



ASPHALT TECHNOLOGY NEWS

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NCAT COMPLETES NATIONAL STUDY OF AGGREGATE TESTS FOR HMA

The National Center for Asphalt Technology (NCAT) has completed National Cooperative Highway Research Program (NCHRP) Project 4-19. "Aggregate Tests Related to Asphalt Concrete Performance in Pavements." This project on aggregates represented a \$500,000 three-year research effort. The recently completed Strategic Highway Research Program (SHRP) for asphalt—a \$50-million, five-year research effort—did not include aggregate research. Although SHRP has developed a performance-based asphalt binder system and Superpave mix design system, it did not include performance-based characterization of aggregates. (SHRP did convene a meeting of an Aggregate Expert Task Group (ETG) which considered the existing aggregate tests and criteria. Through the Delphi process the ETG

recommended guidelines for aggregate testing to be used in the Superpave mix design system.)

Aggregates constitute about 94 percent of hot mix asphalt (HMA) by weight. Therefore, the properties of coarse and fine aggregates used in HMA are very important to the performance of the pavement system in which these mixtures are used. Many of the currently used tests were developed to empirically characterize aggregates without, necessarily, any relationship to the performance of HMA in pavement systems. Therefore, research was needed to evaluate existing aggregate tests and potential new aggregate tests in terms of their relationship to pavement performance. The objective of this research project was to recommend a set of aggregate tests that are related

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Test equipment for quantifying the particle shape, angularity, and surface texture of coarse aggregates for HMA

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to performance of HMA used in pavement construction.

The following steps were taken to complete this research project:

- Step 1. Identification of the performance parameters of HMA that may be affected by the properties of the aggregates.
- Step 2. Identification of the aggregate properties that influence the performance parameters established in Step 1.
- Step 3. Identification and evaluation of aggregate tests currently used in U.S. and foreign countries, which measure the properties identified in Step 2.
- Step 4. Identification of potential tests for measuring aggregate properties for which no suitable test method was identified in Step 3.
- Step 5. Laboratory investigation to evaluate aggregate tests identified in Steps 3 and 4 for their relationship to the performance of HMA.
- Step 6. Recommendation of a set of aggregate tests related to the performance of HMA in pavement based on the results of the laboratory investigation in Step 5.



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Micro-Deval test method has been recommended as a replacement for Los Angeles abrasion test

The following three HMA performance parameters were considered in this study:

(a) permanent deformation, (b) fatigue cracking, and (c) raveling, popouts or potholing. Permanent deformation resulting from moisture-induced damage or stripping of HMA was also considered. Frictional resistance of HMA was not considered due to limited project funding.

The following six aggregate properties, which are related to HMA performance parameters, were included in the laboratory research plan:

- Coarse aggregate particle shape, angularity, and surface texture
- Fine aggregate particle shape, angularity, and surface texture
- Plastic fines in the fine aggregate
- Toughness and abrasion resistance
- Durability and soundness
- Characteristics of P200 (material passing No.200 sieve)

Aggregate gradation and size, although related to HMA performance, were not included in the research plan because standard sieve analysis methods already exist.

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A large variety of aggregates were selected, which gave a wide range of test values for the specific property to be evaluated. For the toughness/abrasion study and the durability/ soundness studies, field performance history was factored into the selection process.

After measuring the specific property (for example, particle shape, angularity, and surface texture) of all aggregates by different aggregate tests, both existing and new, these aggregates were incorporated in HMA mixtures. Mix validation tests were then conducted to measure the pertinent mix performance properties such as permanent deformation and fatigue cracking. Mix validation tests included the Superpave shear tester (permanent deformation and fatigue cracking), Georgia loaded wheel tester (permanent deformation), Hamburg wheel tracking device (stripping), and AASHTO T 283 (stripping).

The following set of nine aggregate tests which are related to HMA performance parameters (identified in parenthesis), have been recommended to evaluate aggregates for HMA pavements:

1. Gradation and size
(permanent deformation and fatigue cracking)
2. Uncompacted void content of coarse aggregate
(permanent deformation and fatigue cracking)
3. Flat or elongated particles (2:1 ratio) in coarse aggregate
(permanent deformation and fatigue cracking)
4. Uncompacted void content of fine aggregate
(permanent deformation)
5. Methylene Blue test of fine aggregate
(permanent deformation resulting from stripping of HMA)
6. Particle size analysis of P200 material for determining D 60 and D 10 sizes
(permanent deformation resulting from traffic loads as well as stripping)
Note: D60 and D 10 are particle sizes in mm that have 60 and 10 percent passing, respectively.
7. Methylene Blue test of P200 material
(permanent deformation resulting from stripping of HMA)
8. Micro-Deval test
(raveling, popouts or potholing)
9. Magnesium sulfate soundness test
(raveling, popouts or potholing)

Test protocols have been developed in AASHTO format for all new aggregate test methods and it is expected that these tests will be considered by AASHTO for adoption as provisional standards. It should be noted that the following new aggregate tests have been recommended in lieu of some existing Superpave aggregate tests:

- Uncompacted void content of coarse aggregate (in lieu of percentages of 1 or 2 fractured faces)
- Flat or elongated particles 2:1 ratio in coarse aggregate (in lieu of flat and elongated particles 5:1 ratio)
- Methylene blue test for fine aggregate (in lieu of sand equivalent test)
- Micro-Deval test (in lieu of Los Angeles abrasion test)
- Magnesium sulfate soundness test (in lieu of sodium sulfate or other freeze and thaw tests)

AGGREGATE SPECIFIC GRAVITY FOR VOLUMETRIC MIX DESIGN - BULK OR EFFECTIVE?

Standard Marshall and Superpave volumetric mix designs require the use of *bulk* specific gravity of the aggregate (AASHTO T 84 and T 85) for calculating the voids in the mineral aggregate (VMA) and the amount of asphalt binder absorbed by the aggregate. However, some highway agencies use the *effective* specific gravity of the aggregate for calculating the VMA. The VMA values calculated with the *bulk* specific gravity can be significantly different than those calculated with the *effective* specific gravity in case of absorptive aggregates. In the last issue of the **Asphalt Technology News** we had invited arguments from both camps (those in favor of using the *bulk* specific gravity and those in favor of using the *effective* specific gravity). The following responses were received, which have been edited for reasons of consistency and space.

W.R. Meier, Jr. (Western Technologies, Inc., Arizona)

In order for VMA to have significance when performing a volumetric mix design for asphalt concrete, the bulk specific gravity needs to be used to define effective asphalt content and to compute VMA. Asphalt binder absorbed into the aggregate contributes nothing to the asphalt concrete performance. Assume two aggregates that are identical in all ways (gradation, surface texture, angularity, etc.) except that one has low absorption and one has high absorption. These aggregates are then mixed with asphalt binder and compacted in the same manner to an identical air voids level. The absorptive aggregate will have a higher total asphalt content and a higher VMA if computed from the effective specific gravity. However, the aggregate structure for the two mixtures will be identical and would have the same effective asphalt content. It is logical that the two should have the same VMA, which

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(SPECIFIC GRAVITY, Continued from page 3)

they will have if computed from the bulk specific gravity.

Rudy Jimenez (Consultant, Arizona)

I am in favor of using the effective specific gravity since 1958 because of the following reasons:

- (a) The aggregate has one weight, therefore, it should have one aggregate specific gravity.
- (b) In service the aggregate specific gravity is the effective one.
- (c) The Rice maximum specific gravity of a mixture is used to determine the effective specific gravity of the aggregate. The measurement for Rice specific gravity is more reliable than the measurements for saturated surface dry (SSD) values for fine aggregate or coarse aggregate.
- (d) I would question why is Rice specific gravity (thus effective specific gravity) used for air voids determination and not for VMAS.
- (e) It would seem that etymologically the definition of voids-in-the-mineral aggregate (VMA) is such that the VMA is equal to the sum of the volume of air plus the volume of asphalt binder. This means one should use the effective specific gravity for calculating the volume of aggregate.
- (f) It would seem that the use of effective specific gravity would be quite appropriate when utilizing recycled material.

