ specification limit of equal to or less than 98 percent G_{mm} is also needed to determine whether the $N_{maximum}$ requirement is necessary for Superpave mixture design or analysis. The $N_{maximum}$ requirement was developed to ensure that designed mixtures do not continue to densify more than 2 percent past the design air voids of 4 percent. It is believed that mixtures exceeding the requirement stand a greater chance of permanent deformation or rutting in the field than mixtures meeting the requirement. However, past data has shown that the mixtures most likely to fail this requirement are mixtures with coarse aggregate gradations (i.e., below the restricted zone). It is generally believed that these are the most rut resistant mixtures.

The requirement for $N_{initial}$ for low volume pavements is also an item which needed addressing. Superpave specifications contain the same criteria at $N_{initial}$ for all traffic levels. At high traffic levels the criterion is appropriate, but at low levels, where permanent deformation is of less concern, weaker aggregate skeletons would be appropriate and would result in more economical mixtures. Under the existing criteria, fine gradations could meet both the gradation and fine aggregate angularity requirements but would be eliminated by the density requirement at $N_{initial}$.

The slope of the densification curve can be calculated between $N_{initial}$ and N_{design}. The density criteria at N_{design} and $N_{initial}$, when evaluated together, limit the minimum slope that is acceptable. It is assumed that mixtures with steeper densification curves have stronger aggregate skeletons. Although the densification slope is not a Superpave criteria, it is interesting to consider the minimum slope which is allowed within each traffic category. Curiously, the slope is required to increase as the amount of traffic decreases. In other words, lower volume mixtures are required to have stronger aggregate skeletons than higher volume mixtures. If the minimum densification curve slope for the highest traffic category is applied to other traffic levels, the allowable density at $N_{initial}$ is allowed to increase.

The objective of the study was to evaluate the current N_{design} compaction matrix and determine whether the number of N_{design} levels could be consolidated into a more manageable matrix. The Superpave density requirements at $N_{maximum}$ and $N_{initial}$ were also evaluated to determine whether the requirements are justified and correctly established. Additionally, the gyratory

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compaction slope was evaluated to determine its ability to provide an indication of the compacted mixture's aggregate strength.

In the experimental plan a total of four factors were varied and their effect determined. These factors included the level of N_{design}, the mineral aggregate, the aggregate gradation, and the asphalt content. The levels of N_{design} evaluated consisted of the lowest (68) and highest (172) levels of N_{design} currently specified by PP28. Three levels of N_{design} (93, 113, and 139) were evaluated between these lowest and highest levels. In addition, another level of gyration (40) was analyzed for low volume roads. It was anticipated that compacting mixtures at these values of N_{design} would allow interpolation of the specimen volumetric properties at intermediate N_{design} levels.

The mineral aggregates consisted of a New York gravel, a Georgia granite, an Alabama limestone, and a Nevada gravel. These aggregates were chosen for use in this study because they exhibited a wide range of physical properties, such as absorption, flat and elongated particles, Los Angeles abrasion, etc., which should better provide an indication of performance of various aggregate types that are currently used in the Superpave mix design.

The overall study effort was in part a sensitivity study to determine and evaluate the effects of varying the compaction level (N_{design}), aggregate type, and gradation on volumetric properties. The first step in the task was to perform mix designs for each combination of N_{design} aggregate type, and gradation (48 total mix designs: 6 N_{design} levels x 4 aggregates x 2 gradations. Some designs did not meet all of the Superpave volumetric requirements; however, this was not of major concern since the study was designed to determine the sensitivity of the volumetric properties to changes in mixture and compaction parameters.

Based upon an analysis of the test results from the study the following conclusions were presented:

• The current N_{design} compaction matrix of 28 levels used in the Superpave mixture design procedure can be reduced to four levels and still provide a range of quality for all traffic levels. These traffic levels include very low (50 gyrations), low (70 gyrations), medium (100 gyrations), and high (130 gyrations).

[Editor's Note: The FHWA Mix Expert Task Group subsequently recommended gyration levels of 50, 75, 100, and 125, respectively, to AASHTO.]

• The requirement of $\%G_{mm}$ at $N_{initial}$ of 89 percent for lower volume roadways is too stringent. Fine graded mixtures tend to fail this requirement even when high quality materials are used. Suggested requirements are given as follows:

Less than 0.1 million ESALs
91.5 percent

0.1 million to 1.0 million ESALs
90.5 percent

Greater than or equal to 1.0 million ESALs
89.0 percent

[Editor's Note: The FHWA Mix Expert Task Group subsequently recommended maximum $\%G_{mm}$ at $N_{initial}$ requirement of 91.5 percent for less than 0.3 million ESALs, 90.5 percent for 0.3 to 3 million ESALs, and 89.0 percent for more than 3 million ESALs.]

