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NCAT EVALUATES RELATIONSHIPS OF HMA IN-PLACE AIR VOIDS, LIFT THICKNESS, AND PERMEABILITY

The National Center for Asphalt Technology (NCAT) has undertaken National Cooperative Highway Research Program (NCHRP) Project 9-27, "Relationships of HMA In-Place Air Voids, Lift Thickness, and Permeability." The objectives of this \$350,000 research project are as follows:

1. Determine the in-place density needed to achieve an impermeable and durable pavement;
2. Determine the minimum lift thickness needed for desirable pavement density levels to be achiev-

able, thus obtaining impermeable pavements; and

3. Recommend improvements to AASHTO T166 in order to achieve a more precise, uniform, and accurate determination of bulk specific gravity for compacted HMA mixtures.

It is generally accepted that proper compaction of hot mix asphalt (HMA) pavements is vital for a stable and durable pavement. High air voids resulting from low in-place density allow water and air to penetrate into
(continued on page 2)



Photo 1. NCAT field permeability device is in use on a new Superpave mix pavement.

In This Issue

NCAT Evaluates Relationships of HMA In-Place Air Voids, Lift Thickness, and Permeability



— Page 1

NCAT Undertakes National Pooled-Fund Study of New Generation OGFC

— Page 3

NCAT Test Track Update



— Page 3

Putting Research Into Practice

— Page 6

Asphalt Forum

— Page 10

Two Research Engineers Join NCAT Staff

— Page 12

Specification Corner

— Page 14



—NCAT Evaluates Relationships

(continued from page 1)

the HMA pavement leading to an increased potential for water damage (stripping), oxidation, raveling, and cracking. Past research has shown dense-graded HMA pavements become excessively permeable at in-place air voids above 8 percent. However, recent studies have indicated that coarse-graded Superpave mixtures can be excessively permeable to water at in-place air voids less than 8 percent. Therefore, there is a need to determine the minimum in-place density (maximum allowable air voids) needed for Superpave mixtures to achieve a relatively impermeable and durable HMA pavement.

Recent research conducted by the Florida Department of Transportation (FDOT) has indicated that HMA lift thicknesses can have an influence on density, and hence permeability. FDOT constructed several pavement test sections on Interstate 75 that included Superpave mixtures of different nominal maximum aggregate sizes (NMAS) and lift thicknesses. Results of this experiment suggest that increased lift thicknesses can lead to increased pavement density and, hence, lower permeability. Therefore, there is a need to determine the minimum lift thicknesses corresponding to different NMAS Superpave mixtures to achieve the desired in-place density.



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Another major concern that has come to the forefront since the adoption of Superpave is the proper method to measure the bulk specific gravity (G_{mb}) of compacted HMA samples. Most Superpave mixtures that have been designed and placed on the roadway have been coarse-graded. The currently accepted method for determining the G_{mb} is AASHTO T166. This method consists of first weighing a dry compacted sample in air and then obtaining the submerged and saturated surface dry masses. This procedure was usually adequate for the relatively fine-graded mixes used in the past. However, with the coarser gradations typically being used today, errors in G_{mb} measurements have been observed in some cases at typical in-place air void ranges.

The importance of the G_{mb} measurements lies in the fact that it is the basis for volumetric calculations utilized during both HMA mix design and construction. During Superpave mix designs, volumetric properties such as air voids, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA) at the design number of gyrations are used to evaluate the acceptability of mixes. All of these volumetric properties are based upon G_{mb} .

In most states, acceptance of constructed pavements is based upon percent compaction. Pay factors, whether reductions or bonuses, are generally applied to percent compaction. Thus, the errors observed when utilizing AASHTO T166 can significantly affect both the owner and the contractor.

The three objectives of this research project as stated earlier are all interrelated. Permeability has been shown to be related to pavement density. Increased lift thickness has been shown to allow desirable density levels to be more easily achieved. Permeable mixes tend to increase the potential for errors in G_{mb} measurements when using AASHTO T166.

The proposed experimental plan for this project includes the following variables:

- Three aggregates (crushed gravel, granite, and limestone)
- Four gradations (above, below, and through the restricted zone for Superpave mixtures and one stone matrix asphalt mix)
- Six NMAS (9.5, 19.0, and 37.5 mm for Superpave mixtures and 9.5, 12.5, and 19.0 mm for stone matrix asphalt mixtures)
- Three lift thicknesses (2.0, 3.0, and 4.0 times NMAS)

This research project is scheduled to be completed by October, 2003.

NCAT UNDERTAKES NATIONAL POOLED-FUND STUDY OF NEW GENERATION OGFC

NCAT has undertaken a national pooled-fund study, "Refinement and Validation of a New Generation Open-Graded Friction Course Mix Design Procedure."

Although developed in the U.S. and largely used since the 1970s, the open-graded asphalt friction course (OGFC) or porous asphalt is used extensively in Europe with success. The OGFC significantly improves wet weather driving conditions by allowing rain water to drain through its porous structure away from the pavement surface. Besides minimizing hydroplaning during rainfall, the OGFC offers the following advantages compared to other dense surfaces: (a) reduced splash and spray behind vehicles, (b) enhanced visibility of pavement markings, and (c) reduced tire-pavement noise. Some countries in Europe use the OGFC primarily to reduce traffic noise levels in urban areas, thus minimizing the use of noise barriers. [Editor - Refer to the detailed article on OGFC in the Spring 2001 issue of the Asphalt Technology News.]

The performance of OGFC has been mixed in the U.S. According to a recent survey, a vast majority of the states reporting good experience are using polymer-modified asphalt, high asphalt contents, and relatively coarser aggregate gradations for OGFC similar to Europe.

The National Center for Asphalt Technology (NCAT) has developed a mix design procedure for new generation OGFC based on NCAT research, experience of successful states in the U.S., and experience in Europe. The new procedure addresses potential raveling/delamination and clogging problems associated with the use of OGFC in cold climates.

There is a need to refine and validate this new design procedure by constructing several test sections throughout the U.S. in different climates. Therefore, the primary objective of the pooled-fund study is to refine and field validate the new-generation OGFC mix design procedure developed by NCAT. Additionally, guidelines for the production and construction of the new-generation OGFC will be developed.

The proposed work plan for this study has three main phases. Initially, a laboratory phase will be needed to refine the mix design procedure developed by NCAT. The second phase will include field validation of the refined mix design procedure through the construction of experimental test sections designed with the refined OGFC mix design procedure. The third phase will entail

monitoring the performance of each test section for three years. After three years, the mix design procedure will be further refined, considering construction and performance experiences, and a final OGFC mix design procedure developed.

Thirteen states are participating in this pooled-fund study: Alabama, Arizona, Colorado, Florida, Georgia, Michigan, New Jersey, Nevada, Rhode Island, South Carolina, Texas, Utah, and Vermont.