Richard Welters (Dakota Asphalt Pavement Association)

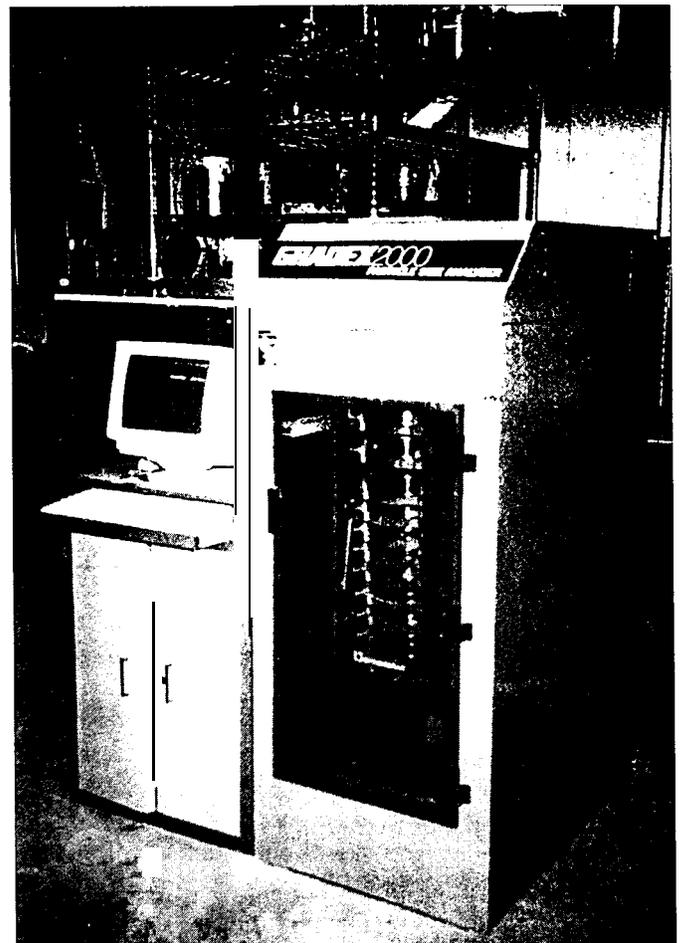
The aggregate specific gravity used by national standards is the bulk (dry) for the purpose of computing VMA. Some agencies, however, use the effective specific gravity which is determined from measurements obtained in the maximum theoretical gravity (Rice) test. Using the effective specific gravity is a shortcut procedure designed to eliminate the aggregate specific gravity test on the source aggregates. There are a number of reasons for this, such as, limited laboratory personnel, testing time involved, expedited results, test procedure subjectivity regarding "slightly slumped" for the fine aggregate portion, process control decisions, mixture acceptance, and needed job mix adjustments.

The resultant usage of the effective aggregate specific gravity value has the net effect of a VMA value determination too large as it includes the asphalt binder volume that has been absorbed into the aggregate. Absorbed asphalt binder is **not** considered to aid in mixture durability. The VMA based on the bulk (dry) aggregate specific gravity excludes the absorbed asphalt and only includes the "available" or "effective" or

"unabsorbed" binder. The discrepancy in the VMA value between the two methods of calculation increases as asphalt absorption increases. In general, the larger or greater the aggregate porosity, as measured by water absorption, the greater the asphalt absorption. There is no established relationship to my knowledge between aggregate water absorption and aggregate asphalt absorption. This is true because aggregate pore size and a number of construction variables have an added impact. A good rule of thumb which is used is that the aggregate asphalt absorption is approximately 50-80 percent of the combined aggregate blend water absorption value as determined from the bulk (dry) and apparent aggregate specific gravity testing.

The tests used to measure VMA of an asphalt mix need to be standardized. As transportation partners (agency, industry, academia, consultant labs, etc.) we need standardization prior to the disputes of which number to use for mix design, process control, or acceptance. Only then can we truly compare performance on a national or local basis.

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NCAT is developing an automated aggregate gradation equipment suited for HMA, which can display and print out the gradation. The operator simply needs to feed the aggregate at the top. The material retained on each sieve is weighed independently and the sieve is also brushed to dislodge aggregate particles.

(MIX DESIGN GRAVITY, Continued from page 4)

Bill Maupin (Virginia Highway Research Council)

Virginia uses the aggregate bulk specific gravity to determine VMA. We feel that the use of bulk specific gravity produces VMAS that are closer to the true values. In some cases the difference between VMA calculated by using bulk specific gravity and effective specific gravity is several percentage points apart. It is important and necessary that the values for aggregate specific gravity be correct, and there have been problems with some aggregates in getting repeatable test results. It is also essential that the aggregates be tested frequently in order to detect changes that may occur in the aggregate. Virginia also uses a shift factor which is established from the difference between the latest bulk and effective specific gravities to avoid having to run bulk gravities on aggregates for each set of field Marshalls.

Joseph Smith (Consultant, New Jersey)

I don't believe it is practical to use the bulk specific gravity (G_a) during production of HMA. There seems to be an opposition to using the effective specific gravity (G_{se}) during production of HMA. I was involved in New Jersey's first Superpave project and we tried a new approach that worked well for us. I would like to submit this method for your review and comments.

I have taken the formula (see below) used by FHWA and the Asphalt Institute in Superpave design procedures to calculate estimated G_{se} and worked it backwards to find the estimated G_{sb} . G_{sa} is the apparent specific gravity of the aggregate.

$$G_{se} = G_{sb} + 0.8 (G_{sa} - G_{sb})$$

During HMA production we perform the Rice test to obtain the theoretical maximum specific gravity (G_{mm}) and the G_{se} . Since we know the G_{se} and ($G_{sa} - G_{sb}$) from historical data or recent design work, we can use the above formula to find estimated G_{sb} . An example for estimating the combined aggregate bulk specific gravity in a paving mixture during production follows.

Design Stage

1. Obtain the apparent and bulk specific gravities of each aggregate component in the mixture. The apparent specific gravity values for aggregate A (90'70) and aggregate B (107c) were determined to be 2.980 and 2.650, respectively. The bulk specific gravity of aggregate A and aggregate B were determined to be 2.930 and 2.620, respectively.
2. Calculate the combined average apparent and bulk specific gravities:

$$G_{sa} = \frac{100}{\frac{90}{2.980} + \frac{10}{2.650}} = 2.943 \quad G_{sb} = \frac{100}{\frac{90}{2.930} + \frac{10}{2.620}} = 2.896$$

3. Calculate the difference ($G_{sa} - G_{sb}$).

$$\text{Difference} = 2.943 - 2.896 = 0.047$$

$$(G_{sa} - G_{sb}) = 0.047$$

Production Stage

1. Perform the maximum specific gravity (Rice) test on the paving mixture.
2. Calculate the effective specific gravity of the combined aggregates (G_{sc}) from the maximum specific gravity test on the paving mixture: $G_{sc} = 2.934$.
3. Estimate the combined aggregate bulk specific gravity (G_{sb}) of the produced mix as follows:

$$G_{sb} = G_{sc} - [0.8 \times (G_{sa} - G_{sb})]$$

$$G_{sb} = 2.934 - [0.8 \times (0.047)]$$

$$G_{sb} = 2.934 - 0.038 = 2.896$$

$$G_{sb} = 2.896$$

* 0.8 factor accounts for absorption. High absorptive aggregates may require values closer to 0.6 or 0.5.

** 0.038 becomes a constant value for these aggregates only. During production: $G_{sc} - 0.038 = \text{Estimated } G_{sb}$.

Rob Jester (Federal Highway Administration)

VMA in an asphalt concrete mixture consists of two things: air and non-absorbed asphalt binder. In order to arrive at a true measure of the VMA, the bulk specific gravity of the aggregate has to be used in the calculation. The bulk specific gravity can be considered to be the weight of the aggregate divided by its volume including all permeable voids, i.e., the voids permeable to both water and asphalt binder. By subtracting out this volume, what is left is the actual VMA. If the effective specific gravity is used, then the aggregate volume does not include the voids permeable to asphalt binder and therefore the volume of absorbed asphalt would be included in the calculated VMA which is incorrect.

