ASPHALT TECHNOLOGY NEWS

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NCAT COMPLETES EVALUATION OF RESTRICTED ZONE IN SUPERPAVE GRADATION

The National Center for Asphalt Technology (NCAT) has completed National Cooperative Highway Research Program (NCHRP) Project 9-14, "Investigation of Restricted Zone in the Superpave Aggregate Gradation Specification." The primary objective for this research was to determine under what conditions, if any, compliance with the restricted zone requirement is necessary when the asphalt paving mix meets all other Superpave requirements such as fine aggregate angularity (FAA) and volumetric mix criteria.

The Strategic Highway Research Program (SHRP) primarily researched the properties of asphalt binders and paving mixes and their effect on asphalt pavement performance. The study of aggregate properties (including gradation) was intentionally excluded from the asphalt research program. However, SHRP researchers had to recommend a set of aggregate properties and an aggregate gradation specification (without the benefit of experimentation) so that a comprehensive Superpave mix design system could be formulated.

An Aggregate Expert Task Group (ETG) consisting of 14 acknowledged experts in the area was formed by SHRP. In lieu of a formal aggregate research program, ETG used a modified Delphi approach to develop a set of *recommended* aggregate properties and criteria that

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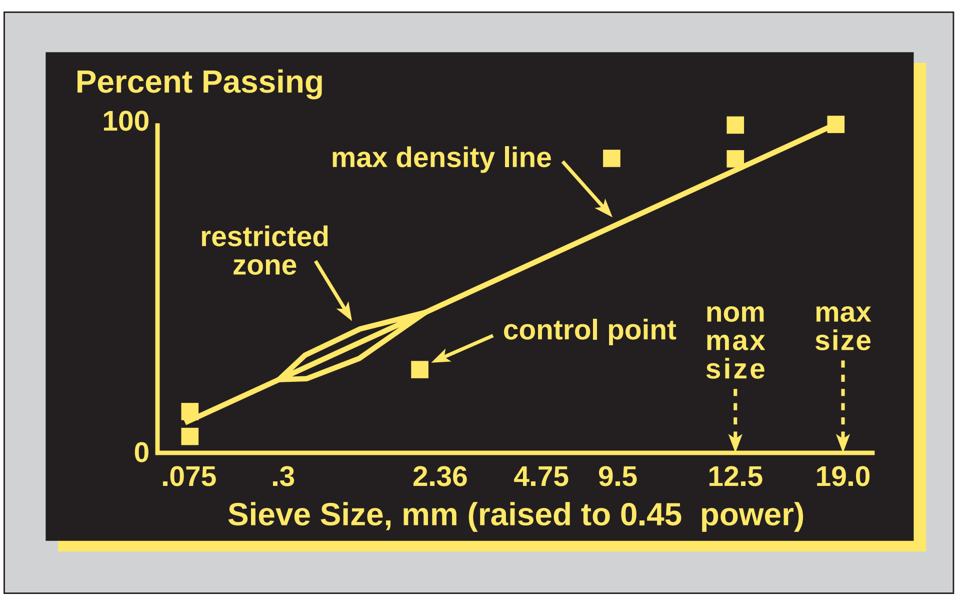

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are now included in the Superpave volumetric mix design method. The Delphi process was conducted with five rounds of questionnaires. The final recommended aggregate gradation criteria included control points between which the gradation must fall, and a restricted zone that lies along the maximum density line (MDL) between the intermediate size (either 4.75 or 2.36 mm depending on the nominal maximum size of the aggregate in the mix) and the 0.3 mm size.

Although the restricted zone was included in Superpave as a recom-mended guideline and not a required specification, some highway agencies are interpreting it as a requirement.

It is believed by many asphalt technologists that compliance with the restricted zone criteria may not be necessary, or even desirable in every case, to produce asphalt mixes with good performance.

If highly angular aggregates are used in the mix it is likely that it will not exhibit any tenderness during construction and will be rut resistant under traffic although its gradation may pass through the restricted zone. The Georgia Department of Transportation has successfully used such mixes for many years. Some asphalt technologists also question the need for the restricted zone when the mix has to meet volumetric properties such as minimum voids in the mineral aggregate (VMA) and specified air void contents at $N_{initial}$, N_{design}, and $N_{maximum}$ gyrations.

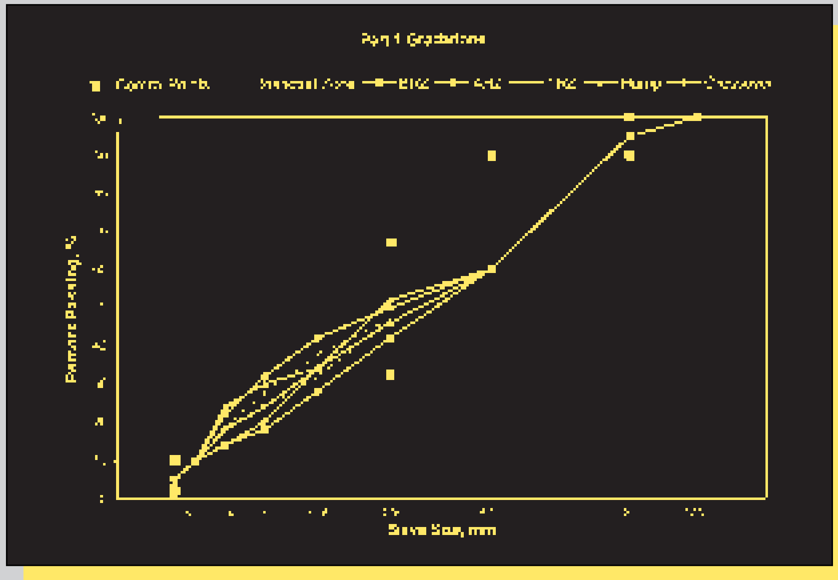

Figure 1. Gradations

It was obvious that the effect of the restricted zone on mix performance should be evaluated on the basis of statistically planned and properly controlled experiments, which is the subject of this NCHRP Project.

Since the restricted zone is applied within the fine aggregate sieve sizes, the shape and texture of the fine aggregates are the most important factors affecting the performance of HMA mixtures. Therefore, the approach taken in identifying and selecting fine aggregates for use in the study was to select aggregates with varying values of fine aggregate angularity (FAA). Also included within the selection criteria were the mineralogical composition of the fine aggregates and type of crusher. Maximization of these three criteria ensured using fine aggregates with a wide range of properties.

