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NCAT Asphalt Content Tester Easy to Use, Also Avoids Use of Chlorinated Solvents

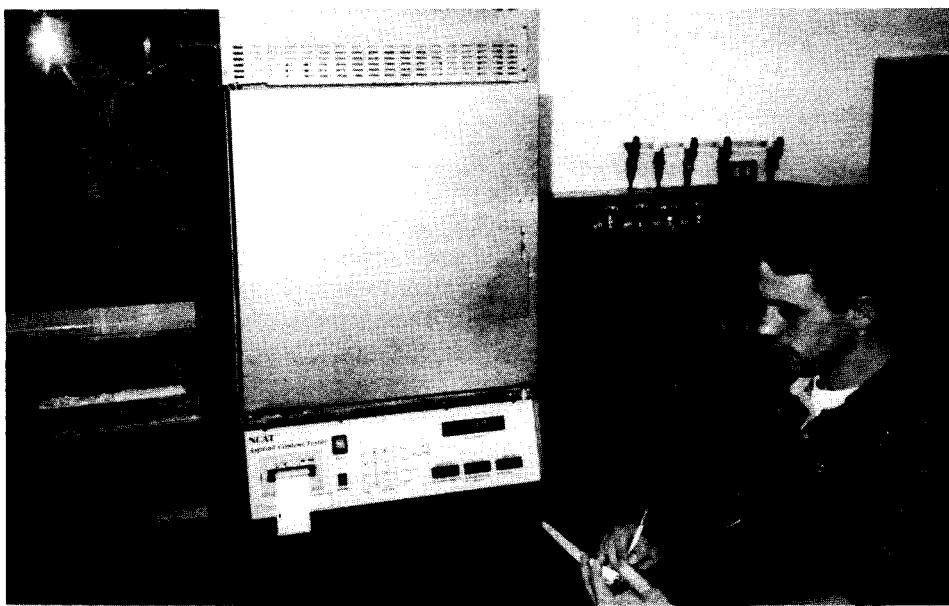
The National Center for Asphalt Technology (NCAT) completed a round-robin study in March to determine the accuracy and precision of the NCAT asphalt content tester. The Center has conducted research since 1990 to develop this test method for determining asphalt content of hot mix asphalt (HMA) mixtures by ignition (See the fall, 1994, issue of *Asphalt Technology News*). In the ignition method, a sample of HMA mixture (about 1,200 grams) is subjected to 538°C (1000°F) in a furnace to ignite and burn the asphalt cement from the aggregate. NCAT's work has resulted in a test procedure and equipment that automatically measures the asphalt content in 30-40 minutes. The gradation of the aggregate can then be determined

using standard sieve analysis. A larger HMA sample size (2,400 grams) can also be tested.

The HMA test sample is divided into two portions and placed in two stainless steel No. 8 mesh trays which are stacked on top of each other in the furnace of the NCAT asphalt content tester. The unit has a built-in scale with a digital readout underneath the furnace to weigh the HMA sample continuously during ignition. A built-in printer prints the asphalt content on completion of the test.

After equipment for the procedure was developed by Barnstead Thermolyne, 12 units of the NCAT asphalt content tester were purchased for round robin testing to determine the accuracy and precision of

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NCAT asphalt content tester in operation.

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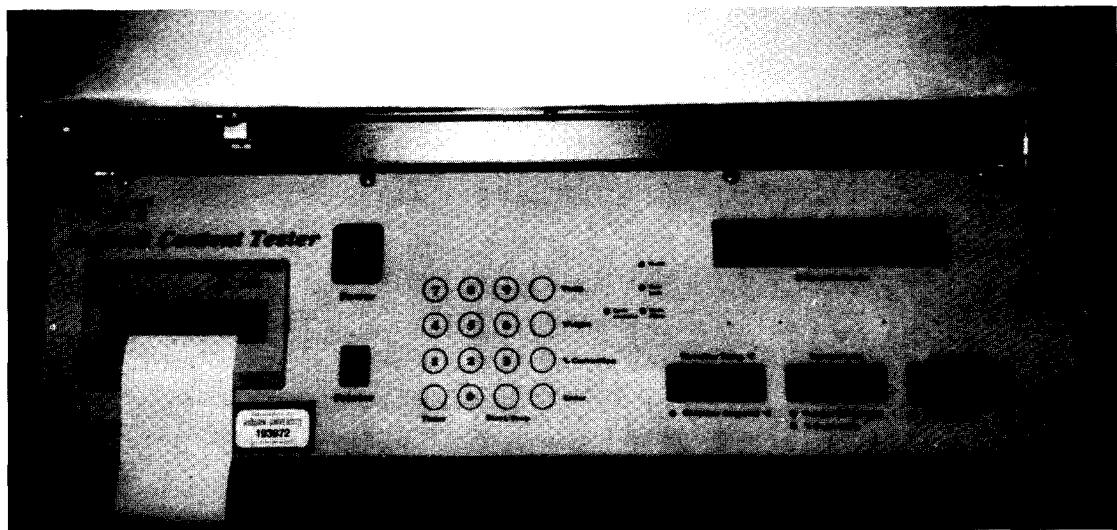
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Closeup of NCAT Asphalt Content Tester showing the built-in printer and digital readout



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the ignition test method. These units were provided along with laboratory prepared HMA samples to laboratories throughout the U.S. Four replicates of four HMA mixtures containing different aggregate types and asphalt contents were provided for testing. The participating laboratories (which

represented the FHWA, State DOTS and HMA producers) did not have knowledge of the asphalt content or aggregate gradation contained in the four HMA mixtures. Testing was completed by 12 laboratories and the results provided to NCAT for statistical analysis. Most aggregates experience minor mass loss (usually 0.2-0.3 percent) when subjected to 538°C (1000°F) temperature. Therefore, to optimize accuracy, a calibration factor has to be established for the aggregate used in the HMA mixture. The blended aggregate (without any asphalt binder) is placed in the furnace until a constant mass is achieved. The mass of the aggregate before and after ignition is used to calculate the calibration factor. This factor is loaded to the NCAT asphalt content tester which automatically adjusts the asphalt content. All 12 laboratories were provided with aggregate samples to establish their own calibration factors for the four HMA mixtures.

Two important items of information are obtained from round robin studies: (a) how close the test results are to the true properties (accuracy), and (b) what the variability is of the test results within a laboratory and between different laboratories (precision). Tables 1 and 2 (on page 3) provide the information on accuracy and precision, respectively. It is evident that the NCAT asphalt content tester can accurately measure the asphalt content of HMA mixtures, and the precision (as measured by standard deviation) of this method is significantly better than that of solvent extraction methods. As can also be seen in Table 1, the tester does not significantly affect the aggregate gradation during the ignition process. The percentages of aggregate passing the No. 4 and No. 200 sieve after ignition are reasonably close to the percentages actually incorporated in the HMA mixtures. Therefore, this test method has shown excellent potential for replacing solvent extraction methods, which are being eliminated due to growing health and environmental concerns associated with the use of chlorinated solvents. This test method is being proposed as an AASHTO standard test method.

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TABLE 1. NCAT Asphalt Content Tester Data

TEST	HMA MIX TYPE*			
	Gravel	Granite	Limestone	Traprock
Asphalt Content: Actual	6.00	6.00	5.00	5.50
Asphalt Content: Measured	5.98	5.99	4.97	5.53
% Passing No. 4: Actual	71.6	66.8	61.4	57.0
% Passing No. 4: Measured	71.5	66.6	61.4	56.6
% Passing No. 200: Actual	200: Actual	6.0	7.7	6.7
% Passing	No.200:Measured	5.6	7.7	7.2
				5.3
				5.1

* Each number shown is the average of 48 test results (12 laboratories x 4 replicates).