Editor's Last Word

To be equitable to all HMA producers, the minimum specified VMA should be based on bulk rather than effective specific gravity of the aggregate. If the effective specific gravity is used to calculate the VMA, the HMA producer using an absorptive aggregate will easily meet the minimum VMA requirement compared to the HMA producer using a less absorptive aggregate,

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South African Bitumen Association (SABITA) officials visited NCAT in August. From left to right: Doug Hanson (NCAT), Martin van de Ven (SABITA), Rob Vos (SABITA), Mike Zacharias (SABITA), and Ken Kandhal (NCAT).



(SPECIFIC GRAVITY, Continued from page 5)

although the aggregate structure of the two mixtures may be identical. Experience has shown that meeting the minimum VMA requirement in Superpave volumetric mix design can be difficult. Therefore, if the producer using an absorptive aggregate gets only a 0.5 percent higher VMA than the producer using a less absorptive aggregate, it is very significant. For aggregates with asphalt absorption of 1.2 percent by weight (water absorption of about 2 percent), the difference between the VMA values calculated from bulk and effective specific gravity of the aggregate can be more than 2 percent.

It is realized that the reproducibility of the test for measuring the bulk specific gravity of fine aggregate is not very satisfactory because of the subjectivity regarding the saturated surface dry (s SD) condition. One state highway agency has tackled this problem by demonstrating this test to all HMA and aggregate producers' technicians at the central laboratory. This action significantly improved the reproducibility of the test. The agency defines the "slightly slumped" condition of the cone test as the slump "leaving a portion of the top surface about the size of a dime" upon removal of the mold. The agency also requires the HMA producer to conduct at least 10 tests to measure the bulk specific gravity of coarse and fine aggregate and use the average values for developing a new HMA mix design. Generally, the aggregate bulk specific gravity is quite uniform and, therefore, it does not need to be measured every day. The testing frequency can be reduced to once a week or once a month. If the aggregate is not uniform, then estimating the bulk specific gravity from the measured effective specific gravity during production

(as suggested by Maupin and Smith) is a very good idea.

NCAT is in the process of developing an automated equipment and method of determining the saturated surface dry (S SD) condition of the fine aggregate so that its bulk specific gravity can be measured with satisfactory precision and accuracy. This will help in obtaining realistic values for VMA. The proposed test consists of placing the saturated sample of the fine aggregate in a miniature rotating drum, using a hot blower to dry the fine aggregate uniformly with warm air, and measuring the temperature and/or humidity gradient of the incoming and outgoing warm air. The temperature and/or humidity gradient should change as soon as free moisture on the surface of the fine aggregate particles is eliminated in the drying process, thus achieving the SSD condition. This concept was attempted by Arizona Highway Department in 1974, but some equipment difficulties were encountered. However, such difficulties are very likely to be surmounted with modern-day electronic technology. We will keep you posted of NCAT experiments in this area in the future.

JOIN US!

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

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ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the Spring 1997 Asphalt Forum.

Are there many states that are currently using bituminous underselling? If so, how do they determine which pavements need to be undersealed? Any other information on undersealing would be appreciated.
(John Haddock, Indiana DOT)

Illinois (Bruce Peebles, Illinois DOT)

Illinois DOT quit using bituminous underselling approximately 20 years ago.

Virginia (Bill Maupin, Virginia Transportation Research Council)

Virginia uses underselling when it is needed. The need is determined by visually assessing pumping, faulting of jointed pavements, etc. The falling weight deflectometer determines the load transfer efficiency at joints.

Pennsylvania (Tim Ramirez, Pennsylvania DOT)

The Pennsylvania DOT uses a cement/pozzolan grout for slab stabilization of existing portland cement concrete pavements. The department does not perform slab stabilization using bituminous undersealing. It has developed standard drawings showing the procedure for detecting voids at each joint and crack. Voids typically develop at the outside corners of slabs. The standard drawings show the locations for placing two gauges and positioning a loaded vehicle to detect slab movement. The gauges are placed and zeroed at the joints in an unloaded condition. A loaded vehicle having a dual-tire single axle with an 18,000 pound single axle load is positioned on the approach slab and the deflection on the gauges is measured. Then, the loaded vehicle is positioned on the leave slab and the deflection on the gauges is measured. The specifications require the stabilization of all joints or cracks that have a loaded slab corner deflection of 0.02 inches or more and a joint efficiency at 65 percent or more. The specifications require patching and stabilization of all joints or cracks that have a loaded slab corner deflection of 0.02 inches or more and a joint efficiency of less than 65 percent.

Georgia (Lamar Caylor, Georgia DOT)

No bituminous underselling is used by GDOT. High pressure grout underselling is performed if slabs have deflections exceeding 0.03 inches. Testing is restricted to the hours of 3-9 a.m. to avoid "lock up" of slabs.

A few HMA paving projects last year exhibited a distinctive oily brown color during construction. It became very apparent during the compaction process.

The asphalt binder was being physically separated from the aggregate particles as if it were stripping off, leaving behind a thin brownish coating on the aggregate particles. Therefore, a "broil'17 asphalt" study was initiated. The investigation, to date, has not identified the cause for this type of stripping. As a result, Illinois DOT is currently investigating the use of waste burner fuels at the HMA plants and the use of dust suppressants at aggregate quarries. Illinois would like to know if other states have any specifications or restrictions on the types of burner fuels or 017 the use of dust suppressants in the production of aggregates. (Jim Gehler, Illinois DOT)

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

Ontario has had experience with certain lithographic limestones (Uthhoff Quarry) in which the asphalt binder failed to coat and a similar brownish coating formed on the aggregate particles.

As far as we are aware, Ontario aggregate sources only use water as a dust suppressant. In any case, we do not think that the use of a dust suppressant is likely to cause a problem which you experienced due to small amount that would be present due to dilution. Instead, a more thorough study of the aggregate particles is warranted.

Utah (Wade Betenson, Utah DOT)

Your problem may not be burner fuels. Some grades of PG binders have been made with plastomer polymers (EVA or others). We have had problems with them. They have poor cohesion, exhibit some stripping, and appear as brown asphalt. Also, there has been a light amount of mineral oil added with the plastomer oil used to meet the PG specification. We are seriously considering banning a plastomer polymer.

Georgia (Lamar Caylor, Georgia DOT)

Georgia DOT does not specify use of dust suppressants during aggregate production. Dust emission is controlled by the Georgia Environmental Protection Division (GEPD). Quarry sources typically use some form of dust suppression to meet GEPD regulations.

There is no restriction on the type of burner fuel used, as long as the fuel burns clean so as to not contaminate the mixture. There are specification requirements on the use of waste processed oil.

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Kentucky (Allen Myers, Kentucky Department of Highways)

Kentucky has experienced a few projects this year on which the pavement exhibited a brown tint in the wheel tracks. One of these projects involved two different surface mixtures from two different plants using two different burner fuels. Both mixtures exhibited the brown color.

Illinois DOT has evaluated a few aggregate sources that have demonstrated excessive, variable aggregate mass loss when tested in the ignition furnace. These sources have a 3 to 4 percent correction factor. Illinois would like to know if any other states have experienced similar problems. (Jim Gehler, Illinois DOT)

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

The Ontario Ministry of Transportation is currently developing test methods for the ignition furnace. We have experienced problems when using limestones at 538°C so we are currently working at only 427 and 482°C. We are also using end of test detection points of 1.0 g rather than 0.1 g.

Louisiana (Chris Abadie, Louisiana DOT)

The highest correction factor seen at Louisiana Transportation Research Center using the Troxler oven is about 0.5 percent. The biggest problem has been the breaking of the largest aggregates when using 25 mm nominal size mixes and larger. One contractor, Barriere Construction, has reduced the amount of breakdown by lowering the temperature some and by manually placing the largest aggregate on the bottom tray.

Virginia (Bill Maupin, Virginia Transportation Research Council)

The highest weight loss for Virginia has been approximately 3.0 percent for a mix containing a granite. Because the weight loss was high and variable the oven temperature was lowered from 538°C to 482°C, which required some additional time for burning.