Factor-level combinations included in Part 1 of this project consisted of two coarse aggregates (granite and crushed gravel), ten fine aggregates (FAA ranging from 38.6 to 50.3), five 9.5 mm nominal maximum aggregate size (NMAS) gradations, and one compactive effort (100 gyrations). Of the five gradations used, three violate the restricted zone while two fall outside the restricted zone (control). These five gradations are illustrated in Figure 1.

All five gradations follow the same trend from the

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12.5 mm sieve down to the 4.75 mm sieve. From the 4.75 mm sieve, the BRZ gradation passes below the restricted zone and above the lower control points. The ARZ gradation passes above the restricted zone and below the upper control points. These two gradations are designated the control gradations since they do not violate the Superpave restricted zone. The remaining three gradations do violate the restricted zone. From the 4.75 mm sieve, the TRZ gradation passes almost directly along the maximum density line through the restricted zone. The Hump gradation follows a similar gradation as the TRZ gradation down to the 1.18 mm sieve where it humps on the 0.6 and 0.3 mm sieves. The hump gradation (HRZ) represents gradations generally containing a large percentage of natural sands, and is likely to cause tender mixes. From the 4.75 mm sieve, the Crossover gradation (CRZ) begins above the restricted zone on the 2.36 mm sieve but then crosses through the restricted zone between the 0.6 and 0.3 mm, sieves. The crossover gradation represents gradations which are not continuously graded between 2.36 mm and 0.60 mm sizes and generally exhibit low mix stability. All five of the gradations then meet at the 0.15 mm sieve and follow the same trend down to the 0.075 mm sieve. A common material passing 0.075 mm sieve or No. 200 sieve (P200) was used in all HMA mixtures to eliminate P200 as a variable. Different P200 materials stiffen the asphalt binder and HMA mixtures to a different degree and, therefore, affect the mix performance test results.

Part 2 of this project involved the same NMAS of 9.5 mm but two additional compactive efforts of 75 and 125 gyrations were used. Part 3 involved 19.0 mm NMAS mixtures and two compactive efforts of 75 and 100 gyrations.

Mixtures meeting all volumetric requirements were used for performance testing. This approach was selected because the Superpave volumetric requirements are believed to detect a potential problem mixture.

The performance of mixes meeting volumetric requirements was evaluated on the basis of performance related mechanical tests. Since the primary purpose of the restricted zone was to avoid rut-prone mixes, the mixes in this study were evaluated for their rutting potential. This was accomplished by two different types of tests: empirical and fundamental. For the empirical test, the Asphalt Pavement Analyzer (APA) was used. The Superpave shear tester (SST) and the repeated-load, confined creep test were utilized as fundamental tests. These three tests were proposed to ensure a satisfactory conclusion of this study.

The Asphalt Pavement Analyzer (APA) II is an automated, new generation of Georgia Loaded Wheel Tester. The APA II features controllable wheel load and contact pressure, adjustable temperature inside the test chamber, and the capability to test the samples either while they are dry or submerged in water. The APA test was conducted dry with 8,000 cycles, and rut depths were measured continuously. The APA can test three pairs of gyratory compacted specimens of 75 mm height. Testing with the APA was conducted at 64°C, which corresponds to a PG 64 asphalt binder used in this study.

The Superpave shear tester (SST) developed by SHRP is a closed-loop feedback, servo hydraulic system that consists of four major components: a testing apparatus; a test control unit; an environmental control chamber; and a hydraulic system. The ability of a pavement structure to resist permanent deformation and fatigue cracking is estimated through the use of the SST. The SST simulates, among other things, the comparatively high shear stresses that exist near the pavement surface at the edge of vehicle tires; stresses that lead to the lateral and vertical deformations associated with permanent deformation in surface layers.

The repeated load, confined creep test is considered to be a fundamental experimental method to characterize the rutting potential of HMA, since fundamental creep principles can be applied to deformation of viscoelastic mixes. A Material Testing System (MTS) was used to conduct this test. A deviator stress along with a confining stress is applied on a HMA sample for one hour, with 0.1 second load duration and 0.9 second rest period. After the one hour test the load is removed and the rebound measured for 15 minutes. The strain observed at the end of this period is reported as the permanent strain, which indicates the rutting potential of the mix. This test has been used successfully by NCAT in a national study of rutting. The test temperature used was 60°C. Test loadings consisted of 138 kPa (20 psi) confining pressure and 827 kPa (120 psi) normal pressure.

Test results from the three mechanical tests were analyzed to obtain performance data of HMA mixtures containing different gradations and FAA values.

The following tentative findings were made from the analysis of the test results obtained in Parts 1, 2, and 3; final conclusions and recommendations will be published later this year by NCHRP in the research report for Project 9-14.

1. Parts 1 and 2 involved 9.5 mm nominal maximum aggregate size (NMAS) mixes and three compactive efforts: N_{design} of 75, 100, and 125 gyrations corresponding, respectively, to design traffic levels of 0.3 to less than 3, 3 to less than 30, and greater than or equal to 30 million ESALs. The mixes having gradations that violated the restricted zone performed similarly or better than the mixes having gradations passing outside

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NCAT TEST TRACK UPDATE

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

Trucking began on September 19, 2000 with a single truck/trailers. Each trailer assembly consists of three units connected in a train, with each axle approximately loaded to the federal legal bridge limit (20,000 lbs). The average gross vehicle weight is approximately 152,700 lbs. By the end of September, the single truck/trailers had applied 42,699 equivalent single axle loadings (ESALs) to the test sections.

The second and third truck/trailers were placed in service in October and November, respectively. A fourth truck/trailers was added in early 2001. Fuel consumption is being documented to evaluate the effect of pavement surface condition on vehicle operating costs. Each lap of the four truck/trailers applies an average loading of 10.86 ESALs. By early spring this year, approximately 1.7 million ESALs had been applied to the test sections. This value represents 17 percent of the planned 10-million ESAL goal to be applied in two years.

Truck operations currently run from 5:00 am to 11:00 pm, Tuesday through Sunday each week. On Mondays, drivers have the day off and mechanics service the trucks including rotation of tires. NCAT personnel perform a weekly pavement condition survey on Mondays. This includes quantifying mat densification, rutting, and smoothness. No significant distress, either rutting or cracking, has been noted to date. Additionally, personnel from the Alabama Department of Transportation perform monthly independent evaluations to determine change in surface friction, rutting, smoothness, and surface deflection.