All state DOTs and NCAT are contributing \$20,000 each to the pooled fund to complete this three-year study. In case a state DOT decides to construct an OGFC test section, NCAT will furnish the special provisions for the construction contract, design the OGFC mix, monitor the construction, and evaluate performance. The \$20,000 amount also includes travel expenses for a DOT representative to attend three meetings at NCAT.

It is still not too late to participate in this study. State DOTs interested in joining this three-year project should contact Don Watson at <dwatson@eng.auburn.edu> or 334-844-6228, ext. 103.

NCAT TEST TRACK UPDATE

Loading of the 1.7-mile oval NCAT Test Track is continuing on schedule. The layout of 46 test sections (26 on tangents and 20 on curves) and details of various hot mix asphalt (HMA) mixtures used were given in the Fall 2000 issue of the Asphalt Technology News.



Loading of the NCAT Test Track with four tractor/trailers like the one shown here.

Trucking began on September 19, 2000. As of October 1, 2001 a total of 4.3 million ESALs (equivalent 18 kip single axle loads) have been applied to the test sections. This value represents 43 percent of the planned 10-million ESAL goal to be applied in two years. (Editor: It should be noted that a total of about 5 million

(continued on page 4)

ESALs were applied to WesTrack in Nevada, although some test sections were taken out of service due to deep ruts after only 1.5 million ESALs. Additional test sections failed after 2.8 million ESALs.)

With the traffic almost at the halfway point, no test section is in need of replacement. The maximum rut depth is 7.1 mm. Table 1 shows the details of 26 tangent sections along with the rut depths as of October 1. Figure 1 is a histogram showing the relative rut depths in the tangent sections. Sections N1 through N13 are shown as 1 through 13, and Sections S1 through S13 are shown as 14 through 26 on the histogram. The two test sections (N3 and N5) that have exhibited the most rutting to date were both produced with unmodified binder (PG 67-22) at optimum plus one-half percent binder content. However, the ranking of the test sections in terms of rut depth may change after additional traffic, especially during next summer.

Figure 2 shows average track rutting (average of all 46 test sections) as a function of accumulated ESALs. The effect of seasonal temperature on rut development is evident; most of the rut development occurred during summer as expected. No cracking of any type has been observed to date on any test section.

Construction and up-to-date performance data for all test sections may be accessed electronically through a link on the NCAT web site, or via direct URL at <<http://www.pavetrack.com>>.

RESEARCH IN PROGRESS

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

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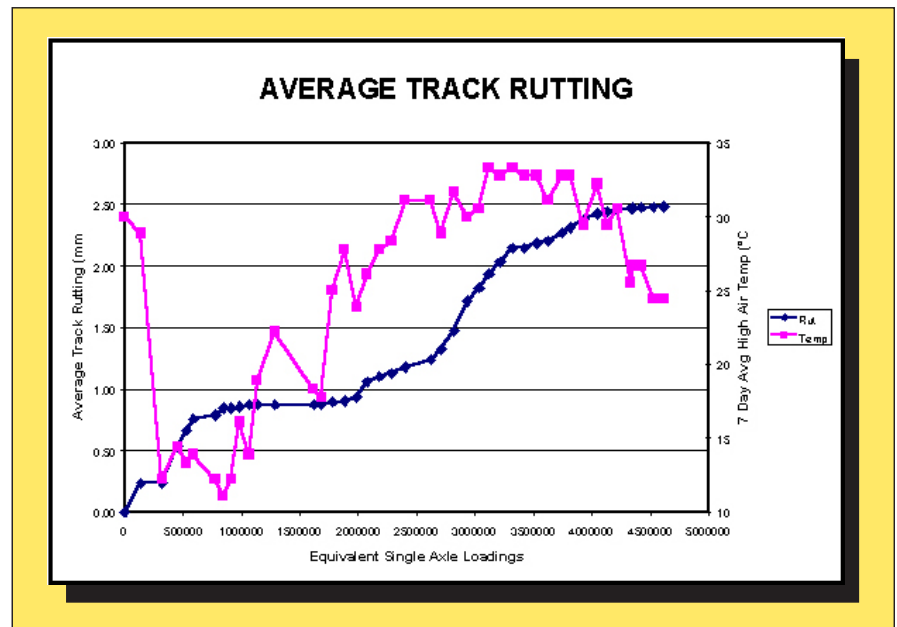


Figure 1. Total rutting on 26 tangent sections

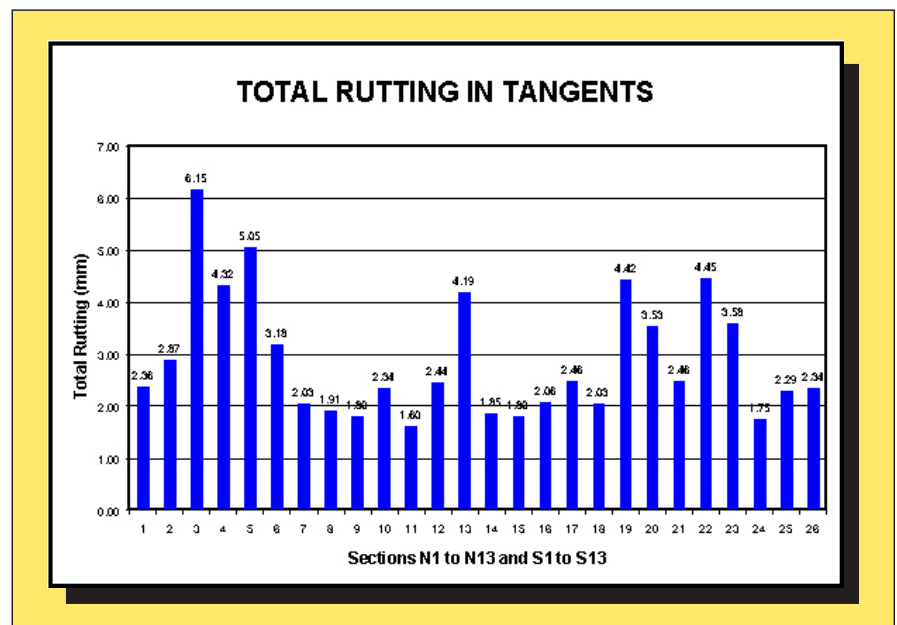


Figure 2. Average track rutting corresponding to ESALs and 7-day average high air temperatures