TABLE 2. Precision Statement

TEST PROPERTY	Standard Deviation, Percent		Acceptable Range of Two Test Results, Percent	
	Within Lab	Between Labs	Within Lab	Between Labs
Asphalt Content (NCAT Tester)	0.04	0.06	0.11	0.17
Asphalt Content (Solvent Extraction)	0.21	0.22	0.59	0.62

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.*

Tennessee (Bobby Rorie, Tennessee DOT)

We are planning to let an HMA paving contract in April bids using a modified asphalt cement that can be met using a "multigrade" asphalt cement.

Indiana (Rebecca McDaniel, Indiana DOT)

We will have four Superpave level 1 projects in 1995 that will include SHRP grades PG 58-28, PG 70-28, and PG 64-34. We will also have one project that will use crumb rubber modifier (CRM) in the wet process for an open-graded binder mixture that is intended as a drainage layer.

Maine (Warren Foster, Maine DOT)

We have used both the dry and wet process to add crumb rubber to HMA mixes. Very few tires were used. Benefits observed to date do not justify the added cost.

Peoples' Republic of China (Jia Yu, Department of Communications)

The Central Testing Laboratory of Jiangsu Department of Communications is procuring SHRP asphalt equipment with a loan from the World Bank. The asphalt binder testing equipment will include a dynamic shear rheometer, bending beam rheometer, Brookfield rotational viscometer, pressure aging vessel, rolling thin film oven, and direct tension tester. The HMA mix testing and evaluation equipment includes the Superpave gyratory compactor, Superpave shear tester, and net adsorption test device. A Marshall compactor to compact 150 mm (6 inches) diameter specimens has been purchased already. This equipment will be used to evaluate the performance of asphalt binders and HMA mixtures used on the Nanjing-Shanghai expressway. A SPS-9 project is also being planned for validating Superpave in Chinese environments.

Connecticut (Charles Dougan, Connecticut DOT)

A task force has been formed to focus on improving the practices and procedures used in placement of hot-mix asphalt (HMA) pavements. Topics will include mix designs; plant operations, including truck loading; placement operations; longitudinal joints; segregation and rideability. The primary focus will be on segregation. Task force representatives are from the following areas: manufacturing, contracting, Federal

Highway Administration, the Asphalt Institute and Connecticut Department of Transportation.

South Carolina (Milt Fletcher, South Carolina DOT)

What are other states' approval procedures for overnight storage of hot mix asphalt (HMA) in silos?

Rhode Island (Francis Manning, Rhode Island DOT)

A number of asphalt modifier salespersons (including crumb rubber modifier salespersons) and some researchers have approached us with test results based on the SHRP binder testing protocol claiming that their modified asphalt binders would outperform virgin asphalt cement binders. However, it is our understanding that the SHRP binder tests and specifications were developed for virgin asphalt cements, and we believe that extending these to modified asphalt binders may not necessarily be appropriate and valid. Because the new SHRP specifications may force us to use modified asphalt binders, we would like to know the opinion of other states and user agencies.

Ohio (Dave Powers, Ohio DOT)

The Ohio DOT experimented with medium traffic dense-graded surface mixes in 1994 by (a) controlling the gradation of the fine aggregate, (b) lowering the percentage passing No. 4 sieve, and (c) using 3.5 percent air voids for increased asphalt content. These 1994 field experimental trials were successful.

Australia (John Bethune, Australian Asphalt Pavement Association)

The Australian Asphalt Pavement Association (AAPA) has developed a draft code of practice for the manufacture and laying of SBS modified HMA mixtures. This standard will be finalized about mid 1995. A guide to good practice in asphalt laboratories was issued in February.

Most stripping of HMA pavements in Australia has been confined to airfield hard standing and taxiways in the past. A number of stripping problems have occurred on a national highway and appear to be caused by a combination of pavement structure allowing water into the HMA base course, and the use of adhesion agents.

ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the fall, 1994, Asphalt Forum.

We would like to hear from other states as to how they run extraction tests on HMA mixes containing SBR or crumb rubber modifiers(CRM). How effective is the nuclear asphalt gauge in determining the asphalt content of these modified HMA mixtures? (Ron Collins, Georgia DOT)

Maryland (Stanley Miner, Maryland State Highway Administration)

Nuclear asphalt determinations using a Troxler 3241-C asphalt content gauge were performed on plant produced rubber modified HMA mixes during 1993. Tests were performed on the dry and wet processes using various percentages of crumb rubber modifier (CRM) in the mix. Different percentages of CRM did not appear to affect the accuracy of the gauge; however, results did vary slightly from mix to mix. We have tested a number of open graded friction courses and SMA with SBR with normal correlation to the reflux method. The major problem tends to be in sampling. In my opinion, nuclear gauge test results are as reliable for SBR and rubber modified mixes as they are for "normal" mixes, as long as the same care is taken in preparing the gauge and sample pans.

Virginia (Bill Maupin, Virginia Transportation Research Council)

Crumb rubber presents problems for extraction tests. The nuclear asphalt content gauge performed well on several

asphalt rubber jobs in Virginia using the wet method. It has been used minimally on some jobs containing polymer-modified mixes. The ignition furnace method of asphalt content determination (developed by the NCAT) may be a solution for the future in determining the binder content of mixes containing modifiers.

Texas (Maghsoud Tahmoressi, Texas DOT)

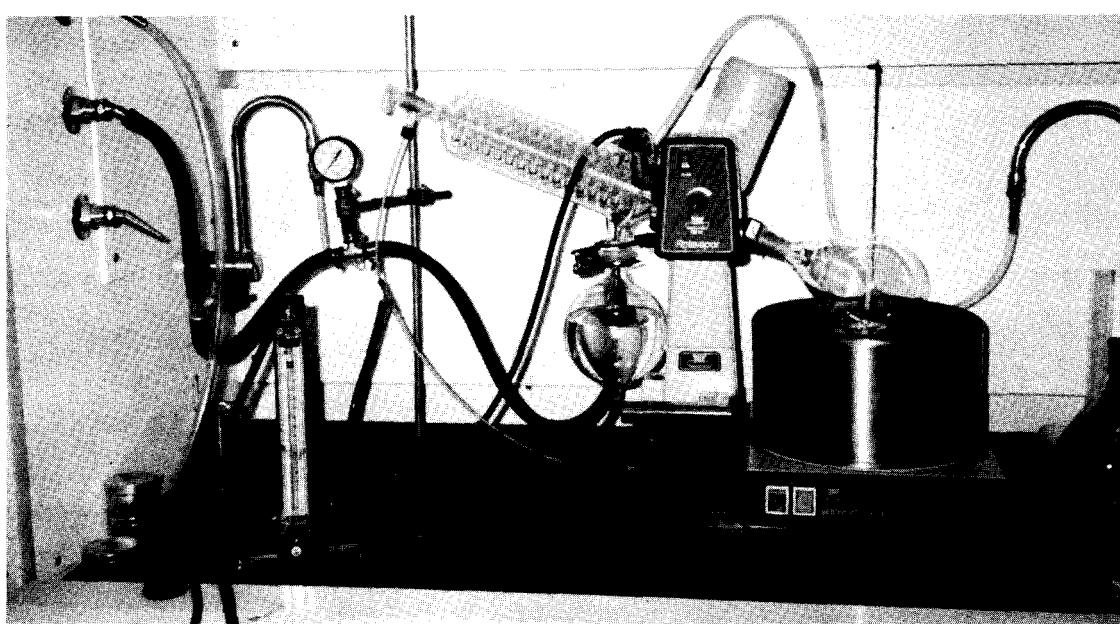
We have found nuclear asphalt content gauge to be very effective in measuring asphalt content of all HMA mixes. We do run extraction on SBR modified HMA mixes with both chlorinated and non-chlorinated solvents. When using vacuum extraction, we find it necessary to increase the amount of filter aid to 100 grams for SBR modified mixes.