Some 5000 Superpave gyratory compactor or beam specimens were made during construction for production volumetric testing and post-construction laboratory performance analyses. Testing of these specimens is in progress.

The initial report summarizing construction data will be available for broad distribution in spring this year. Study results may be accessed electronically through a link on the NCAT web site, or via direct URL at <http://www.pavetrack.com>.

NCAT DEVELOPS NEW GENERATION OPEN-GRADED ASPHALT FRICTION COURSES

BACKGROUND AND HISTORY

In the United States, open-graded asphalt friction course (OGFC) evolved from experimentation with plant mix seal coats by some western states during the 1960s. The cover aggregate used for seal coats (chip seal), typically 9.5 to 12.5 mm (3/8 to 1/2 in) maximum nominal size, was mixed with a relatively high percentage of asphalt cement in a conventional hot mix asphalt (HMA) plant, and placed 15 to 20 mm (5/8 to 3/4 in) thick. This plant mix seal (also called popcorn mix) offered the same benefits as chip seal but it eliminated many of its problems such as loose stones.

It was only in the early 1970s that many states in the western United States began placing plant mix seals on a routine basis. The Federal Highway Administration (FHWA) initiated a program during that period to improve the overall skid resistance of the road surfaces in the U.S. The FHWA considered plant mix seal as one of the tools to accomplish this objective, and the term open-graded asphalt friction course (OGFC) was coined. The FHWA also developed a mix design method for OGFC.

Figure 1. Interstate 5 in Oregon. Note the absence of splash and spray on southbound lanes (left) with OGFC compared to northbound lanes (right) with dense-graded HMA.

The OGFC was designed as an open mix with interconnecting voids that provided drainage during heavy rainfall. The rainwater drains vertically through the OGFC to an impermeable underlying layer and then laterally to the daylighted edge of the OGFC. The following benefits are derived from the use of OGFC in terms of safety and environment:

- **Reduced splash/spray and glare**

It is a frightening experience when driving during rain to run into heavy spray of vehicles (especially trucks) traveling ahead. The use of OGFC almost eliminates spray because there is no standing water on the road surface. Figure 1 clearly shows the difference between conventional dense-graded HMA and OGFC in Oregon. Motorists feel secure when driving on OGFC surface during rain.

Another benefit from the use of OGFC is the reduction of glare from headlights in wet conditions (Figure 2). Obviously it contributes to better visibility and reduced driver fatigue.

- **Improved wet pavement skid resistance**

Research conducted in the U.S., Canada, and Europe has clearly indicated the superior wet pavement skid resistance of OGFC in comparison to dense HMA and PCC surfaces. The resulting reduction in wet weather accidents has also been documented.

The Pennsylvania Department of Transportation obtained skid resistance and speed gradient data on four test sections consisting of OGFC and dense-graded HMA. Speed gradient is defined as the rate of decrease in skid resistance as the speed is increased. A low speed gradient is desirable because it will ensure high skid resistance levels at high operating speeds such as 60 or 70 miles per hour. The data in Table 1 clearly indicates higher skid numbers and significantly lower speed gradients for OGFC compared to dense-graded HMA.

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—New Generation *(continued from page 5)*

Table 1. Skid Data (Pennsylvania)

Mix Type	Skid Number 30 mph	Skid Number 40 mph	Speed Gradient
OGFC (gravel)	74	73	0.10
OGFC (dolomite)	71	70	0.10
Dense-graded HMA (gravel)	68	60	0.80
Dense-graded HMA (dolomite)	65	57	0.80

The Louisiana DOT also compared the skid number and speed gradient of OGFC (called plant mixed seal at the time) with dense-graded HMA at speeds ranging from 20 to 60 mph as shown in Figure 3. It is evident that OGFC had a flatter speed gradient than the dense-graded HMA which resulted in high skid numbers at high speeds.

The Virginia DOT and the Ontario Ministry of Transportation have reported a significant reduction in wet pavement accidents after OGFC was placed.

The Pennsylvania DOT has reported on the performance of three skid resistance treatments on Interstate 80. These treatments were applied to the existing reinforced portland cement concrete pavement which had borderline skid numbers (below 35). The three treatments consisted of slurry seal, OGFC, and longitudinal grooving. All three treatments improved the skid resistance of the existing pcc pavement. The highest skid number readings were obtained from the

Figure 2. Interstate 5 in Oregon. Note the absence of glare from headlights during wet conditions on southbound lanes (right) with OGFC compared to northbound lanes (right) with dense-graded HMA.

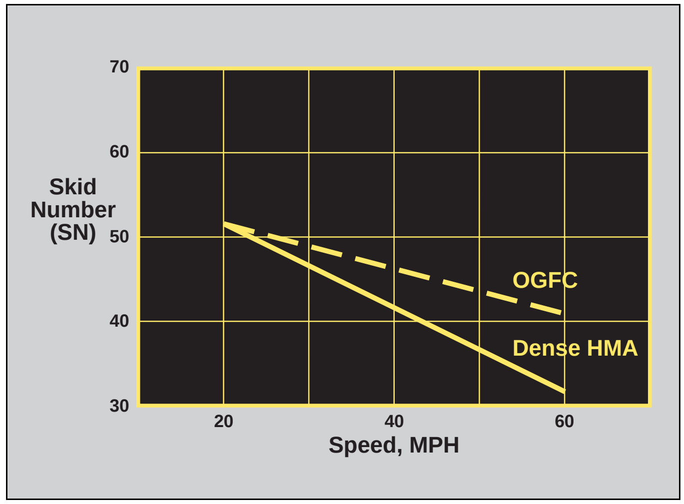


Figure 3. Speed-Friction Relationship of OGFC and Dense HMA Surfaces (Louisiana)

OGFC which averaged at 52. The slurry seal averaged 42, and the longitudinal grooving averaged 37.

- **Hydroplaning**

  The OGFC prevents hydroplaning because the rain water permeates through it leaving no continuous water film on the road surface. Even during a prolonged period of heavy rainfall which may saturate the OGFC, hydroplaning will not occur because the pressure under the vehicle tire is dissipated through the porous structure of the OGFC.

- **Improved visibility of pavement markings**

  The pavement markings on OGFC surface have high night visibility especially during wet weather. This contributes to improved safety.