Table 1: NCAT Test Track Tangent Sections and Rut Depths

Section	Mix Type	Aggregate Type	Binder Type*	Rut Depth (mm)
N1	9.5 mm dense-graded ARZ	limestone/slag	SBS Modified PG 76-22	2.36
N2	9.5 mm dense-graded ARZ	limestone/slag	SBS Modified PG 76-22+	2.87
N3	9.5 mm dense-graded ARZ	limestone/slag	PG 67-22+	6.15
N4	9.5 mm dense-graded ARZ	limestone/slag	PG 67-22	4.32
N5	12.5 mm dense-graded BRZ	limestone/slag	PG 67-22+	5.05
N6	12.5 mm dense-graded BRZ	limestone/slag	PG 67-22	3.18
N7	12.5 mm dense-graded BRZ	limestone/slag	SBR Modified PG 76-22+	2.03
N8	12.5 mm dense-graded BRZ	limestone/slag	SBR Modified PG 76-22	1.91
N9	12.5 mm dense-graded BRZ	limestone/slag	SBS Modified PG 76-22	1.80
N10	12.5 mm dense-graded BRZ	limestone/slag	SBS Modified PG 76-22+	2.34
N11	12.5 mm dense-graded	granite	SBS Modified PG 76-22	1.60
N12	Stone matrix asphalt	granite	SBS Modified PG 76-22	2.44
N13	Stone matrix asphalt	gravel	SBS Modified PG 76-22	4.19
S1	12.5 mm dense-graded	granite (high LA)	SBS Modified PG 76-22	1.85
S2	9.5 mm dense-graded	chert gravel	SBS Modified PG 76-22	1.80
S3	9.5 mm dense-graded	limestone/gravel	SBS Modified PG 76-22	2.06
S4	12.5 mm dense-graded	quartz gravel	SBS Modified PG 76-22	2.46
S5	12.5 mm dense-graded	limestone	SBS Modified PG 76-22	2.03
S6	12.5 mm dense-graded ARZ	limestone/RAP	PG 67-22	4.42
S7	12.5 mm dense-graded BRZ	limestone/RAP	PG 67-22	3.53
S8	12.5 mm dense-graded	granite	SBS Modified PG 76-22	2.46
S9	12.5 mm dense-graded BRZ	granite	PG 67-22	4.45
S10	12.5 mm dense-graded ARZ	granite	PG 67-22	3.58
S11	9.5 mm dense-graded	granite	PG 67-22	1.75
S12	12.5 mm dense-graded (Hveem design)	limestone	PG 70-28	2.29
S13	12.5 mm dense-graded ARZ	granite	PG 70-28	2.34

* Plus sign designates approx. 0.5% higher asphalt content than the optimum.

ARZ = above restricted zone (fine) gradation.

BRZ = below restricted zone (coarse) gradation.

PUTTING RESEARCH INTO PRACTICE

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

1. INFLUENCE OF VOIDS IN THE MINERAL AGGREGATE (VMA) ON THE MECHANICAL PROPERTIES OF COARSE AND FINE ASPHALT MIXTURES (Anderson and Bentson)

According to the authors, difficulties in achieving VMA in Superpave mixtures have led to several research studies. One such study by Kandhal et al. argued that the VMA criteria should be different for coarse and fine asphalt mixtures. The belief was that Superpave VMA requirements unfairly penalized coarse mixtures with “low” VMA but adequate film thickness.

The purpose of this study was to evaluate the influence of changes in VMA on the performance-related properties of coarse and fine asphalt mixtures. Specifically, does increasing VMA have an effect on mixture properties at intermediate temperatures (fatigue cracking resistance) and high temperatures (rutting resistance)?

The two variables that were analyzed are gradation (coarse and fine) and VMA (13 percent and 15 percent). All four mixtures were made with a 12.5 mm nominal maximum size aggregate consisting of crushed fine and coarse dolomitic aggregate from a single source. The amount of material passing the 0.075 mm sieve was held consistent between 4.4 and 5.0 percent. A PG 64-22 asphalt binder was used in all mixtures which were designed using 100 gyrations ($N_{\text{design}}=100$) with the Superpave gyratory compactor.

The definitions for coarse and fine gradations were below and above the restricted zone, respectively. After the four blends were developed to achieve the desired coarse/fine and 13/15 percent VMA combination, a full Superpave volumetric mix design was conducted to determine the design asphalt content for each gradation and VMA combination.

Two high temperature tests were conducted with the

Superpave shear tester (SST) to evaluate the rutting characteristics of the four experimental mixtures: repeated shear test at constant height (RSCH) and shear frequency sweep test at constant height (FSCH). The flexural beam fatigue test was conducted at intermediate temperature to evaluate the fatigue life of the four mixtures.

The following conclusions were drawn from this limited study consisting of two gradations (coarse and fine) and two VMA values of 13 and 14 percent.

- There was no statistically significant difference between the fatigue properties of a mixture with 13 percent VMA and a mixture with 15 percent VMA using the flexural beam fatigue test.

- There was not statistically significant difference between the fatigue properties of a coarse mixture and a fine mixture with the same VMA using the flexural beam fatigue test.

- The shear frequency sweep test indicated significant differences between the high temperature stiffness of a mixture with 13 percent VMA and a mixture with 15 percent VMA. The stiffness of the coarse mixture decreased substantially as the VMA increased. The coarse mixture appeared much more sensitive to VMA than the fine mixture.

- Shear frequency sweep and shear fatigue test data suggest that the 15 percent VMA coarse mixture would be more susceptible to both rutting and fatigue cracking than the lower 13 percent VMA coarse mixture.

- Shear frequency sweep (with critical temperature analysis), repeated shear (rutting) and shear fatigue test data, suggest that an increase from 13 percent to 15 percent VMA significantly improves the shear fatigue characteristics of the fine mixture by 50 percent.

In summary, increasing the VMA from 13 percent to 15 percent in the coarse mixture appears detrimental to its performance properties. This result can support the industry concerns that higher VMA in coarse mixtures may be unnecessary and can lead to poor performance. The fine mixtures in this study also exhibited less sensitivity to changes in VMA.

2. A COMPARISON OF OVENS USED IN DETERMINING BINDER CONTENT BY THE IGNITION METHOD (Williams and Hall)

The National Center for Asphalt Technology (NCAT) developed a new method for determining asphalt binder content by ignition during the mid-1990s.

This method has now been standardized by AASHTO and ASTM. The ignition method has been shown to actually have a greater precision than the solvent extraction used in the past. Other advantages of the ignition method are that it is relatively easy to use, no solvents or radioactive materials are necessary, and the resulting aggregate is clean for gradation testing.

The most common type of ignition oven uses a furnace with radiant heat to attain the desired temperature in the oven chamber, thereby heating the HMA sample. The HMA sample is bathed in oxygenated air, which promotes ignition. Ignition ovens with other types of heat sources are also available, including microwave and infrared. The infrared ignition oven used an infrared element, which is claimed to limit the heating of the aggregate while producing an efficient and clean burn process. By limiting the aggregate heating, aggregate particles are less likely to experience degradation.