Wisconsin (Bob Schmiedlin, Wisconsin DOT)

The Wisconsin DOT uses the standard trichloroethylene extraction procedure for HMA mixes with these materials. We have used this procedure in a limited number of extractions of modified binders and have not experienced any problem.

Does any state have specifications for density at the longitudinal joint of HMA pavements ? If so, are the specifications effective? (Maghsoud Tahmoressi of Texas DOT)

(Continued on page 6)



Rotovap equipment is used in the NCAT Laboratory to recover asphalt binder from HMA mixtures.

(RESPONSES. Continued from page 5)

Wisconsin (Bob Schmiedlin, Wisconsin DOT)

The Wisconsin DOT does not have a specification for density at the longitudinal joint of HMA pavements, however, we are conducting a study evaluating various construction techniques of longitudinal joints. Collected data includes density measurements at the joints. The study has lead to the optional use of a notched and tapered (12:1) joint with the method possibly becoming standard in 1996.

Maryland (Jack Zies, Maryland State Highway Administration)

We have a Maryland Standard Method of Test for Longitudinal Joints; however, we do not seem to have a problem in density. We are in the process of changing our random sample site location procedure so the longitudinal joints will be included.

We would like to know which states use the effective specific gravity of the aggregate to determine the voids in the mineral aggregate (VMA). If so, how do they account for absorption of the asphalt binder? What percentage absorption value is assumed, if any? (Doug Coleman, Michigan DOT)

Virginia (Bill Maupin, Virginia Transportation Research Council)

Virginia uses the aggregate bulk specific gravity to determine VMA. We formerly used the effective specific gravity but felt that the higher VMA indicated from the effective specific gravity was detrimental for some of our mix designs. Virginia does use a shift factor which is established from the difference between the bulk and effective specific gravities during the design to prevent having to run bulk gravities on aggregates for each set of field Marshalls.

New Jersey (Eileen Connolly, New Jersey DOT)

New Jersey DOT uses the effective specific gravity in determining the voids in mineral aggregate. The absorption of the asphalt binder is not accounted for which is technically incorrect. Problems with inconsistent results in aggregate

bulk specific gravities, especially with stone screenings, have discouraged us from pursuing more technically correct calculations.

Texas (Maghsoud Tahmoressi, Texas DOT)

We converted to using effective specific gravity of aggregates for VMA calculations. Our research showed that the difference between effective and bulk specific gravity values was within acceptable test tolerances. However, we did not see a consistent difference between VMA values calculated by the two methods.

Wisconsin (Bob Schmiedlin, Wisconsin DOT)

Wisconsin DOT uses effective specific gravity to determine the VMA, but does not account for aggregate absorption.

When taking hot bin samples at HMA batch plants, what sample sizes do other states require from the coarse aggregate bins? (Gary Robson, West Virginia DOT)

South Carolina (Milt Fletcher, South Carolina DOT)

Before sampling a hot bin, we pull about 1,000 pounds from the bin in order to get a representative sample. Then we obtain a 50 to 75 pound sample using the sampling tray. The sample should be reduced according to AASHTO T248 titled "Reducing Field Samples of Aggregate to Testing Size." The minimum weight of the coarse aggregate sample will depend on the nominal maximum aggregate size as required by AASHTO T27 titled "Sieve Analysis of Fine and Coarse Aggregates." Most of our reduced coarse aggregate hot bin samples are in the range of 10-22 pounds.

Some of the older batch plants are not equipped with sampling trays. Hot bin samples are taken by first pulling 1,000-2,000 pounds of bin material through the plant to clean out the pugmill. Then another 1,000-2,000 pounds of coarse hot bin material are collected in a loader bucket. A representative sample is taken from the loader bucket and reduced to an appropriate sample size.

New Jersey (Eileen Connolly, New Jersey DOT)

The minimum sample weights for testing required by New Jersey DOT are: 25 pounds for bins No. 5 and No. 4, 10 pounds for bin No. 3, and 2 pounds for bin No. 2.

Maryland (Tim McCusker, Maryland State Highway Administration)

Maryland's QC/QA specification requires a composite sample of the individual hot bins by percentage of mix. Therefore, sufficient materials from each hot bin must be obtained (approximately 35 pounds minimum per hot bin). The samples are reduced to the size which is specified in AASHTO T27 (sieve analysis of coarse and fine aggregates) corresponding to the maximum nominal size of the aggregate.

Texas (Maghsoud Tahmoressi, Texas DOT)

We require a minimum ten pounds sample size. This sample is then split for further testing.

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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:

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PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of the Transportation Research Board (TRB) in January, in Washington, D.C. Observations and conclusions reported from these papers may be of value to field engineers. These comments are obtained mostly from research projects with a limited scope. Before application to practice, it is recommended that the entire paper be read to determine any limitations. Titles of the papers are given, with names of author(s) in parentheses, followed by NCAT's summary.

1. EVALUATION OF SUPERPAVE GYRATORY COMPACTOR IN THE FIELD MANAGEMENT OF ASPHALT MIXES

(Harman, D'Angelo, Bukowski and Ferragut)

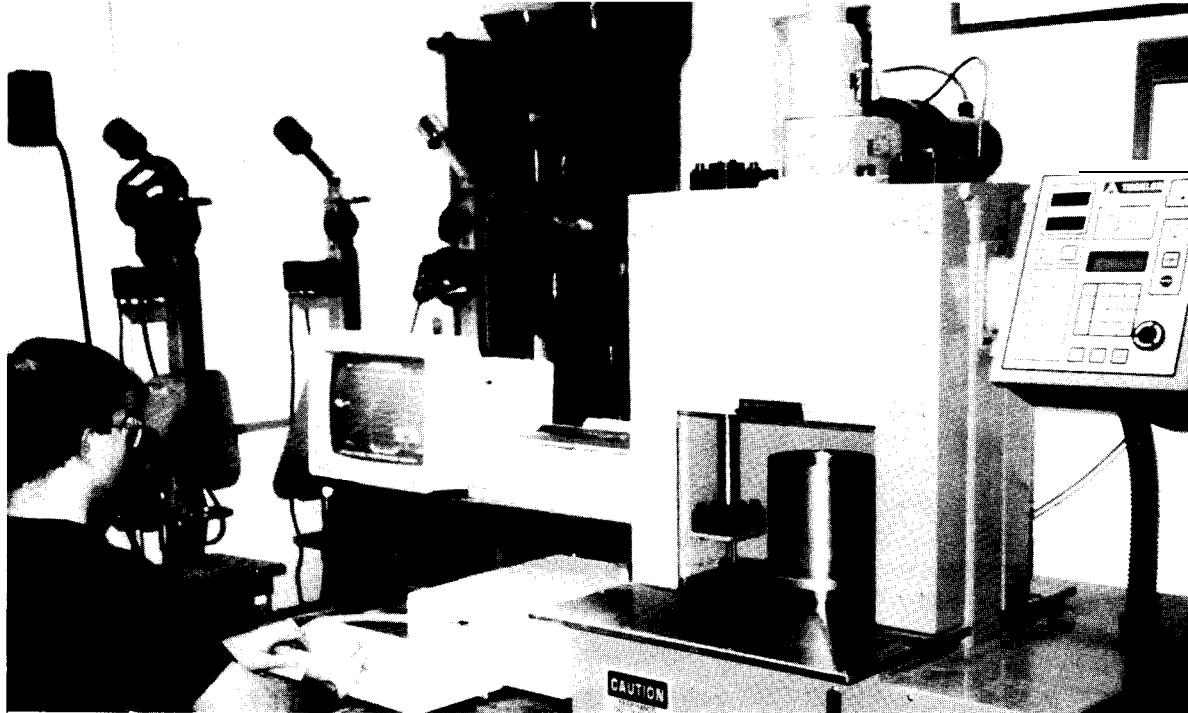
The Federal Highway Administration (FHWA) has implemented a demonstration project (number 90), "Superpave Asphalt Mix Design and Field Management" which centers around two fully equipped mobile asphalt laboratories. For a simulation study, one of the laboratories is brought onto an active paving project site to conduct a Superpave level I mix design and conduct daily tests on the HMA mixture produced by the HMA plant. In the past, the FHWA generally used the Marshall test procedure to demonstrate the concept of volumetric properties in field quality management of HMA mixtures. However, the Superpave mix design system uses a Superpave gyratory compactor (SGC) in lieu of a Marshall compactor. Therefore, the FHWA visited four paving sites to obtain data on