- **Noise reduction**

  Various research studies have been conducted in the U.S. and Europe to evaluate the noise reduction capabilities of OGFC compared to other pavement surface types. Reductions in noise levels: 3dB(A) as compared to dense-graded HMA, and 7 dB(A) as compared to PCC pavement, have been reported in Europe. As a comparison, sound barriers which are used adjacent to highways in urban areas generally reduce levels by about 3 dB(A). A significant difference in noise level is noticed by most people when the noise level changes by 3 dB(A).

  The variation of tire/road contact noise (both outside and inside a car traveling at 80 km/h) within different surface types (OGFC, dense-graded HMA, surface dressing or chip seal, portland cement concrete, and stone paving) was measured in Europe and is shown in Figure 4.

  Placing an OGFC overlay may be a viable alternative to the construction of sound barriers to mitigate traffic noise. Barriers usually cost between $15 and $20 per linear foot and generally reduce the noise level by 3 to

5 decibels. To reduce the noise level by 3 dB(A), either the traffic volume has to be cut by half or the noise protection distance to the road has to be doubled. Noise barriers or earth berms have been used for noise reduction but they are partially effective and do not offer equal noise reduction in every direction as illustrated in Figure 5.

Experimental test sections of OGFC were encouraged by the FHWA and were placed in several states. According to a 1998 NCAT survey only 18 states of 42 states responding used OGFC. Many states had discontinued its use because of the following significant reported problems: (a) premature raveling of OGFC, (b) stripping of underlying HMA course, (c) clogging up of voids by ice control materials such as sand and reduced permeability, and (d) difficulty in snow and ice control.

The survey indicated that mixed performance results were resulting from differences in (a) mix gradation, (b) mix design methods, (c) asphalt binder type (neat versus modified), (d) specifications, and (e) construction procedures. The vast majority of states reporting good experience use polymer-modified asphalt binders. Also, the gradations of aggregates used by these states tend to be somewhat coarser than gradations used earlier and gradations used by the states that had bad experience with OGFC. The survey concluded that good design and construction practice was the key to improved performance of OGFC mixes. The OGFC is being used with success in several states, notably Washington, Oregon, California, Nevada, Arizona, Florida, and Georgia.

Because of the mixed performance results in other states as discussed before, there was a need to develop specifications and mix design for a new generation OGFC to ensure consistently good performance. This task was undertaken by the National Center for Asphalt Technology (NCAT). Specifications and mix design method have been developed based on research conducted by NCAT and experience gained in the U.S. and Europe. The following are the main features of the mix design:

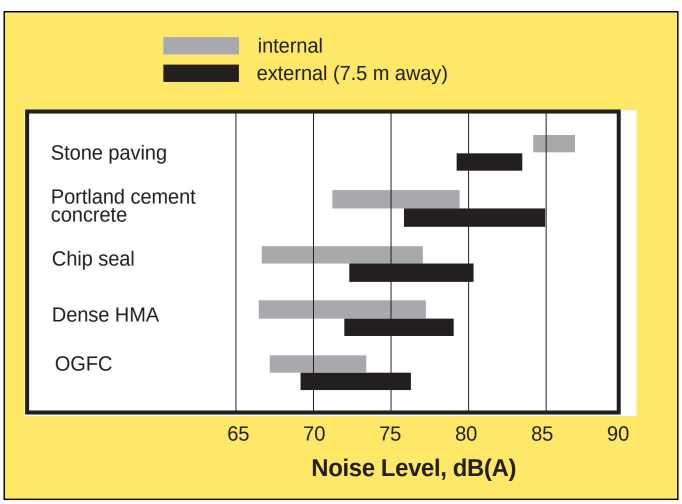
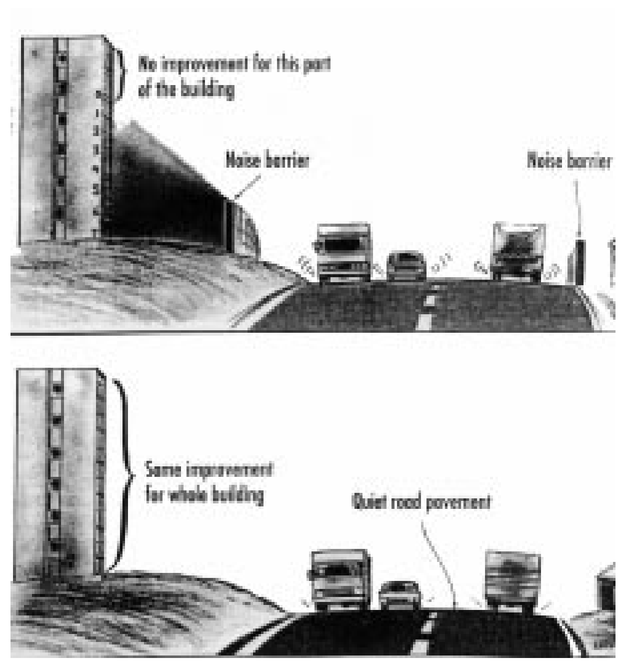


Figure 4. Variation of Tire-Pavement Contact Noise (Outside and Inside a Car at 8- km/Hour) on Various Surface Types



Note: A "quiet" OGFC pavement may be a more attractive solution than a noise barrier in some cases. It does not obstruct vision and offers equal noise reduction in every direction.

Figure 5. Conceptual Differences in the Effectiveness of OGFC and Noise Barriers (After Nordic Road & Transport Research)

- High stiffness binders, generally two grades stiffer than normally used for the local climatical conditions (such as PG 70-XX or PG 76-XX), made with polymers are recommended.
- Either cellulose or mineral fiber is used.
- The gradation band has been recommended but the coarse aggregate skeleton must be checked for stone-on-stone contact by the specified procedure.
- The loose mix is subjected to draindown test.
- Both unaged and aged specimens compacted with a Superpave gyratory compactor (N_{design}=50) are subjected to Cantabro abrasion test (it is an abrasion test carried out in the Los Angeles abrasion machine without steel balls).
- A minimum of 18 percent air voids is required.
- The selected mix is evaluated for moisture susceptibility using AASHTO T283 with five freeze/thaw cycles.

More information on the design, construction, and performance of OGFC can be obtained from NCAT Report 2000-01, which can be downloaded free from the NCAT web site <http://www.eng.auburn.edu/center/ncat> by clicking on NCAT Publications.

ASPHALT FORUM RESPONSES

The following responses have been received to questions raised in the Fall 2000 Asphalt Forum.

At what frequency do other states check the moisture content of plant-produced HMA? Is the asphalt binder content adjusted when the moisture content reaches a specified level?