Pennsylvania (Tim Ramirez, Pennsylvania DOT)

The Pennsylvania DOT has detected some aggregate blends with mass losses from ignition oven testing near or above 3 percent. These have been primarily gravel aggregate blends, but some dolomite and limestone aggregate blends have also shown mass losses greater than 2.5 percent. A list of some of the aggregate blends found to have relatively high mass losses is available. Please call (717) 787-5754.

Ohio (Dave Powers, Ohio DOT)

Ohio has only seen excessive mass loss in the ignition oven in a single dolomitic stone source. no others so far. A specification for acceptance using the oven will be drafted this fall following this year's trials. The oven is allowed now for binder removal for gradation.

Utah (Wade Betenson, Utah DOT)

This is not uncommon for limestone aggregate. Depending on the type of limestone, it can vary widely.

Georgia (Lamar Caylor, Georgia DOT)

We have not experienced high mass loss when using the ignition furnace. Georgia aggregates typically have about 0.3 to 0.6 percent absorption and the correction factors for ignition oven testing are very similar. about 0.3 percent being typical.

Kentucky (Allen Myers, Kentucky Department of Highways)

Kentucky has tested a few dolomitic aggregates in the ignition furnace that exhibited very high and variable mass loss.

1. *How many states have experienced tender mix problems with Superpave?*
2. *Do any states question the use of AC-2.5 and AC-5 viscosity graded asphalt cements for use as base asphalt grades in polymer modified binders?*
3. *VMA is related to the nominal maximum size of the aggregate and the fineness or coarseness of a mix. Do any states question the minimum Superpave VMA requirements? Are they set too high?*
4. *Gradation control points and maximum density line. To create VMA in a mixture the designer must pull the combined aggregate gradation further from the maximum density line. Does this create mix stability problems in the field? (Jim Campbell, Missouri Highway & Transportation Department)*

Arizona (Julie Nodes, Arizona DOT)

Arizona has elected to increase the minimum VMA requirement by a half percent for Superpave mixes. We have not experienced any mix stability problems in the field to date on Superpave mixes.

Utah (Wade Betenson, Utah DOT)

1. The mixes don't act like traditional tender mixes. Tenderness seems to occur when mix temperature and rolling is done between 220°F and 265°F.
2. Most polymer modified binders for grades PG64-34 and PG70-40 are made from asphalt cements with 300-400 penetration.

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3. We pay bonus or deduct for VMA; this has not been a problem.
4. Gradation—I think we may have a problem as the gradation line drops below the maximum density line. We have less intermediate aggregate going into the mix and end up filling the voids with asphalt binder in these gap gradations if we are not careful. We have a gyratory testing machine (GTM) and some of these mixes show a slight plastic condition in the GTM. Also, one should question the long term fatigue resistance.

Georgia (Lamar Caylor, Georgia DOT)

1. Georgia DOT has had only a few minor isolated instances of tender mix problems—nothing significant.
2. GDOT does not use soft viscosity-grade asphalts, due to the hot summer service temperatures. Asphalt cement, in order to be modified, must be AC-20 or AC-30 (PG 64-22 or PG 67-22) initially, and it must be “straight run” material that is not oxidized by air-blowing.
3. GDOT has had difficulty meeting minimum VMA requirements on some coarse “base” and intermediate mixes, even under the Marshall design criteria. There is also subjectivity and variability in conducting the bulk specific gravity test for fine aggregate, which could make a significant difference in the calculated VMA. The effective specific gravity can be calculated from AASHTO T-209 test results, and it is more accurate and more feasible to use, especially when RAP materials are included in the design mixture. For these reasons, GDOT uses the effective specific gravity to calculate VMA. This procedure yields VMA results about 1.0 percent higher than if the bulk specific gravity were used. The same minimum values are used as those specified in Superpave.
4. Although GDOT has not had mix stability problems, it is conceivable that such problems could occur. Both mix stability and fatigue resistance may be affected as mixes are designed coarser with less asphalt cement. One of the reasons for success with stone matrix asphalt (SMA) mixes is the strong mortar matrix, which consists of high mineral filler content and high optimum asphalt content.

Ohio (Dave Powers, Ohio DOT)

Ohio has experienced tenderness on most Superpave mixes with gradations above the restricted zone and

manufactured aggregates. One of these was very bad but part of this was attributed to high dust (1.2 fines/asphalt ratio by weight) and low binder content with the dust accentuating the tenderness in the mix. Other designs with lower dust but same aggregates (mixes had some RAP) were tender but to a lesser degree. General tenderness is attributed to fine aggregate/binder relationship with the binder acting as an over-riding lubricant in a certain temperature range in the high surface area fine aggregate.

Ohio has a concern with the VMA limits used in Superpave. VMA limits were taken from Marshall experience (volumetric is the same) but not at the Superpave compaction levels. Coarse gradations allowed in Superpave have little Marshall experience to validate the VMA required. Under QC/QA where contractors submit designs, the minimum VMA requirement always forces the gradation toward the finer side. Ohio went through this in the 1980s and does not necessarily want to revisit VMA, design voids, and compaction all directly affect binder content. Ohio has come to believe that each of these must be considered if a binder content increase is desired. Thus, Ohio has concerns as well with Superpave gyration levels for most traffic levels. Ohio is designing surface courses at 3.5 percent voids.

Virginia (Bill Maupin, Virginia Transportation Research Council)

Virginia has experienced a tender mix problem with one 19.0 mm mix containing AC-30 binder. The desired field density could not be achieved because of tenderness during compaction.

Superpave minimum VMA requirements are based on VMA criteria for dense graded mixes recommended by the Asphalt Institute. Our experience indicates that these values are reasonable for our materials.

Mix stability is related to the total aggregate structure. Even though we use a gap-graded structure for our SMA, which has a high VMA, these mixes are very stable.

Indiana (John Haddock, Indiana DOT)

I have heard several people from various DOTs question the validity of the Superpave VMA requirements. We are working on a study in Indiana that will hopefully answer this question. The National Pooled Fund Study No. 176, Validation of SHRP Asphalt Mixture Specifications Using Accelerated Testing, is currently under way. There are 27 states participating in the study. One of the objectives of the study is to determine if the currently specified VMA requirements in Superpave are adequate to distinguish between well- and poor-performing mixtures. Initial data from the project should be available around the first of the year.

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Illinois (Bruce Peebles, Illinois DOT)

Illinois has not experienced any tender mix problem with Superpave mixes. Illinois currently has minimum VMA requirement on all interstate type mixes. A surface course on a full depth, new pavement has a minimum VMA of 15, and a minimum VMA of 14 on overlays. The minimum VMA for binder courses is 13 percent.

Louisiana (Chris Abadie, Louisiana Transportation Research Center)

Louisiana has adopted Superpave VMA requirements. This has forced the use of up to 50 percent of #67 limestone in our 19mm mixes. It is possible that this stone with a VMA in production of about 12 to 12.5 percent will perform very well as it has for the past 10 years. It will be interesting to see the actual performance versus laboratory performance of these mixtures.

Are any states willing to share their specifications (Task Force 31, SHRP or other) for SBR, SBS modified asphalt binders. (Dave Powers, Ohio DOT)

Utah (Wade Betenson, Utah DOT)

We have a binder management program. So far it has worked very well for modified asphalt binders.

Georgia (Lamar Caylor, Georgia DOT)

In years past, GDOT has used a generic polymer-modified asphalt cement (PM AC) specification that served well, but with the implementation of Superpave binders this year, GDOT has adopted the PC 76-22 performance grade. To ensure an adequate level of polymer modification, GDOT further specifies that the blended PMAC must have a phase angle of no more than 75 degrees.

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

Ontario has developed a specification for polymer-modified binders which has been superseded by a non-standard specification for performance-graded asphalt cement. Ontario would be willing to share our specifications with any interested agencies.

Alabama would like to know if any agencies have found a polymer that is not acceptable for use in hot mix asphalt. A wide variety of polymers are available and we are interested to know if there are some that provide less than satisfactory performance. Also, does anyone have experience producing acceptable Superpave mixes even though the mix is produced using an aggregate gradation that passes through the "restricted zone?" (Robert Jackson, Alabama DOT)

Ohio (Dave Powers, Ohio DOT)

Ohio has performed trials with polyethylene type polymers but found the compatibility issues troubling and benefits for our moisture/freeze thaw conditions minimal. If the compatibility were not an issue the high temperature performance improvement would be good. Other more compatible polymers for high temperature use are now available.