volumetric properties by both Marshall and gyratory compactors for comparative purposes. Three projects were designed by the Marshall procedures and one project was designed by Superpave level I procedures. Three HMA mixtures were compacted with 75 blows/side (or 112 blows/side for six-inch diameter specimens) and one HMA mixture was compacted with 50 blows/side. The design number of gyrations (N_d) for SGC was based on the traffic and climate at the paving site.

The following observations were made from this project:

- The SGC provided a significantly higher compactive effort at N_d compared to 50 or 75 blows of the mechanical Marshall hammer. On average, the SGC compacted specimens had 1.7 percent lower voids in the total mix (VTM) and 1.6 percent lower voids in the mineral aggregate (VMA) compared to Marshall specimens.

(Continued on page 8)



Superpave gyratory compactor is used extensively in the NCAT Laboratory

- The SGC reacts differently to variations in asphalt content and gradation than the Marshall compactor. Therefore, there is no fixed factor that can be established to estimate gyratory volumetrics from Marshall compacted specimens.
- Because of the preceding observation, the use of Marshall compactor as a field surrogate for HMA mixes designed under the Superpave system does not provide effective mix verification.
- The SGC provides an effective means for production mix verification of design volumetric properties and field quality control of HMA mixes. The effectiveness of this new tool for field management is tied to the selection of pertinent acceptance parameters and the determination of their associated tolerance limits. The following volumetric acceptance parameters and their associated tolerance limits from the job mix formula are recommended from this study: asphalt binder content (± 0.4 percent), VTM (± 1.2 percent), and VMA (± 1.0 percent).

2. MECHANISTIC EVALUATION OF ASPHALT CONCRETE MIXTURES CONTAINING RECLAIMED ROOFING MATERIALS (Ali, Chan, Potyondy, Bushman and Bergan).

This study was carried out to determine the feasibility of using reclaimed roofing material (RRM) in HMA pavement. The paper presents the results of a mechanistic evaluation of three HMA mixes containing 0, 15, and 25 percent RRM by weight of the mix. Using laboratory prepared specimens of RRM mixes mechanical properties such as resilient modulus, creep and permanent deformation, fatigue, and moisture sensitivity of these RRM mixes were determined. Performance of representative RRM pavements were modeled using the VESYS performance prediction model. Performance parameters, such as rut depths, cracking index, and the present serviceability index, were used to assess potential improvements of HMA mixes using RRM.

A common RRM discarded by contractors at residential sites was used. The RRM was shredded in the laboratory by freezing it to approximately -10°C and then shredding it with a 10" circular carbide tipped blade on a chop saw. RRM at ambient temperature was added to and mixed with crushed aggregates which were preheated to about 150°C. Virgin asphalt cement (200-300 penetration grade) was then added to the mix and blended thoroughly. The hot asphalt mix was then compacted with 75 blows/side with a Marshall compactor. All three HMA mixtures satisfied the Marshall mix design criteria. Since the asphalt binder in the RRM was taken into account, the virgin asphalt cement content had to be reduced from 5.25 percent for control mix to 1.87 percent for the mix containing 25 percent RRM, a reduction of almost three percent.

The following conclusions have been drawn from this laboratory study:

- Acceptable HMA mixes containing up to 25 percent RRM by weight can be produced at a savings of approximately 3 percent asphalt cement as compared to conventional HMA mixes.
- Permanent deformation prediction results strongly suggest that an increase in RRM content (up to 25 percent) reduces the rutting potential in HMA pavements.
- The use of RRM in asphalt mixes improves fatigue life of HMA pavements, especially at 25 percent RRM content.
- Although field verification is required, preliminary analysis using the VESYS model predicts that the mix containing 25 percent RRM will outperform the other two mixes (0 and 15 percent RRM), resulting in smaller rut depth, and less fatigue cracking. This in turn gives an improved serviceability index.
- Recycling waste roofing material in HMA pavement is commercially feasible with existing technology. However, expensive start-up costs encountered in large scale production may limit its usefulness.

3. SHRP PROPERTIES OF ASPHALT CEMENT (Hanson, Mallick and Foo)

This paper presents the results of a study of 48 asphalt cements being used in the Southeastern United States. These viscosity graded asphalt cements were tested using the current capillary tube testing technology and new SHRP (Strategic Highway Research Program) technology. The test results were evaluated to determine how the viscosity graded asphalt cements relate to the new performance grades (PG) developed by SHRP.

The 48 asphalt cements consisted of 24 AC-30, 23 AC-20, and one AC-10 asphalt cements. Stiffness ($G^*/\sin\delta$) measurements were made at 64°C and 70°C on original or neat asphalt cements and rolling thin film oven (RTFO) residues of all asphalt cements were tested using the dynamic shear rheometer (DSR). Similar measurements were made at 7°C, 10°C and 13°C on pressure aging vessel (PAV) residues of all asphalt cements. Stiffness (S) and slope (m) were also measured on PAV residues of all asphalt cements at -6°C, -12°C, and -18°C using a bending beam rheometer (BBR).

The following observations were made after analyzing the test data:

- Of the 24 AC-30 asphalt cements, 23 graded to be a PG "64", and one graded to be a PG "70". On the cold temperature regime, 16 of the AC-30 asphalt cements graded to be a PG "-22", six graded to be a PG "-16", one graded to be a PG "-28", and one graded to be a PG "-34".
- Of the 23 AC-20 asphalt cements, 19 graded to be a PG

"64" and four graded to be a PG "58". On the cold temperature regime, 16 of the AC-20 asphalt cements graded to be a PG "-22", four graded to be a PG "-16", and three graded to be a PG "-28".

- The AC-10 asphalt cement tested graded to be a PG grade 58-22.

• The AC-20 and AC-30 asphalt cements currently being used in the southeastern United States generally meet the requirements of a PG-64 grade.