For states that require a minimum VMA value for plant-produced HMA, what value is specified? Kentucky uses the minimum VMA values from AASHTO MP2 for both laboratory and field criteria. Should a reduction in the minimum VMA be allowed for plant-produced HMA? **(Allen Myers, Kentucky Transportation Cabinet)**

Arizona (Julie Nodes, Arizona DOT)

The moisture content of every sample of plant-produced HMA (typically 4 samples per day) is determined. The maximum permissible moisture content behind the paver is 0.5 percent. The Arizona DOT specifies minimum and maximum VMA for mix design only. It is not controlled on plant-produced HMA.

Colorado (Tim Aschenbrener, Colorado DOT)

For our volumetric acceptance specifications, we use a statistically based percent within limits (PWL) specification. The elements for the HMA are air voids, VMA, and asphalt content. Each element, including VMA, has a target and tolerances (plus and minus). The target for VMA is initially set on the average of the first three field produced results. The mix design and the target can never be below our minimum specified VMA. However, with our tolerances it is possible to accept field produced material that has a VMA below the target. Depending on the number of samples tested, if approximately 85 percent of the results are statistically within the tolerances, the contractor would get 100 percent payment for that element.

Louisiana (Chris Abadie, Louisiana DOT)

Moisture content of aggregate cold feed is measured and reported at least once/day for quality control. Moisture content of mixture is measured as needed for acceptance (maximum = 0.5 percent by weight). When high moisture contents are encountered, the plant should be shut down. The contractor then suggests proposed corrective action such as improving the plant operations (such as adjusting flights to increase the aggregate drying time, or waiting for aggregate stockpiles to dry). Louisiana requires polymer modified asphalts in the top two lifts of all pavements. This has ensured mixing temperatures above 320°F (the aggregate dries faster at these higher temperatures). Liquid antistrip is required in all mixtures thus reducing initial susceptibility to moisture. Another test we require is Modified Lottman which is used in design as well as during production. At least one test is conducted per 10,000 tons of HMA produced.

Louisiana uses the same minimum VMA requirement for mix design and mix production. However, consideration is being given to allow production variation of VMA to fall below the design VMA.

New Mexico (Parveez Anwar, New Mexico State Highway Department)

The contractor checks the moisture content of the cold feed twice a day; and the moisture content of the HMA is checked on each sample.

Utah (Murari Pradhan, Utah DOT)

The Utah Department of Transportation has VMA requirements for both the design and production of HMA in the specification. The requirements are as follows:

- VMA range for mix design -
  12.0-14.0 percent for 25.0 mm mix
  13.0-15.0 percent for 19.0 mm mix
  14.0-16.0 percent for 12.5 mm mix
  15.0-17.0 percent for 9.5 mm mix
- VMA range for plant mix production -
  11.5-14.5 percent for 25.0 mm mix
  12.5-15.5 percent for 19.0 mm mix
  13.5-16.5 percent for 12.5 mm mix
  14.5-17.5 percent for 9.5 mm mix

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These ranges are used for the percent within limits (PWL) computation for determining bonus or deduction in pay.

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

Ontario tests every sublot (500 tons) of HMA for moisture content.

There is a minimum VMA requirement for design and not for plant-produced HMA. Plant mix is checked for asphalt content, gradation, and air voids. These attributes of the mix make VMA test during production redundant.

Does anyone have a strong opinion about the tack coat under hot-mix concerning the type, amount, etc., for different situations? If you use asphalt cements for tack coat how much does this add to the cost over emulsions and is it worth it? **(Bill Maupin, Virginia Transportation Research Council)**

Arizona (Julie Nodes, Arizona DOT)

The Arizona DOT typically uses SS-1 emulsified asphalt (diluted 50:50 with water) for tack coat at a typical application rate of 0.12 gal/sq yd (may be adjusted for conditions). For mixes using asphalt-rubber binder (used extensively by Arizona DOT) we specify asphalt cement tack coat with application rates of 0.06-0.08 gal/sq yd. We believe that for the asphalt-rubber mixes we get better bonding using asphalt cement tack coat, thus any increased cost is justified.

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

We typically use an emulsified asphalt for tack coat to achieve an undiluted reside of 0.05 gal/sq yd. A uniform, quality application of tack coat is essential for satisfactory performance of the pavement structure. In recent years we have observed a number of “slippage” failures which we attribute to an inadequate application of tack coat.

Can anyone comment or provide experience on the use of a 4-inch specimen adapter in the gyratory compactor as I understand Colorado is doing? I see the advantages to it but what about possible disadvantages like variability in voids, stone size, etc.? **(Dave Powers, Ohio DOT)**

Colorado (Tim Aschenbrener, Colorado DOT)

The Colorado DOT primarily uses 4-inch specimens. This enables us to use our empirical strength test (the Hveem stabilometer) and moisture damage test (the modified Lottman procedure). With only the 6-inch specimen, we would have no strength test. Moreover, correlation to our tensile strength ratio (TSR) specification would be doubtful.

The Hveem stability is not perfect, but it has identified HMA that was potentially rutting susceptible although it had acceptable void properties. I am glad we have it. With regards to the modified Lottman test, NCHRP 9-13 has shown that going from the 4-inch kneading compactor specimens to 6-inch gyratory compacted specimens has a large impact on the TSR results. When going from the 4-inch kneading compactor specimens to 4-inch gyratory specimens there is a small impact on the TSR results. Since Colorado was previously a kneading compactor state, we have a high level of confidence in the acceptable specification limits we have set.

We were concerned about the lower asphalt contents obtained when the Superpave gyratory compactor is used. For the same mix, we found that the 4-inch diameter specimens produced optimum asphalt content slightly higher than when designed with the 6-inch diameter specimen. This was also considered a positive for us.

In terms of variability, we have volumetric acceptance specifications for HMA. The tolerances are set at two times the standard deviation for production, sampling, and testing variability. We have found the normal standard deviation to be 0.6 percent for volumetric properties based on results from numerous projects. Therefore, we have set out acceptance tolerances at 1.2 percent. I have not seen any specifications with the 6-inch specimens that have a lower standard deviation.

We only use the 4-inch specimens on the 19.0 mm (3/4 inch) and smaller nominal size aggregate mixes. We have one of our Superpave gyratory compactors set up with 6-inch specimen capability for our large stone mixtures.

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ASPHALT FORUM

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

Florida (Gregory Sholar, Florida DOT)

What confidence level do agencies have in AASHTO T 283 used for determining the moisture susceptibility of HMA?