This study was undertaken to compare the performance of the infrared ignition oven with the standard radiant heat ignition oven. The behavior of the two ovens was addressed relative to aggregate correction factor (ACF) and binder content measurements.

Twelve Superpave mix designs containing various Arkansas aggregate sources such as limestone, sandstone, syenite, and river gravel, were used for testing in the two ovens. Aggregate blends with nominal maximum aggregate sizes of 12.5 mm and 25.0 mm were tested. The mixes contained PG 64-22 and PG 70-22 asphalt binders.

The infrared oven allows the user to choose from a selection of burn profiles. The aggregates used were able to withstand the most aggressive burn, which was, therefore, used for all samples tested in this project.

For each mix, HMA calibration samples were used to determine an ACF. Additional testing was performed such that identical pairs of samples were tested in the ovens. The ACF values were compared for the two ovens.

In order to compare the measured binder content values of the two ovens, companion samples of each mix design were tested. A total of 77 HMA samples were split and tested such that “matching” samples were tested as pairs in the two ovens. The appropriate ACF for each oven and mix design was applied, and the resulting binder content measurements were compared. This comparison provided a measure of the consistency of binder content measurement of the two ovens.

Next, the accuracy of the ovens was investigated.

Fifty-three pairs of samples of known binder content were tested in the ovens. The appropriate ACF values were applied, which resulted in the oven-based measurement of binder content. This measurement was compared to the known, or true value, which provided a measure of accuracy for both ovens.

The following conclusions were drawn from this study:

- The infrared ignition oven appears to be an adequate method for measurement of binder content when compared to the standard ignition oven.

- Aggregate correction factors (ACF) for the two ovens are not the same based on aggregate type. Although the infrared heating element is said to limit the heating of the aggregate, ACF values were not smaller, as expected. Upon closer inspection, it was discovered that the peak temperature recorded by the infrared oven during a burn was often greater than the peak temperature recorded by the standard ignition oven for the same type of sample. This means each blend of aggregate should be calibrated separately for each oven that is to be used for testing of that blend.

- For 77 paired samples, binder contents were measured in each of the ovens. The results were statistically similar. Therefore, it can be said that the infrared ignition oven is capable of measuring binder content as well as the standard ignition oven.

- For 53 paired samples, binder contents were measured for samples of known binder content. An error for each sample was calculated based on the difference in measured and known binder content. The errors of the ovens were similar. Thus, the two ovens have similar levels of accuracy.

- The ovens were very similar relative to length of test. The average time required to complete a test was approximately 40 to 45 minutes.

- The appearance of the aggregate after ignition was about the same for the two ovens. Some completed samples tested in the infrared oven had some black residue on the basket assembly, indicating that the burn may not have been complete. This residue, however, was insignificant relative to measurements of binder content.

3. PREMATURE FAILURE OF ASPHALT OVERLAYS FROM STRIPPING: CASE HISTORIES (Kandhal and Rickards)

Numerous papers have been published during the last 20 years on the possible causes of stripping, methods

for predicting stripping potential of HMA mixtures, and use of antistripping agents to minimize or prevent stripping. However, very few papers are available in the literature, which have evaluated this phenomenon in the field considering the pavement permeability and drainage in the total highway pavement system or the interaction between different HMA courses including open-graded friction courses. This paper presents four field case histories where premature failure of HMA pavement occurred due to stripping. The four projects were located in Pennsylvania (Pennsylvania Turnpike, Cumberland County); Oklahoma (Interstate 40 and Will Rogers Parkway); and New South Wales, Australia (Hume Highway).

Unlike wet coring which is commonly used in forensic work, HMA pavement layers were sampled with a jack hammer without adding any water. The actual moisture profiles obtained in HMA pavements, which are generally not found in the literature, have been reported. Thus, the stripping phenomenon in a specific HMA course has not been evaluated in isolation but in the context of the total pavement system. In all cases, critical asphalt pavement layers were substantially saturated and this is believed to have preceded the resulting stripping.

The following observations and recommendations have been made by the authors from the four case histories and the review of literature:

- It is a fundamental tenet of practicing pavement engineers that three things are vital for pavement performance: drainage, drainage, and drainage. Stripping of asphalt courses will not occur in absence of moisture and moisture vapor.

- The case studies presented identified saturation of asphalt layers by various mechanisms. In each case it is reasonably concluded that saturation is the cause of the problem; stripping is the outcome.

- The degree of saturation of the pavement and asphalt layers is a critical element in the appraisal of stripping failures. Forensic examinations of failures should include a measure of the moisture conditions in failed and non-failed sections of each project to ascertain the degree of saturation in each pavement layer.

- Various mechanisms that explain the saturation process in the asphalt courses have been presented.

- If subsurface drainage of the pavement is inadequate, moisture and/or moisture vapor can move upwards due to capillary action and saturate the asphalt courses.

- Thermal pumping of moisture may occur if trafficking does not reduce the permeability of typical

dense-graded HMA, and saturation may follow.

- If saturation exists then stripping is highly likely and is caused by the mechanical scouring of the binder from the aggregate surface due to extreme cyclic pore water pressure generated by heavy traffic. The potential for premature stripping is enhanced further if the HMA mixture consists of a stripping prone aggregate.

- An asphalt treated permeable material (ATPM) base course is recommended at the bottom of the asphalt pavement to intercept moisture and/or moisture vapor. The ATPM should be connected to edge drains on both sides to provide a positive drainage.

- Prior to the application of an open-graded friction course (OGFC) as a wearing course the following are the recommended treatments to minimize saturation in the underlying asphalt course(s):

- (a) Delay the placement of OGFC for two summers if the underlying HMA course has excessive air voids (more than six percent) so that the surface of the underlying mix is effectively sealed by traffic to be practically impermeable to water residing in the OGFC.

- (b) If the placement of OGFC cannot be delayed due to project logistics or safety considerations, apply a uniform emulsion fog seal (use a slow-setting emulsion diluted 50 percent with water) to completely fill the surface voids just prior to the placement of OGFC.

- (c) Use a relatively fine-graded surface course mix with not more than 12.5 mm maximum nominal size underneath OGFC. The evidence suggests coarse-graded mixes are more permeable.

- (d) Use an “effective” antistripping agent in the underlying surface course mix. The Georgia Department of Transportation has used hydrated lime with success in such applications.

- The pavement design engineer should evaluate the condition of all existing pavement courses in terms of stripping and drainage before deciding about the depth of milling and/or the selection of new asphalt overlays (both type and thickness). Quite often, stripping is not apparent around the surface of a pavement core. Each course should be separated by sawing, slightly warmed (not to exceed 40EC to avoid recoating), and crumbled so that the loose asphalt mix can be examined for stripping. For major projects, it may be prudent to obtain the moisture profile of the pavement (using a jack hammer or coring with dry ice) similar to what was done in the case histories.