• Viscosity of neat asphalt cement (60°C) shows a fairly strong correlation with DSR stiffness ($\text{G}^*/\sin\delta$ at 64°C and 70°C). Typically, an AC "16" would meet the requirements of a PG "64" and an AC-40 might meet the requirements of a PG 70 grade.

• For the asphalt cements in the study, the BBR slope "m" value was found to be about 0.27 for the corresponding stiffness "S" value of 300 MPa. Therefore, the currently specified "m" value of 0.30 will be the controlling value for the PG graded asphalt binder specifications.

4. DEMONSTRATION OF A VOLUMETRIC ACCEPTANCE PROGRAM (Aschenbrener)

At the present time, the Colorado DOT (CDOT) field acceptance specification uses gradation, asphalt content, and density of the compacted mat. When using this field acceptance specification, rutting was a sporadic but persistent problem. The field verification data collected on 74 HMA projects were evaluated and correlated with known field performance. Air voids were also measured in the wheel path of 33 pavements and correlated to pavement performance. Pavements with rut depths greater than or equal to 8 mm (0.3 inch) were considered unacceptable. The following conclusions were drawn from the study of these 74 pavements:

- An air void content of 3.0 percent in the wheel path of the pavement tended to delineate between the pavements with good and poor rutting performance. The pavements that rutted generally had less than 3.0 percent air voids in the wheel path.
- An air void content of 3.0 percent in the laboratory compacted samples of plant produced HMA mixture also delineated between pavements with good and poor rutting performance. When field verification air voids were less than 3.0 percent, there was a high probability the pavement rutted.
- The Hveem stability and air void properties from field verification are related to the air voids in the wheel path and the pavement's rutting performance. Therefore, acceptance specifications for HMA based on Hveem stability and air

void properties from field verification samples should be related to performance. It is believed the volumetric acceptance test results will relate more closely to the long-term performance of the pavement than the gradation acceptance test results.

Based on the preceding observations, CDOT is considering changing its gradation acceptance specification to a volumetric acceptance specification. The proposed acceptance specification uses five elements to calculate the pay factor. These elements include field compaction, air voids, voids in the mineral aggregate (VMA), asphalt content, and Hveem stability. A six-year plan has been developed to implement the new specification.

5. PERFORMANCE OF RECYCLED HOT MIX ASPHALT MIXTURES IN STATE OF GEORGIA (Kandhal, Rao, Watson and Young)

The Georgia Department of Transportation (GDOT) has been constructing recycled HMA pavements routinely for about four years. Most of the recycled pavements in Georgia have been constructed using AC-20 asphalt cement whereas virgin HMA pavements are generally constructed using AC-30 asphalt cement. This research project was undertaken (a) to evaluate the performance of hot recycled and virgin (control) HMA pavements, and (b) to review GDOT's present hot recycling specifications and recommend changes where necessary. Only the dense-graded HMA wearing courses were evaluated in this project.

Five HMA projects, each consisting of a recycled section and a control section, were subjected to detailed evaluation. The percentage of recycled asphalt pavement (RAP) material in the HMA mixtures ranged from 10 to 25 percent. In-situ mix properties (such as percent air voids, resilient modulus, and indirect tensile strength), recovered asphalt binder properties (such as penetration at 25°C , viscosity at 60°C , SHRP rutting factor $\text{G}^*/\sin\delta$ at 64°C , and SHRP fatigue factor $\text{G}^*\cdot\sin\delta$ at 22°C), and laboratory recompacted mix properties (such as Gyratory Stability Index (GSI) and confined, dynamic creep modulus at 60°C) were measured. The pavement surface was evaluated to quantify the extent of distresses such as rutting, raveling, and alligator cracking.

The following conclusions have been drawn from this study:

- Both recycled and virgin sections of the five projects are performing satisfactorily after $1\frac{1}{2}$ to $2\frac{1}{4}$ years in service with no significant rutting, raveling, and fatigue cracking.
- There was no statistically significant difference between the following properties of recycled and virgin sections of the five pavements:
 - (a) In-situ mix properties such as percent air voids, and resilient modulus at 25°C measured on pavement cores.
 - (b) Aged asphalt binder properties such as penetration at 25°C , viscosity at 60°C , SHRP rutting factor $\text{G}^*/\sin\delta$ at

64°C, and SHRP fatigue factor $G^* \cdot \sin\delta$ at 22°C measured on asphalt binders recovered from pavement cores.

(c) Recompacted mix properties such as percent air voids, GSI and confined dynamic creep modulus at 60°C measured on specimens compacted in the laboratory using the HMA mix from the pavements.

•Based on the preceding conclusions, it can be implied that the existing Georgia DOT hot recycling specifications, recycled mix design procedures, and quality control are satisfactory. The specification to achieve a viscosity (60°C) of 6,000 to 16,000 poises for the blend (RAP binder + virgin binder) appears reasonable based on the present data.

SHRP IMPLEMENTATION UPDATE

by
A. Haleem Tahir - AASHTO

With its latest ballot in October, 1994, the AASHTO Subcommittee on Materials (SOM), approved and adopted Superpave binder and mix design tests in the form of provisional standards. These standards are included in the March, 1995, AASHTO Publication on provisional standards. The Superpave tests included are:

AASHTO No.	Designation	Title
1	MP1-93	Specifications for Performance Graded Binders
2	PP1-93	Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel
3	PP2-94	Practice for Short and Long Term Aging of Hot Mixed Asphalt (HMA)
4	TP1-93	Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using The Bending Beam Rheometer (BBR)
5	TP3-93	Test Method for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
6	TP5-93	Test Method for Determining the Theological Properties of Asphalt Binder Using a Dynamic Shear Rheometer
7	TP48-94	Test Method for Viscosity Determination of Unfilled Asphalts Using the Brookfield Thermosel Apparatus
8	TP6-93	Test Method for the Measurement of Initial Asphalt Adsorption and Resorption in the Presence of Moisture
9	TP4-93	Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens By Means of SHRP Gyratory Compactor
10	TP7-94	Test Method for Determining the Permanent Deformation and Fatigue Cracking Characteristics of Hot Mix Asphalt (HMA) Using the Simple Shear Test (SST) Device
11	TP9-94	Test Method for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device

In addition to the Superpave protocols, the publication contains many other provisional standards based on SHRP products.

The software for the processing of the Superpave test data for the Level 1 volumetric design will be available for distribution in May, 1995. Level 2 and 3 software should be available by the end of the year.

Under the pool fund equipment first round purchase program, 25 state DOTS have been equipped to perform all the Superpave binder tests except the direct tension AASHTO TP3 tests. A redesigned version of this equipment is being evaluated by the FHWA before a wholesale purchase could be made for the states. The delivery of binder equipment under the second round purchase for the remaining state DOTS is scheduled in June, 1995.

The Superpave gyratory compactor (AASHTO TP4) will be available to the states in June, 1995. With the availability of binder equipment and gyratory compactors, the states will have the capability of doing Level 1 mix designs.

The pool fund procurement of relatively expensive and complex equipment units for the Level 2 and 3 mix designs is on a cautious track. The FHWA is acquiring six Superpave shear testers and six indirect tensile creep test devices (AASHTO TP7 and TP9) for experimental purposes. The five Superpave centers and the FHWA's research center will receive one set each by late summer 1995. Further procurement of these units for the states will be based on the information gathered in these centers over a six-month trial period.

Other implementation initiatives include an ongoing NCHRP Project 9-7 entitled "Field Procedures and Equipment to Implement SHRP Asphalt Specifications". The project is expected to yield quality control and quality assurance (QC/QA) procedures as they apply to Superpave. The project should be completed within the next year. At least a dozen states have already built a Superpave Level 1 design section as a part of field validation study. It is anticipated that the states will be specifying and building Level 1 design by 1997 and will be conducting field experiments with Level 2 and Level 3 designs no later than 2000.