*(Editor: Please see the "Asphalt Forum Responses" of the Fall 2000 issue of the **Asphalt Technology News**, wherein nine states expressed their experience with AASHTO T283.)*

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

Has any agency developed a single sampling procedure to be used for <u>all</u> of the testing required for HMA: G_{mm}, G_{mb}, asphalt content, and gradation?

Kentucky (Allen Myers, Kentucky Transportation Cabinet)

Do other states require moisture-susceptibility testing, either by AASHTO T283 or ASTM D4867, for <u>all</u> Superpave mixtures regardless of design ESAL value?

Do other states have significant experience with the non-nuclear density gauge? Does evidence exist to suggest that the results from the non-nuclear density gauge more closely resemble roadway-core density than the results from the nuclear density gauge?

Michigan (Mike Frankhouse, Michigan DOT)

How are other states assuring compliance with the AASHTO MP1 specification in terms of sampling location, testing frequency, tolerance, and price adjustments?

Rhode Island (Francis Manning, Rhode Island DOT)

Since pavement preservation is now being performed by most states, we would like to know what 'tests' are available to determine the performance of the various treatments such as micro surfacing, rubber chip seals, and thin elastomeric (hot mix) overlays. We are particularly interested in knowing whether the Superpave protocols for binders and mixtures are being used where appropriate.

Australia (John Bethune, Australian Asphalt Pavement Association)

The industry collected field and laboratory data from 20 heavy duty asphalt pavements constructed between 1972 and 1990 throughout Australia. The data was independently analyzed and reported by ARRB Transport Research. The data variability was similar to that experienced in the U.K. The results of this pilot trial support the concept developed by TRL (Nunn) and European studies that well constructed heavy duty asphalt pavements built above a threshold depth (generally greater than 200 mm) are unlikely to fail structurally and are long-life, low-maintenance pavements. Further work is proposed to fill the data gaps.

NEW PHONE SYSTEM AT NCAT

NCAT has recently changed over to a new phone system; as such, the individual phone numbers for NCAT staff are no longer valid. You can reach any staff member by calling 334-844-6228, and asking for them by name. There is also a company directory on the phone system which lists everyone's individual extension, so you can call or leave a message after hours. A full list of extensions is available on our web page, **http://www.eng.auburn.edu/center/ncat**, under Staff.

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SPECIFICATION CORNER

Arizona - A new specification book was issued last year. The NCAT ignition oven will now be used for acceptance of asphalt content and gradation of dense-graded HMA.

Connecticut - The Connecticut DOT's Office of Research and Materials initiated a research project in January entitled, "Development and Implementation of a Highway Construction Quality Assurance Program for the Connecticut Department of Transportation, Phase I - HMA Concrete Construction." This two-year project will supplement work being performed under Connecticut's HMA Task Force for Pavement Improvement in the area of quality assurance (QA). Once the QA elements are defined (quality control, acceptance, independent assurance, dispute resolution, etc.) and special provisions are created, a series of "focus" projects will be constructed and evaluated. The evaluation will consist of field visits to observe sampling procedures, construction operations, quality control processes, and obtain feedback. Any QA specifications will be subsequently revised as necessary prior to statewide implementation.

Florida - Pilot projects are being constructed with the new "QC 2000" asphalt specification. The specification requires more frequent testing (especially for roadway core density) and uses contractor's test result data for pay. There are frequent checks and balances to verify contractor's data and a resolution system in cases of discrepancies. The specification also uses percent within limits to determine pay factors.

Paving is no longer allowed in the rain under any circumstances.

Kentucky - Two SMA projects will be placed this year in different locations on a route carrying very heavy coal-haul traffic. A warranty project involving the widening of one major interstate will be let this year. Historical HMA acceptance data is being evaluated in an effort to refine the allowable tolerances between the contractor's acceptance results and the department's verification results. Requirements for the use of material transfer vehicle (MTV) have been revised. The use of MTV is now required on any project involving four or more driving lanes and 10,000 or more tons of HMA mixtures.

Michigan - Severe mix segregation identified at the paving site will be evaluated on several projects this year by using nuclear density tests to compare segregated and nonsegregated areas of HMA pavements. Software developed through research with Michigan State University will evaluate the density results and validate the severity of segregation. Corrective actions will be taken to eliminate further segregation.

The Michigan DOT certifies PG binders for use on projects prior to the start of the construction season. An updated procedure has been developed for certification when construction project binder samples taken during production fail. Additional samples are then taken from the truck delivering binder to the HMA facility and tested for compliance.

New Mexico - The requirement of restricted zone in Superpave gradation has been deleted. HMA specifications have been revised to allow reclaimed asphalt pavement (RAP) material in Superpave mixtures. The Mix Expert Task Group guidelines were followed in developing these specifications for recycled mixtures. New specifications require moisture content of combined aggregate to be at saturated surface dry (SSD) condition plus 2 percent at the time of addition of hydrated lime.

A smoothness specification based on IRI obtained with lightweight profilers will be implemented this year.

New York - The requirement to comply with the restricted zone in Superpave gradation has been deleted this year. According to the New York Department of Transportation the restricted zone tended to encourage producers to produce coarse mixes that are "economical" but not "optimum." Problems in obtaining roadway density and increased permeability of coarse mixes and the fact that good performing mixes could be produced through the restricted zone, led to this logical decision.

At the request of HMA producers the DOT is looking at the possibility of reducing the number of PG grades used in the state. A meeting will be held with asphalt suppliers to determine the available options.

Rhode Island - For the pavement preservation program, the Rhode Island DOT has developed specifications for rubberized asphalt chip seal and paver placed surface treatment (Novachip). Both were used on projects last

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year. Specifications are being developed for the use of rubberized asphalt, chemically modified by the FHWA method, in chip seals and in thin overlays. Both treatments will be used in pavement preservation to be contracted this year.

Utah - HMA specifications are now in CSI (Construction Specifications Institute) format. All HMA specifications (QC/QA, non-QC/QA, and maintenance) have been combined into one specification. Referee test requirements for dispute resolution have been deleted.

Australia - Austroads (national association of Australian and New Zealand road transport and traffic authorities) believe they can agree shortly on a specification framework based on the existing Australian Asphalt Pavement Association's prescriptive specification issued in January last year. Eventually the goal is to develop a performance based specification for HMA.