- There is a need to develop a reliable and realistic laboratory test method to predict moisture susceptibility of HMA mixtures. It was observed in these case histories that the asphalt pavements were near 100% saturated with water (not 55-80% saturated as specified in ASTM

D4867 or AASHTO T283) and the cyclic pore pressure generated by the traffic mechanically scoured the asphalt binder off the aggregate surface. A laboratory test procedure which simulates such conditions will be more realistic. Tests similar to the SHRP-developed ECS (Environmental Conditioning System), in which specimens can be tested under saturated conditions, and wheel tracking type test (such as Hamburg) also have potential. Validation of any new test procedure should be done on short field test pavements which are intentionally saturated with water by designing an inadequate drainage system.

4. EVALUATION OF GAMMA RAY TECHNOLOGY FOR THE MEASUREMENT OF BULK SPECIFIC GRAVITY OF COMPACTED ASPHALT CONCRETE SPECIMENS (Malpass and Khosla)

The determination of bulk specific gravity (G_{mb}) plays a critical role in the design, construction, and quality control of hot mix asphalt (HMA) mixtures. With the implementation of volumetric properties as the design criteria in the Superpave mix design system, the accuracy of the calculated air voids and voids in mineral aggregate depend on the measurement of bulk specific gravity in the laboratory. The objective of this study was to evaluate a new gamma ray bulk specific gravity measurement gauge and to compare its results for a wide range of mixture types to those determined by dimensional analysis, saturated surface dry (SSD), and parafilm procedures.

The gamma ray method for bulk specific gravity measurement is based on the scattering and absorption properties of gamma rays with matter. The gamma ray instrument operates in the transmission mode—the test sample is placed between the gamma ray source and the gamma ray detector. The instrument is equipped with a mounting system that can accommodate 100 mm and 150 mm diameter cylindrical samples. The instrument is calibrated using calibration cylinders with known specific gravities.

Twelve different HMA field mixtures containing two aggregate (limestone and granite), nominal maximum aggregate size ranging from 9.5 to 25 mm, and asphalt content ranging from 4.1 to 8.9 percent were used in this study. Of the twelve mixtures, eight mixtures were fine-graded (gradation above restricted zone) and the remaining were coarse-graded.

Loose mixture samples were taken from hot mix plants and compacted to an approximate height of 115 mm using a Superpave gyratory compactor (SGC). The mass of the loose mixture placed in the compaction

molds was varied by trial and error so that each mixture was fabricated at three different compaction levels: high, medium, and low. The geometry of each sample was measured using calipers before being tested in the gamma ray device. The dry mass of the specimens was then determined before and after being wrapped with parafilm. The submerged mass of the parafilm wrapped specimen was measured before the sample was unwrapped. The saturated surface dry mass of the specimen was then finally measured.

The calibration of the gamma ray device was checked using a solid magnesium standard, solid aluminum standard, and a calibrated asphalt concrete specimen at the beginning and end of each workday.

The following conclusions were drawn from this study which included SGC compacted cylindrical specimens only.

- The specific gravity determined from a 2-minute gamma ray collection interval was found to be statistically similar to that calculated from an 8-minute collection time. Since there is no increase in precision or other benefit from the longer collection interval, the gamma ray device gives a quick method for determination of the specimen specific gravity.
- The calibration of the gamma ray gauge was checked twice a day in this study, with no real shift or significant changes in the calibration over the study period. The test procedure of this device is extremely simple and should reduce the variability in duplicate bulk specific gravity measurements between operators and laboratories.
- An analysis of variance of the test data showed that there were statistically significant differences among the different methods for determination of the bulk specific gravities.
- For samples with low to medium voids, the gamma ray device and SSD methods provided practically similar bulk specific gravity values.
- For mixtures fabricated with high air voids and having a relatively rough surface texture, the SSD method overestimated the bulk specific gravity as compared to that determined by the gamma ray device. The parafilm and dimensional analysis methods underestimated the bulk specific gravity as compared to the gamma ray device on the same specimens.
- Gamma ray measurements are not dependent on the connectivity of the voids, the resulting water absorption, specimen surface texture, or aggregate type.
- The gamma ray device provides a quick, simple, nondestructive, precise and completely automated procedure for determining bulk specific gravity of compacted laboratory HMA specimens.

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.*

New York (Zoeb Zavery, New York DOT)

The New York DOT is working jointly with the HMA industry to develop a mixture for low-volume roadways. Construction of a few pilot projects was planned for this year and next year. The mixtures are designed at 50 gyrations and the objective is to determine the ease of construction and durability compared to Marshall mixtures used prior to Superpave.

Connecticut (Keith Lane, Connecticut DOT)

Is anyone having problems with “delayed setting” of HMA mixes? We use a PG 64-28 binder in our HMA mixes and have experienced some sporadic instances of mixes remaining soft and pliable for a day or more.

This goes beyond the standard “tender mix” issues such as moisture in the mix and hump in the gradation.

Rhode Island (Francis Manning, Rhode Island DOT)

In the Superpave binder specification, when bumping up the high temperature grade of the PG binder, we inadvertently bump up the test temperature of the dynamic shear rheometer when testing the pressure aging vessel (PAV) residue. What are the states doing about this? This will become crucial when dealing with the modified asphalt binders.

Is the elastic recovery test being used by any states for asphalt binders? Is this an appropriate test for evaluating the elasticity of modified binders, especially at lower temperatures?

NCAT Board of Directors and staff met in Atlanta in August.

Sitting left to right: Tim Doctor, Bob Skinner, Charles Potts, Chuck VanDeusen, Joe Judkins, Scott Rowe, and Bill Deyo.
Standing left to right: Paul Parks, Mike McCartney, John Spangler, Ray Brown, Don Gallagher (Chairman), Mac Badgett, Mike Acott, Jon Epps, and Larry Benefield

ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the Spring 2001 Asphalt Forum.

Many precision statements are based on laboratory fabricated specimens such as those developed for the ignition oven. However, agencies are using these precision statements for plant-produced mix, which includes unaccounted for variability with sampling the truck and splitting the sample into test size. How are agencies handling this issue?

Has any agency developed a single sampling procedure to be used for all of the testing required for HMA: G_{mm} , G_{mb} , asphalt content, and gradation?
(Gregory Sholar, Florida DOT)

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

Test verification tolerances for comparing the contractor's acceptance tests with department's verification tests are based on historical data. While these tolerance values do not exactly correspond with the precision statements of the applicable test methods, they appropriately represent HMA produced in Kentucky.

A sample of HMA is obtained from the truck at the HMA asphalt plant for conducting all tests.