Ohio currently allows Superpave mixes that go through the restricted zone as long as a rut test is performed in design and in early field production. Since essentially 100 percent manufactured aggregates are being used in our Superpave mixes, Ohio does not believe a restricted zone is even necessary in these applications.

Georgia (Lamar Caylor, Georgia DOT)

With the generic polymer-modified asphalt specification GDOT used before Superpave, it was found that SB and SBS type polymers generally provided greater strength and greater elastic recovery than other modifiers. While GDOT continues to evaluate other polymers, only SB and SBS polymers are currently permitted.

GDOT has produced 19 mm mixes for the past 15 years that are the most rut-resistant of all GDOT conventional mix types. These mixes have been used on interstate projects, carrying as much as 300,000 vehicles per day with very good performance, even though the gradation goes through the center of the Superpave restricted zone. Proof testing results with the Georgia Loaded Wheel Tester have averaged only 2.6 mm for all 19 mm mixes tested over the past 8 years. It could be argued that the 19 mm mixes used previously are not Superpave mixes, since they were designed using the Marshall hammer instead of the gyratory compactor. However, the ultimate proof of a mixture is in its performance, and these mixes have performed extremely well under some of the highest traffic volumes in the country.

Utah (Wade Betenson, Utah DOT)

We are probably going to change our specification to allow only elastomer polymers. We use 100 percent crushed aggregate and no natural sand in Superpave mixes on the Interstate.

Has any one experienced cracks forming in HMA overlays during compaction process over paint strips or thermoplastic materials on underlying surface? How did you combat the problem? (Bill Maupin, Virginia Transportation Research Council)

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(*ASPHALT RESPONSES*, Continued from page 10)

Kentucky (Allen Myers, Kentucky Department of Highways)

Kentucky has experienced cracks in new HMA pavement placed over thermoplastic pavement markings. The mixture contained a PG 76-22 binder, compacted at about 310°F. To combat this phenomenon, the markings were milled off prior to paving. Since this sort of cracking had not been noticed previously, it was thought that perhaps the high temperatures associated with the PG 76-22 were the cause.

Illinois (Bruce Peebles, Illinois DOT)

This has happened on occasion but is not viewed as a big problem.

We have the following questions for other agencies:

- *How many states regularly use some version of a rut-testing device? Does this device have the capability of testing samples in a submerged condition? What parameters (temperature, wheel load, hose pressure, number of cycles, etc.) are used?*
- *How are other states handling the training and certification of personnel in Superpave procedures (binder and mixture)? Is most training completed*

at nationally recognized sites (Asphalt Institute, Superpave Centers, etc.)? Have any states developed in-house Superpave training programs?

- *Are any states using the ignition oven as an option for asphalt content determination? Has any state experienced excessive loss of aggregate through the ignition oven when analyzing a mixture containing dolomite?* (Allen Myers, Kentucky Department of Highways)

Illinois (Bruce Peebles, Illinois DOT)

Illinois has recently purchased an Asphalt Pavement Analyzer. We will initially follow guidelines suggested by the manufacturer and user group of 40±1 °C test temperature, 700 kPa (100 psi) hose pressure, and 45 kg (100 lb.) wheel load. This device also has the capability to test submerged specimens.

Illinois requires technicians using the gyratory compactor to complete a one and a half day training course on the use of the gyratory compactor and ignition oven. Training is provided by Lake Land College of Mattoon, Illinois, which is contracted as out- QC/QA Training Center.

Illinois currently requires the use of ignition ovens on all Superpave demonstration projects, but their use
(Continued on page 12)



Government and industry engineers from Australia visited NCAT in August. NCAT director Dr. Ray Brown discussed NCAT's activities with the group.

(ASPHALT RESPONSES, Continued from page 11)

is optional on remaining projects. Some dolomite sources have demonstrated excessive mass loss requiring a 3 to 4 percent correction factor.

Ohio (Dave Powers, Ohio DOT)

Ohio uses a dry loaded wheel tester. We are not a believer in wet testing unless it is believed stripping is a problem with the aggregate sources. Our primary concern with rut testing is mix stability at high temperatures, wet or dry. Ohio has a specification for this purpose. Superpave training is currently managed by the state asphalt paving association, FPI. See our response to Illinois for ignition oven experience.

Indiana (John Haddock, Indiana DOT)

Indiana has begun using the Purdue Laboratory Wheel (PURWheel) to test many of the Superpave mixtures. This rut tester can test mixtures in either wet or dry conditions. The test temperature, wheel load, tire pressure, and number of cycles are all variable so users can select each at their own discretion.

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

Ontario uses a rut-testing device for evaluating mixes of questionable stability. We have one device which is used to test samples in a submerged condition and

another for testing samples in a dry condition. The parameters which we use are 60°C, 80 psi and 4000 passes. A rut depth of 3 mm or less is considered to be good.

We have sent three of our staff to the Asphalt Institute for training in Superpave mix design, binder testing and analysis. We are planning to set up an in-house training program (or join with Ontario's industry) in the near future to get everyone familiar with Superpave.

Arizona (Julie Nodes, Arizona DOT)

Arizona does not regularly use a rut-testing device. Arizona is still addressing training/certification in Superpave. To date we have made use of training at the Asphalt Institute and the South Central Superpave Center. A considerable amount of our training has been in-house, hands-on-training conducted by Arizona DOT personnel, typically this training has been done at laboratories just prior to the start of Superpave projects.

Virginia (Bill Maupin, Virginia Transportation Research Council)

Virginia is using the Georgia loaded wheel tester to proof test some of their mixes. Currently we use APA 11 tester manufactured by ASTEC Industries, Inc. which is capable of testing under water. The beams are loaded with a wheel load of 534 N, hose pressure of 827 kPa for 8,000 cycles (16,000 passes) at 49°C.

Virginia has developed its own training and certification of personnel for Superpave. Approximately 100 industry and VDOT personnel have been certified through an intensive three-day hands-on course, which includes an exam.

Virginia is in the third year of using the ignition furnace for asphalt content determination. Our aggregates with the greatest loss have been a granite and quartzite. Virginia's limestones and dolomites typically have low correction factors (<0.20). However, lime is produced from dolomite at temperatures on the order of 420-480°C. Losses on ignition up to 52 percent may occur for pure dolomite. So, higher losses are possible.

Utah (Wade Betenson, Utah DOT)

We use the loaded wheel tester and Hamburg wheel tracking device. These two types of testing machines do not generally indicate rutting to be a problem in Superpave mixes.

The plan is to use Superpave centers for training and certification. We are using the user/producer group to manage and set policy.

We use the ignition oven for acceptance. We have 29 ignition ovens and have eliminated the vacuum/solvent extraction test. Most limestone aggregate will give you a negative number. We have not experienced

(Continued on page 13)

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 two-week intensive course, which will be held February 2-February 13, 1998, 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) 844-6241 or visit our web site at <http://www.eng.auburn.edu/center/neat> for brochure or information.

SUPERPAVE VOLUMETRIC MIX DESIGN WORKSHOPS

Superpave volumetric mix design workshops will be held at NCAT on October 22-24, 1997; November 19-21, 1997; December 17-19, 1997; March 4-6, 1998; and March 25-27, 1998. These workshops consist of two and a half days of intensive lecture, demonstration, and hands-on training on Superpave mix design procedures. Upon completion the participants will be able to conduct the Superpave mix designs in their laboratories.

Please call (334) 844-N CAT(6228) for brochure or information, or visit our web site at: <http://www.eng.auburn.edu/center/ncat>

(ASPHALT RESPONSES, Continued from page 12)

a change in gradation.

South Carolina (Milt Fletcher, South Carolina DOT)

The South Carolina DOT has been allowing contractors the option of using the ignition oven in lieu of the solvent extraction testing. Most contractors are using the ignition ovens for asphalt binder content determination.