SPECIFICATION CORNER

Wisconsin - The Wisconsin DOT (WisDOT) will specify use of asphalt cement according to a dual specification for either penetration-graded or viscosity-graded asphalt cements in 1995. Begun in 1994, and continuing through 1995, the WisDOT will specify, by special provision specifications, an optional notched and tapered (12:1) longitudinal joint for HMA pavements. The study will investigate the use of this technique with the method possibly becoming standard by 1996. To encourage the use of reclaimed asphalt pavement (RAP) material in the HMA mixtures, the WisDOT has implemented a policy to pay contractors for the asphalt cement binder contained in RAP material.

Ohio - The Ohio DOT will no longer use asphalt cement blending charts (no Abson recovery of asphalt cement needed) if the RAP content in the hot recycled HMA mixture is less than 25 percent. The maximum permissible RAP content has been reduced from 30 to 20 percent in the surface courses, and from 50 to 35 percent in the binder courses. The Ohio DOT will also selectively use loaded wheel testers on heavy traffic mixes to evaluate rutting potential.

Michigan - The Michigan DOT will use the new SHRP Performance Graded (PG) Asphalt Binder Specification in several projects in 1995 and 1996.

New Jersey - The New Jersey DOT has developed a specification to allow the use of RAP in dense-graded HMA base courses.

Maine - Work is continuing in quality control/quality assurance (QC/QA) specifications. One project was completed in the fall of 1994. No bonus or penalties were assessed. It is hoped to incorporate QC/QA specifications into four or five projects in 1995.

West Virginia - The West Virginia DOT will continue to use new end-result specification on all HMA paving projects in 1995 after a successful trial year in 1994.

Texas - QC/QA specification has been modified based on experience gained in 1994. Crumb rubber modified (CRM) hot mix specification (dry process, wet process, and open-graded friction course) has been revised to require 30 mesh crumb rubber. Eight CRM projects: five wet process, two dry process and one open-graded friction course, were completed in 1994. All projects are performing satisfactorily at the present time.

Ontario, Canada - A draft end-result specification for smoothness based on the California Profilograph will be finalized this spring. A simulation using the new specification will be undertaken for at least one HMA paving contract advertised in 1995. More simulations are planned for 1996.

The special provisions for acceptance of asphalt content and aggregate gradation have been revised as follows: (a) coring will no longer be allowed for re-testing, and (b) lots for asphalt content/gradation and compaction will be run parallel. The specification for verification of contractor mix design (administration of Marshall air voids, etc.) has been revised to increase the rejection limits for air voids from 2.0 to 2.5 percent. It was felt that 2.0 percent was much too low.

Australia - Current sealing and asphalt binders are specified without a focus on their performance related properties. A revision of the Australian standard for residual bitumen is about to start with the aim of introducing performance based specifications for asphalt grade binders.

Israel - Penetration grade asphalt cement specification (similar to ASTM D946) was changed to viscosity grading (similar to ASTM D3381) in 1994. -



Department of Transportation Donates Historical Texts to NCAT

Mr. Larry Lockett of Alabama Department of Transportation has donated three historical textbooks pertaining to highway construction and asphalt pavements. These books were published in 1905 and 1908. We appreciate his kind gesture.

We solicit donations of asphalt related books and journals (such as AAPT, ASTM and Transportation Research Board) from others.

Non-Conventional Pavement Mixes Set the Standard in Georgia

by

Donald E. Watson

Assistant State Materials and Research Engineer
Georgia Department of Transportation

Since the first hot mix asphalt (HMA) pavement was placed, federal, state, and local transportation agencies have looked for ways to make these systems perform better and last longer. Much of the emphasis of the recent SHRP research program was to find a better way of defining and measuring performance-related properties of these mixtures so that overall performance could be predicted and improved.

The European Asphalt Study Tour of 1990 was also conducted in order to investigate European methods for designing, contracting, and constructing pavement systems. One of the most widely publicized discoveries of that tour concerned stone matrix asphalt (SMA) pavements. Another discovery that is just as exciting, but less publicized, involves the Porous European Mix. Ronald Collins, state materials and research engineer for the Georgia Department of Transportation, says, "We think SMA mix, or a type of SMA mix, is the mix of the future for helping eliminate the rutting problems we have experienced in the past due to our hot summer temperatures and heavy traffic loading conditions."

Georgia has been accused of using a "belt and suspenders" approach in that both polymers and fibers are used in the SMA and porous mixes. The polymer modified asphalts have an increased softening point nearly 22°C (40°F) higher than conventional paving asphalt cements. This allows the asphalt binder to remain stiff even in hot southern climates. The stabilizing fibers form a reinforcing network which holds the thick asphalt film in place on the aggregate particles during production and placement of these mixes so that draindown of the asphalt cement is not a problem.

The stone-on-stone concept of the SMA mix design procedure provides more efficient distribution of load-related stresses throughout the HMA pavement, which is instrumental in reducing rutting potential. However, the increased fatigue life of the SMA mixes is also a clear advantage. Preliminary fatigue tests conducted by the Georgia Institute of Technology show that SMA mixes endure 10 times, or more, the number of cycles to failure as conventional mixes. This supports claims by Europeans that SMA mixtures have 20-40 percent increase in service life over conventional mixtures.

According to Collins, SMA mixtures have held up well, and after nearly four years, with the rut depth about 1.5mm (1/16 inch) in the first SMA test section placed in Georgia. This test section undergoes about 2 million ESAL's per year due to heavy traffic volume. As a result of the potential benefits of SMA mixtures, Georgia DOT has implemented a policy requiring SMA on all interstate projects in lieu of the

dense-graded surface mix used in the past.

Another mix that is also being required on all interstate projects in Georgia is a modified open-graded friction course (OGFC) based on the European porous mixes. The OGFC is placed over SMA. Collins adds, "From a public relations standpoint, the modified OGFC is one of the most positive things we have done in recent years." The traveling public readily notices improved driving conditions on this surface course due to a reduction of backspray and enhanced water drainage characteristics.

This modified OGFC is coarser than traditional OGFC mixes and has resulted in a permeability at least two to three times greater than OGFC mixes of the past. The coarser gradation has also resulted in a binder film thickness about 30 percent greater than previous mixes. The Georgia DOT uses both polymer modified asphalt and mineral fibers to stabilize the thick asphalt film. These modifications also allow OGFC mixtures to be produced at temperatures around 163°C (325°F) as compared to mix temperatures of about 121°C (250°F) for traditional OGFC mixtures. This difference is significant for improving workability of the mix. While aggregates with low absorption are used in Georgia, these production temperature differences would also be very beneficial for those states which have highly absorptive aggregates and have experienced moisture problems when producing these mixtures in the past.

In spite of the advantages, use of these non-conventional mixes has presented problems which must also be overcome. Even at higher production temperatures, the mixtures are still harsh. As Collins states, "You have to do all the things you have been taught to do right." Continuity of operations is critical for these mixes. These mixtures are also expensive. However, agencies must look beyond the initial capital outlay and consider the total life cycle cost. Once this is done, it is obvious that the payoff for using these mixes can come quickly.

These non-conventional mixes have begun to set the standard for what agencies and the motoring public want and expect as far as quality and performance of HMA pavements. As a result, the Georgia DOT has openly embraced the use of both SMA and modified OGFC and these non-conventional mixes are now being specified on all interstate projects in Georgia.