Michigan (Mike Frankhouse, Michigan DOT)

HMA samples for all tests (including volumetrics) will be taken behind the paver starting next year.

New York (Zoeb Zavery, New York DOT)

The New York DOT has used HMA quality control/quality assurance (QC/QA) for the last five years. The precision statements from the standard test methods have been used in the QC/QA program.

Ohio (Dave Powers, Ohio DOT)

The Ohio DOT conducts all testing on HMA samples obtained from trucks at the plant.

South Dakota (Rick Rowen, South Dakota DOT)

Hot mix asphalt is sampled behind the paver. Testing tolerances were determined from analysis of test data

from actual field samples. No single sampling procedure has been developed for all HMA testing.

Utah (Murari Pradhan, Utah DOT)

HMA samples for quality control and acceptance are taken behind the paver. These samples are tested for asphalt content, gradations, G_{mm} , and G_{mb} .

Ontario, Canada (Kai Tam, Ontario Ministry of Transportation)

Rather than using the precision statements from the test methods, the Ontario Ministry of Transportation addresses this through statistical analysis of HMA production test data as part of the development of the end-result specification for a particular attribute. This is done because the production data reflects the historical variability associated with sampling, splitting, and testing.

Regarding a single sampling procedure, a 10-kg plate sample taken behind the paver provides enough material for all routine tests such as G_{mm} , asphalt content, gradation, and G_{mb} .

Florida (Gale Page, Florida DOT)

The Florida DOT has conducted a research study to determine the precision of the ignition oven using samples of plant produced HMA mix. The report is available on the department's web site.

The department now uses a "thieving/scooping" method to sample HMA mix. A report comparing the differences between this method and the quartering method is also available on the department's web site.

Do other states require moisture-susceptibility testing, either by AASHTO T283 or ASTM D4867, for all Superpave mixtures regardless of design ESAL value? (Allen Myers, Kentucky Transportation Cabinet)

Alabama (Randy Mountcastle, Alabama DOT)

The Alabama DOT conducts AASHTO T283 testing on all HMA mixtures.

(continued on page 12)

—Asphalt Forum Responses

(continued from page 11)

Florida (Gale Page, Florida DOT)

The Florida DOT requires moisture sensitivity testing of HMA mixtures for all traffic levels.

Kansas (Glenn Fager, Kansas DOT)

The Kansas DOT requires a modified AASHTO T283 on all Superpave mixtures both in laboratory (mix design) and field (mix production).

Montana (Scott Barnes, Montana DOT)

AASHTO T283 test is conducted on all Superpave and conventional HMA mixtures.

Nebraska (Laird Weishahn, Nebraska DOT)

Nebraska uses AASHTO T283 on all Superpave mixtures.

New Jersey (Joseph Merlo, New Jersey DOT)

AASHTO T283 test is used for all Superpave mixtures.

New York (Zoeb Zavery, New York DOT)

AASHTO T283 is used only when there is a potential of stripping problem.

South Dakota (Rick Rowen, South Dakota DOT)

The South Dakota DOT uses ASTM D4867 for all Marshall designed mixtures and AASHTO T283 for Superpave mixtures.

Utah (Murari Pradhan, Utah DOT)

AASHTO T283 test is used to evaluate all Superpave mixtures regardless of design ESALs.

Vermont (Tim Pockette, Vermont DOT)

The Vermont DOT requires AASHTO T283 testing for all Superpave mixtures regardless of design ESALs.

How are other states assuring compliance with the AASHTO MP1 binder specification in terms of sampling location, testing frequency, tolerance, and price adjustments? (Mike Frankhouse, Michigan DOT)

Kansas (Glenn Fager, Kansas DOT)

The Kansas DOT requires the binder supplier to

submit yearly qualification samples for each grade. If all of the tests pass, the supplier is put on a qualified list. On a statewide basis, samples are obtained from the tanker truck at various intervals. Initially, one out of three trucks is sampled and tested. If the testing is satisfactory the frequency of sampling is increased up to a maximum of one out of 12 trucks. There are no price adjustments or tolerances on the asphalt binders. It either passes or it fails the required tests.

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

Kentucky obtains samples of PG binder from the storage tanks at the HMA plant at a specified frequency based on mixture production. Our central laboratory tests these samples according to MP1 and applies a pay factor, from an acceptance schedule of our design, based on the results obtained.

New York (Zoeb Zavery, New York DOT)

PG binder samples are taken at the HMA plant during production at a frequency of one sample per day. The samples are tested for compliance to AASHTO MP1 specifications as certified by the binder suppliers.

North Dakota (Ron Horner, North Dakota DOT)

North Dakota joined with five other states to form the Combined States Binder Group (CSBG). All MP1 procedures, sample locations, test frequency, tolerance, and price adjustments are spelled out for each state. Any asphalt binder supplier that ships material to these states must be a member of CSBG and conform to all procedures including reference samples.

Ohio (Dave Powers, Ohio DOT)

Ohio's certification program for binder suppliers is not a concern for sampling. Suppliers test binders as per their quality control plan and report monthly. There have been minimal problems in over 15 years of this program.

Vermont (Tim Pockette, Vermont DOT)

The Vermont DOT samples asphalt binders at the HMA plant at a rate of one sample per 750 tons of HMA. The PG binder must meet AASHTO MP1 specification. Price adjustment for failing material varies.

(continued on page 13)

Ontario, Canada (Kai Tam, Ontario Ministry of Transportation)

PG binder sample is obtained at the HMA plant. Deviation in the PG grading equal to or less than 3EC is considered minor and borderline, and is accepted at full price. Deviation of 4 to 6EC is accepted with a price reduction of 5 percent. Deviation of more than 6EC is either rejected or price reduced at the contract administrator's discretion.

TWO RESEARCH ENGINEERS JOIN NCAT STAFF

Two research engineers, Donald Watson and Brian Prowell, recently joined the NCAT staff.

Don Watson (dwatson@eng.auburn.edu) received his B.S. in Civil Engineering Technology from Southern Polytechnic State University in 1986 while working for the Georgia Department of Transportation (GDOT). During his career with GDOT Don served as state asphalt engineer and more recently as assistant state materials and research engineer.

Don has experience in laboratory and field testing, construction inspection and investigating construction problems, conducting pavement evaluations, and writing specifications for materials and construction procedures. Don wrote the specification for and implemented the Superpave asphalt mixture requirements as well as developing and implementing the contractor QC/QA testing program for GDOT. Don is nationally known for his experience with stone matrix asphalt and open-graded mixtures. He has also helped develop training and certification programs.

Don is actively involved in TRB committees related to HMA issues (A2D05) and surface requirements (A2D03), is a member of the Board of Directors of the Southeastern Asphalt User/Producer Group, and is a registered professional engineer in Georgia.