Pennsylvania (Tim Ramirez, Pennsylvania DOT)

The Pennsylvania DOT has specified in our special provision for Superpave mixes that the HMA producer must provide a technician trained in the development and testing of Superpave volumetric mix design. This training can be obtained from any of the Superpave centers, the Asphalt Institute, or other training facility found acceptable to the department. In addition, the department has been working in conjunction with the Northeast Superpave Center in developing a Superpave Volumetric Mix Design Workshop. The workshop is intended for technicians and engineers who understand and are experienced with the basic principles and procedures involved in asphalt concrete mixture design, testing, and voids analysis. The workshop will familiarize participants with the Superpave system and includes two days of hands-on laboratory testing to evaluate a proposed Superpave mixture design.

The Pennsylvania DOT has allowed HMA producers to use ignition ovens for their quality control testing and plant certification of HMA mixtures. However, the department is still in the process of investigating the use of ignition ovens for department acceptance of HMA mixtures.

Georgia (Lamar Caylor, Georgia DOT)

GDOT implemented the use of the rut tester in 1989 as part of the design procedure for mixes used on interstate highways. The Georgia loaded wheel tester did not have the capability to test submerged samples. In 1996, GDOT switched to the Asphalt Pavement Analyzer (APA) for mixture proof testing. Although the APA has the ability to test samples under water, we have not done enough testing in that mode to establish the test parameters needed. For testing in the dry mode, GDOT uses a wheel load of 100 lb., hose pressure of 100 psi, and a test duration of 8,000 cycles. Conventional mixes are tested at 105°F. with a maximum rut depth of 7 mm allowed, while SMA and Superpave mixes are tested at 120°F with a maximum rut depth of 5 mm allowed. Superpave recommends the use of asphalt binder that will perform up to 60°C for Georgians geographical area: GDOT is considering using 60°C as its standard test temperature.

GDOT requires that certification for Superpave binder testing be obtained from one of the Superpave centers. A training and certification program for Superpave mix design is being developed in cooperation with NCAT.

Florida has had some problems with excessive permeability of coarse-graded Superpave mixes, and as a result has developed a relatively simple permeability test that can be used to quantify the permeability of an asphalt pavement core sample. Data obtained on projects in Florida indicate that the in-place air void content needs to be no greater than 6 percent to assure the pavement is impermeable. (Jim Musselman, Florida DOT)

Ohio (Dave Powers, Ohio DOT)

Ohio would like to comment on Florida's experience. The Florida research on coarse-graded mix permeability should be considered by other states. We believe this has been a major influence on our current coarse-graded heavy mix performance. Changes to accommodate this are lower design air voids, density acceptance on all heavy routes and 93 percent minimum mat density based on theoretical maximum density. Voids in coarse-graded mixes are more interconnected than voids in fine-graded mixes, thus greater permeability as shown in Florida's work.



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.*

Arizona (Julie Nodes, Arizona DOT)

Some Arizona asphalt binder suppliers have reported difficulty meeting the minimum G^*/\sin of the RTFO residue (AASHTOMP-1). They report that they must produce an inferior product to meet this portion of the specification. Have any other states experienced similar problems?

There is considerable concern among contractors in Arizona about obtaining smoothness on Superpave mixes (Arizona DOT has incentives for smoothness). Has anyone else had similar problems?

Iowa (Don Jordison, Asphalt Paving Association of Iowa)

Six Superpave projects were identified for 1997 construction. In 1998, 25 percent of the primary and interstate (P & I) asphalt projects will be Superpave projects; in 1999, 50 percent of the P & I projects; and in 2000, 100 percent will be Superpave projects. City and county implementation is scheduled for year 2002.

The certification training program will again be active. The emphasis is now on reciprocity between the various states, with the ultimate goal of having a nationwide reciprocity for field and laboratory technicians.

Kentucky (Allen Myers, Kentucky Department of Highways)

1. How many states use the phase angle to indirectly specify polymer content of PC binders? If used, what phase angle is specified?
2. How do other states specify mixing and compaction temperatures for PC 70-XX and PC 76-XX binders? By temperature/viscosity charts? By manufacturer's recommendation? By state's definition?
3. Are other states allowing gyratory compactors besides Pine and Troxler to be used? If so, what criteria are used to "qualify" these other compactors?
4. What optimum air-void content are other states using for coarse-graded Superpave mixtures? Kentucky's large-stone base mixtures specify a target air-void content of 5.5-6.0 percent. What should we use for Superpave designs: the same targets or 4.0 percent?
5. What design life are other states using for calculation of ESALS for a Superpave project? Twenty years across the board? Different values for resurfacing and

rehabilitation projects versus new construction?!

6. Have any other states experienced a drastic decrease in air voids and VMA between the laboratory Superpave mix design and plant-produced-mixture specimens compacted with the gyratory compactor?'

Missouri (Jim Campbell, Missouri DOT)

Four Superpave projects are being constructed during the 1997 construction season. The projects consist of two full depth jobs and two overlays. Approximately 240,000 tons of mix will be laid on these four jobs. The jobs completed to date have been very satisfactory.

Pennsylvania (Tim Ramirez, Pennsylvania DOT)

The Pennsylvania DOT is continuing with Superpave implementation. PC binders will be fully implemented in 1998 for construction of all Superpave-designed and Marshall-designed HMA pavement courses. A total of 16 Superpave projects have been let and awarded. Approximately one-half of these projects will be completed in 1997 and the remaining will be completed in 1998. The Department has developed a special provision for specifying Superpave pavement courses, which follows all the recommendations and procedures outlined in the Asphalt Institute's Superpave Level 1 Mix Design Manual (SP-2). More Superpave projects are currently being planned for letting during late 1997 and early 1998. So far, no major problems have been experienced by HMA producers in developing acceptable Superpave mix designs. The Department has developed a joint evaluation plan with the Northeast Superpave Center located at the Pennsylvania State University to evaluate these initial 16 projects. The evaluation plan includes PC binder verification, Superpave mix design verification, and mixture analysis of selected projects using the Northeast Superpave Center's Superpave shear tester and indirect tensile tester.

Tennessee (Bobby Rorie, Tennessee DOT)

The Tennessee DOT has recently appointed a Superpave evaluation committee to evaluate test data from the eight Superpave projects that are being placed this year. This committee consists of (1) industry personnel representing both aggregate and hot mix

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SPECIFICATION CORNER

Arizona - The Arizona DOT has fully implemented the Superpave asphalt binder specification (MP-1) without any changes. The implementation of Superpave volumetric mix design has begun. Approximately 10 projects were scheduled this year. At least 40 projects have been scheduled over the next 1 to 2 years. All Superpave mixture projects are end product (QC/QA) type specifications. Some changes have been made to the Superpave mix specification: (a) design air void content of 5 percent, and (b) minimum VMA requirement increased by percent. The full implementation of the Superpave volumetric mix design is anticipated in year 2000 or 2001. Ignition oven is specified on Superpave projects for determination of binder content. The use of ignition oven will be extended to other projects gradually.

Georgia - The Georgia DOT (GDOT) began using a Superpave binder specification in January, 1997. This specification requires a standard binder grade of PC 67-22 for all virgin mixes. Also, PG 76-22 is specified in certain mix types and traffic conditions. A phase angle requirement was added to ensure polymer modification, and the polymer type is specified.

In July 1997, GDOT began to implement contractor acceptance testing. This procedure turns the quality control process over to the contractor, while GDOT monitors the quality acceptance. The contractor is responsible for testing the plant-produced mix, and the contractor test results are used for acceptance as long as they satisfy GDOT verification tests.

Beginning in July 1998, all conventional mixes will be replaced with Superpave mixes. Also at that time, contractors will be required to perform their own asphalt mix designs.

Hawaii - The Hawaii DOT is initiating its Superpave implementation with a pilot project which will utilize both performance graded binder specifications and Superpave mix designs. Construction of the project is scheduled for January 1998.

Illinois - The Illinois DOT has specified PG binders on eight 1997 Superpave demonstration projects. The asphalt binders needing modification must be polymer modified. One of the projects that required polymer modification experienced several failures in meeting the required PG grade. Some of the failures were attributed to faulty testing equipment while others were caused by inadequate binder blending techniques.