• Generally, the mixtures which are more likely to fail the density requirement at N_{max} were coarse graded mixtures, not the fine graded mixtures. Mixtures which have been designed to 4 percent air voids at N_{design} did not fail the N_{max} density requirement.

• Currently, the gyratory compaction procedure requires that specimens be compacted to N_{max} and densities and volumetric properties be back-calculated at N_{design}. This causes an error in the calculated volumetric properties at N_{design}. Since the mixture is designed based upon its volumetric properties at N_{design}, the volumetric mix design procedure should be conducted by compacting samples to N_{design}, not N_{max}.

• Based upon the limited test data, the slope of the gyratory compaction curve does not appear to provide a good indication of the strength of the aggregate structure of the asphalt mixture. Mixtures designed at lower levels of N_{design} have higher compaction slopes than mixtures designed at higher levels of N_{design}.

• During construction the density requirements at $N_{initial}$ and N_{max} should be adjusted accordingly by the difference in the measured and design $\%G_{mm}$ at N_{design}.

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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. 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>**.

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4. REVIEW OF FINE AGGREGATE ANGULARITY REQUIREMENTS IN SUPERPAVE
(Lee, Pan, and White)

Superpave aggregate qualification includes the fine aggregate angularity (FAA). The numerical value of the FAA is the voids in the mineral aggregate of the loosely packed fine aggregate. Use of FAA has been predicated on the philosophy that higher and lower values of FAA represent fine aggregate that will exhibit high and low internal friction, respectively. The amount of friction depends on the aggregate particle shape and surface texture. Higher internal friction is associated with increased rutting resistance.

Fine aggregate angularity levels used in the Superpave system are below 40, 40 to 45 and above 45. The higher values are specified for layers near the surface and for higher traffic levels. This study was conducted utilizing the Purdue University laboratory wheel (PURWheel) tracking device to develop performance-based data on mixtures with various fine aggregates with a wide range of FAA values.

Six fine aggregates or blends consisting of natural sand, crushed limestone sand, dolomite sand, slag sand, and crushed gravel sand were used. The FAA value ranged from 39 (natural sand) to 49 (crushed gravel sand). A common gravel coarse aggregate was used in all 9.5-mm mixtures. A single asphalt binder (PG 64-22) was used.

Mixture designs were conducted using Superpave volumetric criteria. Numbers of gyration in the Superpave Gyratory Compactor (SGC) utilized were $N_{initial}=8$, $N_{design}=96$, and $N_{maximum}=152$, which correspond to a design traffic level of 3-10 million equivalent single axle loads and an average design high air temperature of less than 39°C.

All mixtures were evaluated for rutting potential using the PURWheel test device. This test device was designed and fabricated to evaluate stripping/rutting performance of HMA. Two specimens can be tested simultaneously. Typical test temperatures range from 55 to 60 degrees centigrade, although the test temperature can vary from room temperature to 65 degrees centigrade. In application, test specimens are compacted to 6-8 percent air voids with a laboratory linear compactor. Specimen dimensions are typically 29.0 cm wide and 31.0 cm long. Tests can be conducted with steel or pneumatic wheels. All tests in this study were conducted with the pneumatic wheel. The pneumatic wheel is loaded and tire pressure adjusted to achieve a gross contact pressure of about 620 kPa. Specimens are subjected to 20,000 wheel passes or until 20.0 mm of deformation develops. The following conclusions were drawn from this study:

- FAA alone may not be adequate to evaluate the contribution of fine aggregate to the mixture performance. Other factors including surface texture, absorption, and VMA in the mix would also affect mixture performance.
- Performance is sensitive to the design asphalt content. This result is mirrored in the VMA. VMA is critical because it is determined by fine aggregate shape and texture and mixture gradation. Fine aggregate angularity becomes less critical if an upper limit is adopted for VMA in combination with the use of crushed sand.
- It appears that an acceptable VMA for the 9.5-mm nominal mixture is in the range of from 14 to 16. The upper VMA limit would reduce incidences of high asphalt content. However, mixtures in this study within the 14 to 16 VMA range still have a relatively high film thickness of about 10 microns.
- The PURWheel laboratory wheel test device was effective in showing the relative performance of the mixtures tested in this study. This type of equipment can be utilized to test a large number of material and mixture variables in a relatively short period of time.

NCAT's JUNE 1999 PROFESSOR TRAINING COURSE ATTENDEES AND INSTRUCTORS

Top Row, L-R: *Rajib Mallick, Eyad Masad, Ken Kandhal, Allen Cooley, David Orr, William Barstis, Donald Snethen*

Middle Row, L-R: *Kevin Connor, John B. Stevens, Jesus Larralde-Muro, Heather Sauter, Karim Chatti, Stephanie Otis, Richard Schneider, Mandarm Dewoolkar*

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