Brian Prowell (bprowell@eng.auburn.edu) received

his B.S. from Penn State in 1990, M.S. from Virginia Tech in 1992, and is currently working toward his Ph.D. at Auburn University. Prior to joining NCAT, Brian worked as an instructor for Virginia Tech, teaching civil engineering materials courses and as a senior research scientist for Virginia Transportation Research Council (VTRC).

Brian has conducted research on aggregate properties, asphalt content determination, cold-mix, pavement



Brian Prowell

density and permeability, performance graded (PG) binders, recycling, rut testing, SMA, Superpave mix design, and testing variability. Brian developed a state-of-the-art binder laboratory for VTRC and oversaw Virginia DOT's PG binder testing program. He was the lead implementation engineer for Superpave in Virginia.

He also performed troubleshooting and forensic testing for Virginia DOT. His teaching experience includes numerous courses and seminars on Superpave mix design and aggregate properties, asphalt pavement construction, asphalt material selection for various traffic loadings, pavement maintenance, and rehabilitation in conjunction with Virginia DOT and the Virginia Asphalt Association.

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



SPECIFICATION CORNER

Alabama - Alabama now uses Superpave, stone matrix asphalt (SMA), open-graded friction course (OGFC) and permeable asphalt treated base; conventional mixtures such as Marshall mixtures are no longer used. The gradation of OGFC has been made coarser with the material passing the 4.75 mm sieve limited to 25 percent. The allowable amount of the reclaimed asphalt pavement (RAP) in Superpave mixtures has been increased. RAP is now also allowed in SMA mixtures.

California - The special provisions for the reconstruction of the I-710 Freeway in Long Beach, California, contain a new approach to HMA mix requirements by requiring the contractor to provide mix design and performance data using the SHRP-developed shear and fatigue test equipment. For the HMA pavement to replace the existing PCC pavement, the "rich bottom" concept has been incorporated into the structural section. [This concept involves providing an HMA course containing high asphalt content at the bottom of the asphalt pavement structure to minimize the initiation of potential fatigue cracking from the bottom upwards.] In addition, tack coats are now required between all HMA lifts being placed. This was not required in the past if the next lift was placed immediately after placement of the underlying layer. For construction control on the I-710 project, the California Department of Transportation is using the Rice method (AASHTO T209) for determining the compaction level rather than their method for relative compaction, California Test Method 375.

Florida - The process of refining the Superpave QC 2000 specifications is continuing. Test data from many Superpave projects have been analyzed to reestablish the percent within limits (PWL) tolerances.

Kentucky - A number of specification revisions are being considered for next year: (1) implementing a minimum asphalt content for surface mixtures to address concerns about durability; (2) eliminating the restricted zone requirement in response to regional pressures and the preliminary results from NCHRP 9-14; (3) implementing the direct-tension tester as a normal part of PG binder testing regimen and acceptance program; (4) implementing a rut-test specification using the Asphalt Pavement Analyzer; and (5) strengthening the specification prohibiting diesel fuel usage in truck beds in response to an increase in the number of observed violations.

An immediate change in HMA specifications

regarding RAP is being considered. It is planned to restrict RAP usage to 20 percent in mixtures containing a virgin PG 76-22 binder. The best approach to implement the results of NCHRP 9-12 concerning a drop in the high- and low-temperature grades of the virgin binder for mixtures containing intermediate amounts of RAP, is being explored.

Montana - Optimum asphalt content for Superpave mixtures will be selected corresponding to 3.5 percent air voids rather than 4.0 percent air voids. This will increase the asphalt content and will address the concerns about long-term durability (including stripping) of Superpave mixtures. Although rutting is not expected, it has been planned to conduct some Hamburg wheel-tracking tests for comparing the performance of Superpave mixtures designed with 3.5 and 4.0 percent air voids.

Nevada - A binder specification for PG 76-22 NV to be used in southern Nevada has been implemented. Among others, this specification has requirements for original binder as follows: G^*/\sin^* of 1.40 kPa minimum, ductility at 4EC, dynamic shear consistency, sieve test, and polymer content. [A copy of the binder specification may be obtained from Michael A. Dunn of the Nevada Department of Transportation.]

New Jersey - Superpave Standard Insert will be used on HMA projects next year.

(continued on page 15)

DOWNLOAD NCAT RESEARCH REPORTS AT NO COST

Over 65 NCAT research reports are now available as PDF (portable document format) files which can be easily downloaded at no cost from our web site. You will need the Adobe Acrobat Reader, which can also be downloaded free from our homepage, to open these files. Visit our web site at <http://www.eng.auburn.edu/center/ncat> and click on **NCAT Publications**. Previous editions of **Asphalt Technology News** are also available from our homepage.

New York - The following changes have been made to the Superpave specification:

- The use of restricted zone in Superpave mix design has been eliminated. The decision was based on the experience with the pre-Superpave mixtures, results of the national studies, and current experience with Superpave mixtures.
- The current Superpave specifications which are special provisions, will be incorporated into the 2002 Standard Specification book.
- The number of primary PG binder grades used on department projects has been reduced from three (PG 58-34, PG 58-28, and PG 64-22) to two (PG 64-28 and PG 70-22). Other PG grades may be selected if project location and traffic conditions warrant their use.

North Dakota - Contractors' mix designs are increasingly being used.

South Carolina - A new specification to allow the use of a "Hot Mix Asphalt Thin Lift Seal Course" has been approved. This asphalt course will be used to seal the intermediate layer of HMA if the project's staging requires the layer to be open to traffic for an extended period of time. This mix will be left in place and overlaid with the appropriate HMA surface course.

South Dakota - A ride specification has been implemented, which uses IRI measurements obtained from a lightweight profilometer. Five projects were completed with the specification this year.

Five Superpave projects will be constructed next year. At the present time, most HMA projects are constructed using the Marshall design method with QC/QA specifications including contractor testing and incentive/disincentive price adjustments.

Utah - Significant changes have been made to the specifications for open-graded friction courses including deleting one of the two gradations which did not give desirable field performance.

Vermont - A new specification book which incorporates AASHTO MP1, "Performance Graded Binders," was issued this year.

Ontario, Canada - A new special provision for SMA was implemented this year. Highway selection criteria for using SMA and other mix types have been developed for use next year.

For smoothness, the contractor must now remove the slurry resulting from diamond grinding from the

site and dispose of it properly. Both day and night paving will be combined next year for price adjustments related to smoothness. The segregation specification will be fully implemented next year for all premium HMA surface courses.