Illinois has implemented a specification on control of segregation in HMA that was developed by a joint committee of contractors and Illinois DOT

representatives. It is too early to assess the impact on quality.

Kentucky - Kentucky DOT has 12 districts. One Superpave project was let per district in 1997. Three Superpave projects will be let per district in 1998. Five Superpave projects will be let per district in 1999. The full Superpave implementation is planned in year 2000.

Superpave mixtures are accepted by air voids, VMA, asphalt content, and density. The HMA specimens are compacted with a Superpave gyratory compactor. The mat density is measured from roadway cores.

Louisiana - Nine Superpave projects have been planned for the 1998 construction season. Aggressive implementation of the percent within limits (PWL) and QC/QA specification is planned. The QC/QA specification is modeled after the NCHRP 9-7 report.

The asphalt binder specification to be used in 1998 equals PG 76-22 except (a) force ratio, 4°C, of 0.3 on original binder, (b) elastic recovery, 25°C, of 65 percent on RTFO residue, and (c) $G' / \sin \delta$ limit on RTFO residue reduced from 2.2 kPa to 1.75 kPa based on laboratory data and field performance. The polymer modified asphalt binders have a lower rate of aging in the RTFO test.

Superpave aggregate gradations were implemented in 1996. Most mix designs are on the fine side of the maximum density line. Early rutting has been reported on one project which was on the coarse side of the maximum density line. Segregation was reported on some projects. Louisiana DOT requires the material transfer vehicle (MTV) on all projects.

Minnesota - The Minnesota DOT now allows scrap roofing shingle waste to be added to asphalt mixtures. The amount is limited to 5 percent by weight of total mix. The scrap shingle specification is inclusive in our recycling specification, meaning shingle scrap is treated like RAP. At the present time, only the manufacturers waste shingle scrap is allowed. Although the specification allows shingle scrap, a high use has not been experienced as yet, primarily due to economics (cost of processing and incorporating the produce in HMA).

Missouri - The current goal is to have Superpave fully implemented for the 2000 construction season. The following changes have been made for 1998 Superpave contracts:

(1) Steel slag shall not exceed 20 percent by weight of the mineral aggregate for design ESALS greater than

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three million. For ESALS less than three million, no restriction will be placed on the amount of steel slag. (2) Crushed gravel shall not exceed 20 percent by weight of the mineral aggregate. (3) The contractor shall provide the job mix formula for each Superpave mixture. Representative samples of asphalt cement and mineral aggregates shall be submitted to the Central Laboratory for Superpave mixture verification. (4) Field measured percent asphalt cement may be measured by either nuclear gauge or binder ignition method. (5) Acceptable test strips shall meet density, gradation, percent asphalt cement, and the volumetric requirements of the contract. Test strips which do not meet these requirements shall be removed.

New Jersey - The New Jersey DOT will use PC graded asphalt binders in lieu of viscosity-graded binders to construct six Superpave projects during the next 12 months.

Ohio - The Ohio DOT has planned 10-12 Superpave projects for 1998. The minimum mat density acceptance requirements are being raised to 93 percent of theoretical maximum density to decrease permeability and prevent the delamination of lift. These density requirements are proposed to be applied to all heavy duty routes. Improvements to current heavy duty Marshall mixes are being studied by comparing to Superpave mixes. The number of Superpave gyrations may be adjusted, if necessary, to maintain the minimum binder content for desired durability.

Pennsylvania - The Pennsylvania DOT has begun development of a specification for ride quality in HMA pavement courses. This is in response to public surveys indicating smooth pavements are a primary factor in public satisfaction. The Department intends to include a payment incentive/disincentive for ride quality. Some critical issues to be considered during the specification development include acceptable corrective work, if necessary, measured profile indexes and their corresponding payment percentage factor, and measured profile indexes and their relationship to an actual smooth seat-of-the-pants ride quality. It is intended to refine the payment percentage factors as HMA contractors gain experience in placing smooth pavement courses or as technological enhancement in equipment or techniques are developed.

Rhode Island - Beginning in August 1997, HMA contractors have the option of using PC 64-22 or PC 64-28 asphalt binder in lieu of AC-20 in any HMA mix.

South Carolina - The South Carolina DOT has implemented Superpave mixtures on all interstate

projects beginning in January 1997. The specified mix types for intermediate and surface courses are the 19.0 mm and 12.5 mm mixes, respectively. The Department has also started requiring the use of PC 64-22 in all hot mix asphalt with the January 1997 letting. Superpave mixtures are being designed by the SCDOT at this time, however, in 1998 contractors will be permitted to design Superpave mixes, provided they have a certified technician and mix design laboratory. Starting with the January 1999 letting, contractors will be required to design their own Superpave mixes.

Texas - The Texas DOT let 12 Superpave projects this construction season, which will be completed by December 1997. The moisture damage criteria (AASHTO T283) was changed recently to require a minimum tensile strength ratio (TSR) of 80 percent and a minimum conditioned strength of 70 psi.

Utah - Quality control/quality assurance (QC/QA) is being used on projects 50,000 tons or more. All dense-graded HMA mixes are being designed with the Superpave gyratory compactor. PC binder is used in all mixes. The working grade is PC 64-3-1.

Wisconsin - Starting with the March letting, the Wisconsin DOT is specifying PC graded binders on all projects. A PC 58-28 binder will be used state wide.

The Wisconsin DOT's round robin program, a requirement of their "Certification Method of Acceptance for Asphalt Cements," currently has 35 participants, including testing facilities in Canada and Venezuela. The data being collected is to be used to help in determining testing tolerances and ensuring the reliability of test results.

Wisconsin DOT is working with the Minnesota DOT and Iowa DOT to develop a "Tri-state Certification Method of Acceptance for Asphalt Cements." This program is being developed with input from the asphalt binder suppliers to make a uniform method for the states that share many common suppliers.

New Brunswick, Canada - The first Superpave project was bid this year. Twenty-five percent of contracts will include the use of PC asphalt binders including PC 58-34 and PC 52-34.

Ontario, Canada - The Ontario Ministry of Transportation continued the development of a new end-result specification combining asphalt content, gradation, compaction, and air voids based on percent within limits.

Two HMA specifications are in place: one based on "owner testing" and one based on "contractor testing." The one based on "contractor testing" is used in

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Government and industry engineers from South Africa's Society for Asphalt Technology visited NCAT laboratory during their study tour of USA in August.

*(SPECIFICATION CORNER,
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conjunction with a Bituminous Quality Control Plan. The one for "contractor testing" will be included in all new contracts.

The development of a new specification for visually defective mix was continued. It was implemented on a few contracts this year.

The development of a new end-result specification for smoothness was also continued. Changes in the maximum bonus and an easing of requirements to obtain bonus have been made.

(ASPHALT FORUM, Continued from page 14)

asphalt producers. (2) FHWA representatives, and (3) Tennessee DOT regional and headquarters personnel.

As numerous other states have mentioned, we are having extreme difficulty in obtaining density with Superpave mixes, particularly when designed on the coarse side of the maximum density line. It appears that some gradation changes are needed in order to produce a denser mix.

New Brunswick, Canada (Terry Hughes, New Brunswick DOT)

The addition of anti-stripping agents to PC asphalts binder changes their properties and sometimes results in the product not meeting the specified grade. Should PG grades be specified to meet the specification after addition of the anti-stripping agent, or should the PG asphalt binder be tested prior to addition of the anti-stripping agent?



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 two-week intensive course will be conducted at NCAT June 15-26, 1998. 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>.

PUTTING RESEARCH INTO PRACTICE

The following papers were presented at the annual meeting of Association of Asphalt Paving Technologists held in Salt Lake City in March, 1997. We are reporting observations and conclusions from these papers which may be of value to field engineers. These comments are obtained mostly from research projects with a limited scope; before application to practice we recommend that you read the entire paper to determine its limitations. Titles of the papers are given, with names of authors in parentheses, followed by a brief summary.