Ontario, Canada - A new special provision for stone matrix asphalt (SMA) will be implemented in this year's contracts. Highway selection criteria for using SMA and other mix types have also been developed.

RESEARCH IN PROGRESS

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

—Evaluation *(continued from page 3)*

the restricted zone.

2. Part 3 involved 19.0 mm. NMAS mixes and two compactive efforts: N_{design} of 75 and 100 gyrations corresponding, respectively, to design traffic levels of 0.3 to less than 3 and 3 to less than 30 million ESALs. Again, the mixes having gradations that violated the restricted zone performed similarly or better than the mixes that had gradations passing outside the restricted zone.
3. Various researchers, who evaluated NMAS ranging from 9.5 to 37.5 mm and design compactive efforts from 75 to 152 gyrations, have arrived at conclusions similar to the preceding two findings from NCHRP 9-14. Taken together, these findings suggest: (1) the restricted zone is redundant if the mix meets all Superpave volumetric parameters and the required fine aggregate angularity (FAA), and (2) references to the restricted zone in the AASHTO specifications and practice for Superpave volumetric design for HMA may be unnecessary regardless of NMAS or traffic level.
4. Although not germane to the primary objective of this project, the following observations were made:
   - ARZ, BRZ, and CRZ gradations (respectively: above, below, and crossing over the restricted zone) tended to provide higher VMA values and the TRZ gradation (through the restricted zone) provided the lowest VMA values.
   - Since the TRZ gradations generally provided the lowest VMA values for both the 9.5 and 19.0 mm NMAS mixes, it can be concluded that the maximum density line drawn according to the Superpave guidelines (connecting the origin of the 0.45 power chart to the 100 percent passing the maximum aggregate size) is reasonably located on the gradation chart.
   - Relatively finer gradation mixes such as ARZ and HRZ (humped gradation in the restricted zone) tend to have higher $\%G_{mm}@N_{initial}$ values compared to TRZ, CRZ and BRZ mixes.
   - High FAA values do not necessarily produce high VMA in mixes although there was a general trend of increasing VMA values for increasing FAA.
   - Higher FAA values generally produced lower $\%G_{mm}@N_{initial}$ values. None of the mixes having a FAA value lower than 45 met the $\%G_{mm}@N_{initial}$ requirements of 89 percent and lower for the N_{design}=100 and 125 mixes. This indicates high FAA values contribute to stronger aggregate skeleton at initial compaction levels.

PUTTING RESEARCH INTO PRACTICE

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

1. EFFECT OF SUPERPAVE GYRATORY COMPACTOR TYPE ON COMPACTED HOT MIX ASPHALT (HMA) DENSITY (Buchanan and Brown)

The Superpave gyratory compactor (SGC) was developed as a tool in the Superpave mix design system to better simulate the field compaction of hot mix asphalt (HMA) mixes. All Superpave gyratory compactors are designed to meet the specification criteria found in AASHTO TP4. The criteria include a vertical compaction pressure (600 ± 18 kPa), rotational rate (30 ± 0.5 rpm) height (± 5.0 mm), and a gyration angle (1.25 ± 0.02 degrees). There exists a number of manufacturer models of Superpave gyratory compactor currently available for designing and controlling HMA mixes. All gyratory compactors must be evaluated and provide acceptable results using a standardized evaluation protocol provided in AASHTO PP35 designed to determine their ability to provide similar mix properties to a gyratory compactor which has previously passed the evaluation. The procedure consists of statistical analysis of the bulk specific gravity of compacted HMA samples having varying gradations and nominal maximum sizes.

One point of major concern is the degree of reproducibility between laboratories having different brands of approved SGCs. For example, suppose a contractor uses brand "A" to design and control an HMA mix; can he/she be reasonably assured that the State Department of Transportation (DOT), using brand "B," will get the same mixture results. Many times this scenario occurs with the contractor and a DOT representative each compacting specimens from the same production sample simultaneously at the same location, but using different gyratory compactors.

At the present time, AASHTO TP4 does not contain a precision statement. Some agencies have conducted internal or limited regional programs; however, the degree of variability within and between laboratories for the SGC specimens has not been fully established.

The objective of this paper was to present observed precision values and practical differences between the currently used Superpave gyratory compactors and to discuss the possible project implications resulting from the differing results.

A statistical analysis of data obtained form several projects was conducted and the practical results and potential project implications have been provided. The data used in this study included the Southeast Superpave Center gyratory compactor proficiency sample testing (May 1999, October 1999, and May 2000), results from the initial six projects from NCHRP 9-9 (1): *Verification of the Gyration Levels in the N_{design} Table*, and mix design and quality control/quality assurance results from a state DOT.

The following conclusions and recommendations were drawn from this study.

- Both the single and multi-laboratory precision (in terms of bulk specific gravity of compacted HMA specimens, G_{mb}) of the Superpave gyratory compactor is improved with respect to past data with the mechanical Marshall hammer. Average G_{mb} values for the gyratory compactor of 0.0094 and 0.0133 were determined for single and multilaboratory precision, respectively.
- In very controlled sampling and compaction procedures, significant differences in calculated air voids (in some cases up to almost 2 percent) can result between properly calibrated Superpave gyratory compactors.
- Significant differences in optimum asphalt content can occur between designed mixes and verified mixes when using two different compactors. An optimum asphalt content difference of 1.3 percent was reported in one case which corresponded to a 2.5 percent change in the voids in mineral aggregate.
- Significant differences between quality control (contractor) and quality assurance (owner) air void results can occur even though the utilized gyratory compactors have been properly calibrated. For the data analyzed, an average deviation in air voids of 0.79 percent from the target value will result in approximately 40 percent of the data falling outside the specification limits.
- A protocol for an independent gyration angle measuring device should be developed as quickly as possible to ensure the gyration angle of all gyratory compactors remains within the specification tolerance of 1.23 and 1.27 degrees *during* compaction.
- A full scale program should be conducted to more accurately determine the precision of the Superpave

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gyratory compactor. However, this program should only be conducted after a protocol for the independent gyration angle measuring device has been developed and implemented.

2. EFFECT OF MIX GRADATION ON RUTTING POTENTIAL OF DENSE GRADED ASPHALT MIXTURES (Kandhal and Mallick)

The objective of this study was to evaluate the effect of mix gradations, both complying with and violating the Superpave restricted zone, on rutting potential of hot mix asphalt (HMA) mixtures.