A SHORT COURSE IN ASPHALT TECHNOLOGY

This training course has been developed by NCAT for practicing engineers who are involved with hot mix asphalt (HMA). The purpose of this one-week intensive course, which will be held on February 4-8, 2002 and March 11-15, 2002, is to provide a general understanding of all phases of HMA technology. Upon completion, the participant will be able to make knowledgeable decisions related to HMA pavements and communicate effectively with asphalt specialists when the need arises. NCAT will accept applications from practicing engineers from both private and public sectors in the United States and abroad. This includes personnel from the FHWA, state DOTs, FAA, Corps of Engineers, Air Force, Navy, county engineers, city engineers, consulting engineers, and contractors. Please call (334) 844-6228 ext. 110 or visit our web site at <<http://www.eng.auburn.edu/center/ncat>> (Click on "Education" at the top of the page, then click on "Upcoming Training Courses") for a brochure or information.

PROFESSOR TRAINING COURSE IN ASPHALT TECHNOLOGY

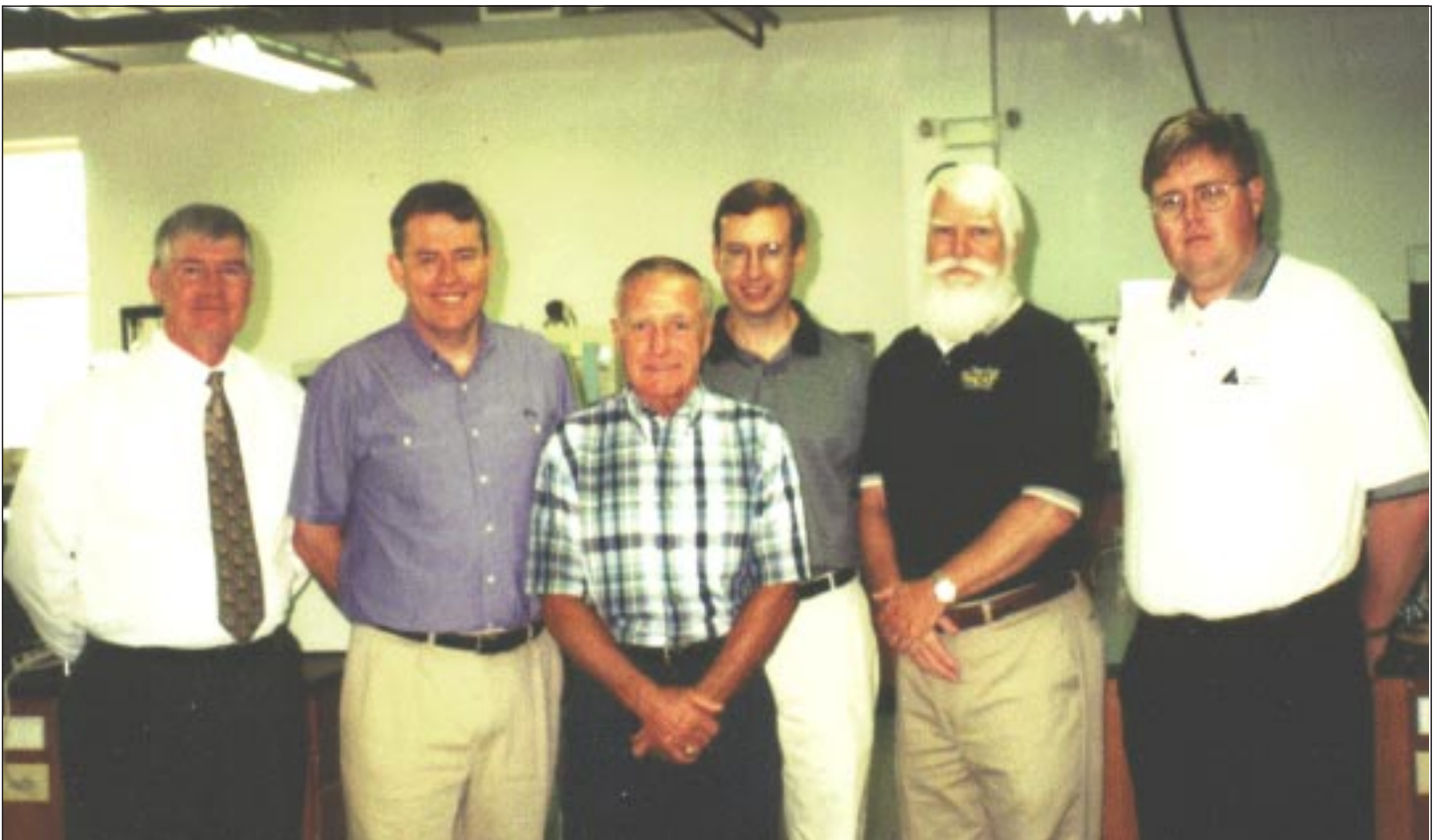
NCAT has written and published an up-to-date college textbook on asphalt technology. NCAT has also developed a training program for college and university civil engineering faculty that will allow them to offer state-of-the-art undergraduate and elective courses in asphalt technology. This 8-day intensive course is conducted at NCAT in June every year. It will be held on June 18-27 next year. The course has been updated to include Superpave binder and mix technology, and stone matrix asphalt (SMA). Some financial assistance in attending this course is possible. Please call NCAT at (334) 844-NCAT for brochure or information or visit our web site at <<http://www.eng.auburn.edu/center/ncat>>.

WORKSHOPS ON HMA MIX DESIGN AND CONSTRUCTION

Workshops on hot mix asphalt mix designs including Superpave will be held at NCAT on January 29-31, 2002, and February 19-22, 2002. These workshops consist of two and a half days of intensive lecture, demonstration, and hand-on training on HMA mix design procedures. Upon completion the participants will be able to conduct the HMA mix designs in their laboratories.

Workshops on "Asphalt Pavement Construction" will also be held on December 11-13, 2001, and January 22-24, 2002. These workshops cover laydown and compaction of HMA in detail.

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



Asphalt Institute (A.I.) engineers visited NCAT laboratories and test track in August.

From Left: Ray Brown, NCAT Director; Mike Acott, NAPA President; Bernie McCarthy, A.I. Vice President; Pete Grass, A.I. President; Tim Vollor, NCAT Lab Manager; and Mike Anderson, A.I. Director of Research.

NCAT's Professor Training Course, June, 2001



Front Row, L-R: Kunchi Madhavan, Brent Vaughn, Robert Pfauth, Michael Dunning, Alexander Appea, Subhi Bazlamit, Wayne Jones, Dean Massier

Second Row, L-R: Brad Putman, Dan Reeves, Xiaoduan Sun, Susan Tighe, Shabbir Hossain, Pedro Romero, Ken Kandhal, Charles Nunoo, Ray Brown

Back Row, L-R: Larry Sutter, Jim Lutz, Amitabha Bandyopadhyay, Wade Collins, Ben Richards, John Benson, Philip Ray, Allen Cooley, Bill Deyo, Doug Hanson

Not Pictured: Osama Abdulshafi



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