(EDITOR'S NOTE: We invite similar articles from others regarding their current policies and/or activities concerning hot mix asphalt)

RESEARCH IN PROGRESS

The following research projects pertaining to hot mix asphalt (HMA) pavements are currently in progress.

STATE	PROJECT	RESEARCHER(S)	COST	COMPLETION DATE	OBJECTIVES
Alaska	SHRP Evaluation of Asphalt Paving Mixtures	Alaska DOT	\$75,000	September 1996	Compare results of Superpave Levels 1,2,3 mix designs with current mix designs by Marshall Method
	Low Temperature Cracking of Polymer Modified Mixes	Alaska DOT	50,000	September 1996	Evaluate low temperature cracking benefits of polymer modified asphalt binders by tests on HMA mixtures
	Rutting of Asphalt Pavements	Technical Research Center of Finland	30,000	September 1996	Optimize the studded tire wear resistance of urban HMA pavements through improved aggregate quality
Georgia	Automated Mix Design and Testing System	Huggins, GTRI and Meadows, Georgia DOT	141,000	June 1995	Develop a computerized system for collecting and processing Marshall mix design data
	Comparison of Modified Open Graded Friction Courses (OGFC) and Standard OGFC	Santha, Georgia DOT	50,300	September 1995	Evaluate the performance of coarse OGFC mixes with modifiers and fibers
	Evaluation of Stone Matrix Asphalt (SMA) Overlay over PCC	Brown, GOT	47,200	July 1995	Title self-explanatory
Indiana	Laboratory Verification of Significant Asphalt Mix Properties Determined from INDOT APT Facility	Coree, Indiana	170,000	August 1995	Relate HMA mixture properties to APT (Accelerated Pavement Testing) facility

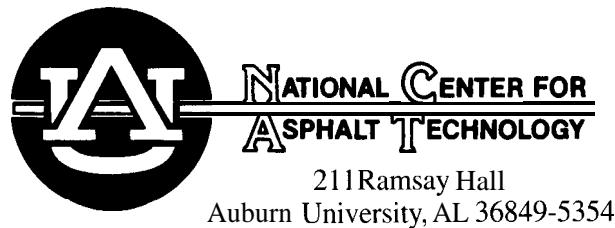
STATE	PROJECT	RESEARCHER(S)	COST	COMPLETION DATE	OBJECTIVES
Indiana	Development of a Procedure to Identify Aggregates for Bituminous Surface Mixtures	McDaniel, Indiana DOT and West, Purdue University	124,200	October 1995	Evaluate British wheel and pendulum plus petrography to identify high friction aggregates
	Determining Percent Crushed Aggregate Requirements Using APT facility	White, Purdue University	342,500	November 1995	Determine required crushed content for stable HMA mixes
	Second Phase Study of Changes in In-service Pavements	White, Purdue University	192,600	May 1996	Conduct SHRP validation
Michigan	Shear Strength and Stability of Dense-Graded Bituminous Mixtures	DeFoe, Michigan DOT	50,700	March 1995	Determine mix strength parameters using different aggregate sources and crushed particle specifications
Mississippi	AASHTO Layer Coefficients for Bituminous Mixtures	George, University of Mississippi	72,500	September 1995	Determine AASHTO layer coefficients for all dense and open-graded HMA mixes
	Use of Stockpiled Aggregates Pretreated with Lime Slurry in HMA	Albritton and Gatlin, Mississippi DOT	64,000	February 1996	Evaluate the performance of HMA made with aggregates pretreated with lime slurry
Ohio	Mixture Design and Performance Prediction of Rubber-Modified Asphalt in Ohio	University of Akron	194,600	September 1996	Title self-explanatory
	Rational Determination of Pavement Layer Structural Coefficients	University of Toledo	101,800	January 1996	Title self-explanatory
South Carolina	Development of Alternative Procedures for Controlling and Accepting Asphalt Mixes	Burati, Clemson University	49,100	October 1995	Title self-explanatory
West Virginia	Performance of Flexible Pavements Reinforced with Geogrids	Siriwardane and Gangarao, West Virginia University	134,800	June 1996	Title self-explanatory

STATE	PROJECT	RESEARCHER(S)	COST	COMPLETION DATE	OBJECTIVES
Wisconsin	Evaluation of Stone Matrix Asphaltic Pavements	Schmiedlin, Wisconsin DOT	90,000	December 1999	Title self-explanatory
	Comparison and Statistical Analysis of Field Rutting Measurements with Laboratory Predictive Methods	Faherty, Marquette University and Johnson & Schmiedlin, Wisconsin DOT	42,000	December 1997	Determine the effectiveness of the Georgia Loaded Wheel Tester for estimating rutting potential of HMA
	Evaluation of Recycling Asphaltic Pavements with Tire Rubber	Johnson, Wisconsin DOT	21,000	May 1997	Determine the recyclability of asphalt rubber pavements (design, construction, performance and environmental impacts)
Transportation Research Board	Field Procedures and Equipment to Implement SHRP Asphalt Specifications	Cominsky, Brent Rauhut Engineering	900,000	September 1996	Develop QC/QA procedures for implementing Superpave mix design procedures
	Designing Stone Matrix Asphalt Mixtures	Brown and Haddock, National Center for Asphalt Technology	498,800	March 1996	Develop mix design and evaluation procedures for SMA
	Aggregate Tests Related to Asphalt Concrete Performance in Pavements	Kandhal and Parker, National Center for Asphalt Technology	499,200	January 1997	Recommend a set of aggregate tests which are related to HMA performance in pavements
	Design and Evaluation of Large Stone Mixtures (LSM)	Button, Texas A & M	300,000	June 1995	Develop mix design and evaluation procedures for LSM (1-2½" max. aggregate size)
Australia	Asphalt Fatigue	Rickards, Australian Asphalt Pavement Association	A\$1 million	December 1996	Develop test method and prediction model for characterizing HMA fatigue
Canada (Ontario)	Evaluation of Varying Stone Contents in Heavy Duty Bituminous Concrete Mixes	Tam and Yacyshyn, Ontario Ministry of Transportation	30,000	June 1995	Title self-explanatory
Israel	Utilization of Propane Precipitated Asphalt (PPA) in HMA Pavements	Ishai and Craus, Technion-Israel Institute of Technology	50,000	July 1995	Title self-explanatory

NCAT's 1995 Asphalt Technology Course Attendees and Instructors



Left to Right: (Row 1) Aubrey Graves, Kathy Petros, Frank Howell, Pok Sum Loong, Bob Fousek, Bob Cartwright; (Row 2) Ken Kandhal, Andy Garnes, Doug Hanson, Steve Garrett, Vaughan Stevens; (Row 3) Nicholas Murphy, Ben Frevert, Bart Lungren, Robert Lee, Robie Jackson, Patrick Bauer, Curt Turgeon, John Haddock, Dave Pittman, and Ray Brown. Not Pictured: Richard J. Miller.



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Note No.1 (Spring 1995)

Hot Mix Asphalt For Heavy Duty Pavements

Background

The amount of traffic has continued to increase in past years and it is anticipated that this trend will continue in the future. This increased traffic has resulted in heavier loads, higher tire pressures, and increased numbers of heavy vehicles. Because of this increased loading the quality of materials being used must continue to improve to provide satisfactory performance for heavy duty pavements.