The following material and mix variables were included in this study:

- 12.5 mm nominal maximum aggregate size (NMAS) wearing course mix and 19.0 NMAS binder course mix
- Three aggregates: granite, limestone, and crushed gravel
- Three gradations: gradation above the restricted zone (ARZ), gradation through the restricted zone (TRZ) in close proximity to the maximum density line, and gradation below the restricted zone (BRZ)
- One PG 64-22 asphalt binder

All mix designs were conducted with a Superpave gyratory compactor using N_{design} of 76 gyrations. Test specimens to be evaluated in rut tests were prepared with four percent air voids content.

Rut tests were conducted at 64ºC (147ºF) with the Asphalt Pavement Analyzer (APA) under 689 kPa (100 psi) contact pressure and 445 N (100 lb) wheel load. Rut depths were measured at the end of 8,000 cycles. Repeated shear test at constant height was also conducted with the Superpave shear tester (SST) to determine the peak shear strain (deformation) of the different mixes.

The following observations were made from this study:

- Statistical analysis of APA rut data generally indicates a significant difference between rut depths obtained in mixes using different aggregate types and different gradations. The gradations violating the restricted zone did not necessarily give relatively higher rut depths compared to the gradations in compliance with the zone.
- Statistical analyses of APA rut data obtained on all mixes indicate a significant difference between rut depths of mixes with gradations passing above (ARZ) , through (TRZ), and below (BRZ) the Superpave restricted zone. For granite and limestone, BRZ generally showed highest amount of rutting, TRZ generally showed lowest amount of rutting, and ARZ generally showed intermediate amount of rutting. For gravel mixes, BRZ generally showed lowest amount of rutting, ARZ generally showed highest amount of rutting, and TRZ generally showed intermediate amount of rutting.
- The effect of VMA on rutting appears to be associated with the effect of binder film thickness. An increase in VMA and film thickness causes an increase in rutting for granite and limestone mixes, whereas it causes a decrease in rutting of gravel mixes. At this time, the effect of VMA on rutting is not clearly understood, and further study is required.
- The SST test data in terms of peak shear strain indicate no significant difference between ARZ, TRZ, and BRZ gradations of granite wearing and binder mixes. In case of limestone wearing and binder mixes, BRZ had the highest peak shear strain (potential of rutting) similar to APA rut depth test data. In case of gravel wearing and binder course mixes, TRZ showed the lowest peak shear strain and ARZ showed the highest peak shear strain. The shear strain from SST does not appear to be as sensitive to difference in gradation as the APA, but it tends to give similar indications as APA results.

3. DEVELOPMENT OF CRITICAL FIELD PERMEABILITY AND PAVEMENT DENSITY VALUES FOR COARSE-GRADED SUPERPAVE PAVEMENTS (Cooley, Brown, and Maghsoodloo)

For dense-graded hot mix asphalt (HMA) mixtures, numerous studies have shown that initial in-place air void contents should not be below 3 percent or above approximately 8 percent. Low air voids have been shown to lead to rutting and shoving, while high air voids are believed to allow water and air to penetrate into the pavement resulting in an increased potential for moisture damage, raveling, and/or cracking.

Past experience has indicated that dense-graded HMA pavements become permeable to water at approximately 8 percent air voids. However, for some coarse-graded Superpave designed mixes (gradation passing below restricted zone), the size and interconnectivity of the air voids have been shown to greatly influence pavement permeability. The problems encountered with coarse-graded Superpave mixes has put a high emphasis on the permeability testing of HMA pavements. This is likely due to permeability giving a better indication of a pavement's durability than density alone.

The objective of this study was to conduct in-place permeability testing on numerous coarse-graded Superpave designed projects, compare in-place permeability to pavement density, and utilize the collected data to recommend both critical in-place density and permeability values at which coarse-graded Superpave designed pavements become excessively permeable.

Field permeability tests were conducted at 11

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—Putting Research Into Practice

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ongoing HMA projects in 7 states. Projects were identified such that four different nominal maximum aggregate sizes (NMAS) were included: 9.5, 12.5, 19.0, and 25.0 mm. Of the 11 mixes, 10 were coarse-graded with gradations below the restricted zone.

For each project visited, field permeability tests were conducted at a total of 15 random test locations. The selected NCAT Field Permeameter consisted of a three-tiered standpipe and used a falling head approach. The standpipe with the smallest diameter was located at the top of the device and the largest diameter standpipe was located at the bottom. This configuration made the field permeameter more sensitive to the flow of water into the pavement. For pavements that were relatively impermeable, the water fell very slowly in the small diameter top tier standpipe. If pavements were relatively permeable, the water level would move quickly through the top tier but slow down when it reached the larger diameter middle tier standpipe.

The following conclusions were drawn from this study:

- Strong relationships were observed between field permeability and in-place air void contents for coarse-graded Superpave designed pavements.
- A mixture's nominal maximum aggregate size greatly affects the permeability characteristics of a pavement.
- The permeability characteristics of coarse-graded 9.5 and 12.5 mm NMAS pavements are similar. These types of pavements become excessively permeable at approximately 7.7 percent air voids. A critical field permeability value of 100×10^{-5} cm/sec was selected.
- Coarse-graded mixtures having a NMAS of 19.0 mm become excessively permeable at in-place air void contents above 5.5 percent. This density related to a critical field permeability value of approximately 120×10^{-5} cm/sec.
- Coarse-graded mixes having a NMAS of 25.0 mm became excessively permeable at in-place air void contents above 4.4 percent. A critical field permeability value of 150×10^{-5} cm/sec was selected for 25.0 mm NMAS mixes.

The term "critical" used in this study infers the point at which a pavement becomes excessively permeable. For the larger NMAS mixes, some permeability may be acceptable as long as the upper courses are impermeable.

NCAT's Asphalt Technology Course, February 12-16, 2001

Front Row, L-R: Howard Johnson, Colby Guidry, Karl Mai, Mark Lowery, Kenny Schlag, Felicia Reid, Darren Ratajski, Mike Bradley, Tod Juergens, Rich Talkowski
Second Row, L-R: Gideon Visser, Greg Stephenson, Mike Uhrig, T.J. Morgan (baseball cap), Carl Armijo, Larry Wilson, Jeff Avant, John Connell, Ken Kandhal
Back Row, L-R: M. Mark Hamel (baseball cap), Todd Sanders (red shirt) Doug Hanson, Morris Cummins, Michael Eppes, Bob Begley, Chris Rahn, Jim Manchego, Jay Goldbaum, Mike Huner

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