1. DEVELOPMENT OF A MIX DESIGN PROCEDURE FOR STONE MATRIX ASPHALT (SMA) MIXTURES (Brown, Haddock, Mallick and Lynn)

The stone matrix asphalt (SMA) has been used in Europe for over 20 years to provide excellent rutting resistance and to resist studded tire wear. However, no standard mix design procedure is available. This study was undertaken by NCAT to develop a simple, straight-forward, and practical mix design procedure for SMA using both Marshall and Superpave methods. The effects of varying different material components of the SMA mix (aggregate, fillers, asphalt binders, and fibers) were evaluated. The effects of material properties such as Los Angeles abrasion, flat and elongated particle content, and fiber type, were also evaluated.

The five steps in the mix design process are as follows:

- Selection of materials.
- Determination of a gradation to ensure stone-on-stone contact. This requires the measurement of voids in coarse aggregate (VCA). The VCA in mix must be equal to or less than VCA in dry rodded condition.
- Selection of gradation to meet both VMA (voids in mineral aggregate) and VCA (voids in coarse aggregate) requirements.
- Selection of asphalt content to provide desired air voids.
- Evaluation of asphalt binder draindown potential.

Some of the specific conclusions drawn from this study are as follows:

- L.A. Abrasion loss showed good correlation with breakdown of aggregates. An increase in L.A. Abrasion loss resulted in a higher amount of aggregate breakdown in the case of both Marshall and Superpave gyratory compactors. Hence, a limit on L.A. Abrasion loss is justified to help minimize aggregate breakdown. The limit of 30 recommended by the SMA Technical Working Group appears to be reasonable.

- The 5:1 flat and elongated particle content criteria was met by all of the eight aggregates used in this study. It appeared that the 2:1 and 3:1 flat and elongated particles provided much better separation in the various aggregates than did the 5:1 ratio.

- The flat and elongated particle content showed excellent correlation with breakdown of aggregate. Breakdown of aggregate increased with an increase in flat and elongated particle content.

- In a SMA mix, the percent passing 4.75 mm sieve must be below 30 percent to ensure proper stone-on-stone contact. Stone-on-stone contact can be evaluated by plotting VMA or VCA versus the percent passing the 4.75 mm sieve. The dry rodded test, as outlined in AASHTO T19, can be used to determine the limiting VCA for the SMA mixture.

- A VMA significantly lower than specified VMA can result from aggregate breakdown. Hence, the mix designer must consider aggregate type, compactor, and compactive effort along with the gradation in meeting the required VMA criteria. Specifying a minimum asphalt content by weight can result in different requirements for aggregates with different specific gravities. Even with sufficiently high VMA values, the optimum asphalt content by weight may be relatively low when using aggregate with high specific gravity.

- Fifty blows of Marshall hammer were found to be approximately equal to 100 revolutions of the Superpave gyratory compactor in terms of resultant density. The Superpave gyratory compactor was found to produce less aggregate breakdown than the Marshall hammer. However, in the case of both compactors, the amount of breakdown was found to be affected by aggregate type and compactive effort.

- Fiber stabilizers were found to be more effective in reducing draindown than polymer stabilizers. However, mixes modified with polymer showed better resistance to rutting in laboratory wheel tracking tests.

2. CRITICAL EVALUATION OF SUPERPAVE LEVEL 1 MIX DESIGN USING ARKANSAS SURFACE COURSE MIXES (Gowda, Hall, Elliott and Meadors)

The Superpave volumetric mix design specifies laboratory compaction levels (in terms of number of gyrations) corresponding to seven (7) traffic levels and four (4) average design high air temperatures. This results in $7 \times 4 = 28$ different levels of compaction. The four average design high temperatures have a very narrow range: $<39^{\circ}\text{C}$, $39\text{-}40^{\circ}\text{C}$, $41\text{-}42^{\circ}\text{C}$, and $43\text{-}44^{\circ}\text{C}$. This study was undertaken to determine whether these

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*(RESEARCH INTO PRACTICE,
Continued from page 18)*

28 different compaction levels give significantly different mix designs in terms of optimum asphalt content, VMA, and VFA. Four crushed stone (one sandstone and three granite) aggregates were used to prepare 12.5 mm nominal size hot mix asphalt (HMA) mixtures. Two asphalt binders, PG 64-22 and PG 76-22 (polymer modified) were used. The eight HMA mixtures were designed by Superpave volumetric mix design method for a design traffic of over 100 million ESALS and a temperature level of 44°C resulting in the highest compaction level ($N_{max} = 288$ gyrations) given in the Superpave gyratory compactive effort table. The height data from the gyratory compaction process was efficiently utilized to back-calculate the bulk specific gravity of the mixes at the remaining 27 design gyration levels and thus perform mix designs at these levels. The mix design data thus generated was used to critically evaluate the Superpave volumetric mix design procedure.

The following conclusions were drawn based on eight mixtures (4 aggregates \times 2 binders):

- The optimum asphalt content and VMA requirements of the mixes tend to decrease with an increase in the design gyratory compactive effort to approximately 90 gyrations. At greater compactive efforts the parameters remain essentially constant over the range of gyrations investigated.
- The VFA of the mixes investigated tend to be less sensitive to mix compatibility than the optimum asphalt content or VMA. The compatibility of the mixes investigated in this study remains essentially constant beyond a particular level of compaction (as low as 90 gyrations).
- The variation in optimum asphalt content and VMA corresponding to an exponential increase in traffic levels for a given temperature environment is not statistically significant.
- Mix designs for design gyration levels (representative of exponential increases in traffic level) which differ by 1 to 2 gyrations do not differ statistically.
- The range of temperature environment selected in the Superpave mix design system are narrow and do not produce mix designs which differ significantly.

Additional research encompassing a wide range of aggregates, aggregate blends, and binders are essential to confirm the trends from this study. Should the research concur with the trends reported in this study, modifications to the Superpave Design Gyratory Compactive Effort Table may be essential to include

the gyratory compactive levels which yield mix designs (at different traffic and temperature environment levels) that are significant from practical stand point of view.

3. PAVEMENT DENSITY MEASUREMENT COMPARATIVE ANALYSIS USING CORE AND NUCLEAR METHODS (Schmitt, Hanna, Russell and Nordheim)

Core samples have been historically used by agencies and contractors as the reference standard for asphalt pavement density measurement. However, the process of using cores for density evaluation has several disadvantages, such as a destructive and lengthy test procedure that requires several hours to complete. Highway agencies and contractors are using nuclear density gauges to offset this shortcoming, but they have experienced differing results between core samples and nuclear readings, raising concern for using a nuclear density gauge to measure pavement density. This paper presents a statistically-based approach that will help agencies and contractors better understand the relationship between core samples and nuclear gauges. Several comparison test sites were randomly collected from 14 asphalt paving construction projects in Wisconsin to compare core sample densities and nuclear gauge readings.

Six-inch (150 mm) diameter core samples were used for pavement density measurements. Three nuclear density gauge models were used.

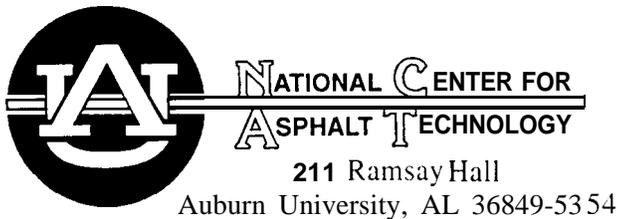
Some of the conclusions drawn from this study are as follows:

- The nuclear gauge measures density lower than cores at low densities, and higher than cores at high densities. The balancing point in the regression equation, or the density where cores equal nuclear readings, was 22.92 KN/m³ (145.8 PCF).
- The relationship between nuclear density gauges and core samples is affected by the thickness of the mat and maximum specific gravity of the asphalt mix.
- An analysis was conducted to find the variation found in the ASTM D2950-91 conversion factor method. In this study, the conversion factor was defined as the mean difference of seven cores and seven nuclear readings. Results of the analysis indicate there is substantial variation in determining the conversion factor with an observed range of 0.65 and 3.60 percent on individual projects. Further research is needed to determine if seven comparison sites are sufficient for developing a conversion factor.

NCAT's 1997 PROFESSOR TRAINING COURSE ATTENDEES AND INSTRUCTORS



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