There are only a few items that can be adjusted in an HMA to improve performance. To minimize permanent deformation (rutting) the primary items to be considered are: (1) aggregate quality (primarily particle shape and surface texture), (2) aggregate gradation, (3) asphalt binder properties (primarily stiffness at high temperatures), (4) asphalt content, and (5) compaction. Obviously there are other parameters to be considered, but these are the most important ones for permanent deformation.

Approach

The approach taken to evaluate permanent deformation problems involved identifying good and bad performing dense-graded HMA pavements in a number of states. These pavements were then evaluated to determine those properties that provide good performance as well as those that provide poor performance. A total of 14 states from various climatic areas of the U.S. participated in this comprehensive NCAT study. Forty-two pavements were evaluated with 30 being identified as poor performers and 12 being identified as good performers.

Findings

This investigation showed that most of the permanent deformation was occurring in the top four inches of HMA. The study clearly showed that the amount of air voids in

the mixture was the single most important property. If the air voids are low (below approximately 3 percent) rutting is likely to occur. While the amount of air voids had a significant effect on rutting, this parameter could not be used to predict rutting. When the air voids were low, significant rutting typically occurred and when the air voids were high rutting was much less likely to occur.

It is therefore essential that air voids be closely controlled during construction. This includes air voids in laboratory compacted samples as well as in-place air voids. At the present time, air voids in the laboratory are determined from samples compacted with Marshall hammer, Texas gyratory, or kneading compactor. In the future, these air voids will be determined from samples compacted with the Superpave gyratory compactor. Regardless of the compaction type used, it is important that the sample be compacted to approximately the same density as it will see in the field after some years of traffic.

The second observation made was that the particle shape and surface texture of the aggregate was important to performance of the mixture as long as the air voids were not low (below approximately 3 percent). The fractured face count was used for the coarse aggregate. The uncompacted void content (determined by ASTM C 1252 Method "A" or AASHTO TP33) was used for the fine aggregate. The data was analyzed to determine the best equation to predict permanent deformation. The best equation for the fine aggregate particle shape and surface texture (quantified by uncompacted void content) was determined and is shown in graphical form in Figure 1. This relationship is based on HMA mixtures with air voids greater than 2.5 percent. If the air voids are controlled sufficiently high (above approximately 3 percent) the rutting can be predicted as shown in the figure. The

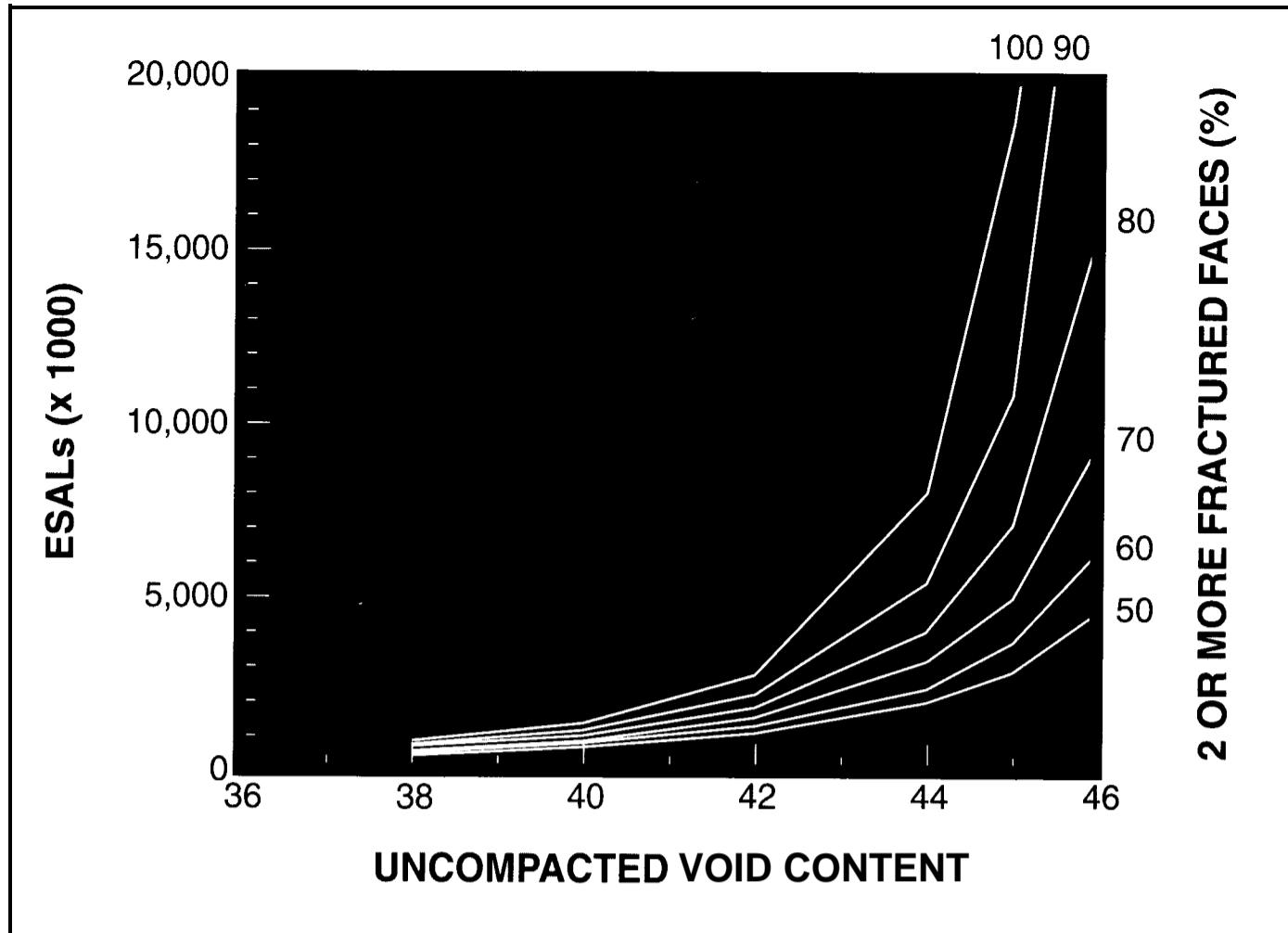


Fig. 1. Factors causing 0.50 inch rut depth for pavement life

shows that the fine aggregate particle shape and surface texture is very important. If the uncompacted void content is 42 or below the resistance to permanent deformation is not significantly affected by the coarse aggregate particle shape. However, if the fine aggregate uncompacted void content is above 42 then the shape of the coarse aggregate has a significant effect. Certainly all mixtures are not going to follow the trend shown in the figure but the rutting study showed that most mixtures did. Thus, it appears that rutting can be predicted by evaluating the aggregate shape and air voids.

For example, let's assume that a mix is to be designed with a design life of 10,000,000 ESALS and 0.5 inch permanent deformation at the end of the life. This design life can be obtained if the laboratory air voids (using proper compaction effort) are maintained above 3 percent and the aggregate shape is properly selected.

For this example, the aggregate properties could be: uncompacted void content of fine aggregate = 46 and percent with two or more fractured faces of coarse aggregate = 70, or uncompacted void content = 45 and percent with two or more fractured faces = 90.

The study did not provide sufficient data to evaluate the effect of asphalt binder properties or aggregate gradation. Certainly, these parameters will affect rutting and will be looked at much more closely as Superpave is further evaluated and adopted. The study did, however, clearly show the effect of aggregate shape and air voids on permanent deformation.

Reference

E.R. Brown and S.A. Cross. A National Study of Rutting in Asphalt Pavement. Asphalt Paving Technology, Volume 61, 1992.