N-Design: Where Is It Heading?

By Thomas Harman, FHWA

Gyratory compaction is at the heart of the volumetrically-based Superpave mixture design system. Compaction levels are specified according to AASHTO PP28 based on traffic level and pavement layer location. The total number of design gyrations, referred to as N-design, ranges from 50 up to 125 gyrations. NCHRP 9-9(1), Verification of Gyration Levels in the N-design Table, is assessing the current compaction requirements compared to field densification under traffic. This work is being conducted by the National Center for Asphalt Technologies (NCAT). Their evaluation uses 40 field projects in 16 States and 32 sections at the NCAT Test Track. Preliminary findings suggest that the current N-design levels may be slightly high and that modified binders can significantly reduce the rate of densification. NCAT will continue to monitor these sections through the year 2005.

Gyratory calibration is also undergoing evaluation. AASHTO T312 allows for the angle of gyration to be calibrated by two non-equivalent means: external and internal. External calibration uses equipment-specific devices to measure and set the angle. Internal calibration uses the FHWA-developed Dynamic Angle Validator™, DAV. The DAV is placed inside the compaction mold with hot mix asphalt to measure the compliance of the compactor under actual operational load. The TRB Superpave Mixture/Aggregate Expert Task Group (ETG) recommends the use of internal angle calibration with the DAV.

However recent innovations have lead to the development of two new twists on internal angle measurement. Pine Instrument Company has developed the Rapid Angle Measurement™ (RAM) device. The RAM works similarly to the DAV, but in lieu of mixture, the RAM uses an eccentric ring to simulate mix forces on the compaction frame. Likewise, Test Quip Incorporated had developed the Hot Mix Simulator™ (HMS) attachment for the DAV device. These “mixless” devices offer a potentially significant time, and in turn cost, savings over the existing procedures.

Since the gyration angle can vary depending on the stiffness of the hot mix in the mold, the mixless devices offer another advantage. Gyratories can be calibrated at the same stiffness - a sort of reference stiffness - using the mixless devices.

The Asphalt Institute, working cooperatively with the University of Arkansas, is currently conducting a detailed evaluation of the two new mixless devices for the FHWA.

The TRB Superpave Mixture/Aggregate ETG will review all final recommendations of these projects for possible inclusion into the AASHTO specifications. For now, at least, N-design isn’t heading anywhere.

NCAT Hosts Symposium on Long Lasting HMA

Auburn University will host the International Symposium on Design and Construction of Long Lasting Asphalt Pavements June 7-9, 2004. The conference is sponsored by the International Society for Asphalt Pavements, National Asphalt Pavement Association, Federal Highway Administration, Asphalt Pavement Alliance and Alabama Department of Transportation. This is the first symposium on the topic; future specialty symposiums will be held at four-year intervals.

During the symposium’s twelve sessions, speakers from around the world will share their expertise. Session topics include the FHWA’s long lasting pavement technology program, concepts for long lasting pavements, pavement design, materials and mix testing, accelerated loading, warranties, construction and case studies. Professor Carl Monismith, University of California Berkeley, will be the keynote speaker. An optional tour of the NCAT facilities, including the NCAT Test Track, is being offered Thursday, June 10.

The NCAT website at http://www.eng.auburn.edu/center/ncat/ has more information on the symposium, including registration materials.

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Simple Performance Tests on HMA Mixtures

Amit Bhasin, Joe W. Button, Arif Chowdhury: Texas Transportation Institute, Texas A&M University

The Federal Highway Administration (FHWA) and the National Cooperative Highway Research Program (NCHRP) have sponsored or are sponsoring research projects that will lead to the development and validation of advanced materials characterization models and associated laboratory testing procedures for hot mix asphalt (HMA). These have been termed simple performance tests (SPT). FHWA and NCHRP are also sponsoring development of a new Pavement Design Guide, which will lead, in part, to recommended methods for characterizing HMA material properties.

The current candidate simple performance tests include the complex modulus (E*) or dynamic modulus (|E*|) of compacted HMA mixes, which is the stress divided by the strain under repeated axial loading. Other candidate tests include the accumulated axial strain from a repetitive load test (flow number) and the tertiary axial strain from a static load test (flow time). While all three tests are possible simple performance tests, the pavement design software relies on the dynamic modulus test for the thickness design of the pavement.

Bhasin, et al., at the South Central Superpave Center performed a study for FHWA to evaluate the simple performance tests as indicators of permanent deformation using unmodified and modified mixtures. A wide variety of HMA field and laboratory mixture designs were tested. One mixture was intended to be rut susceptible so it was designed using rounded gravel and sand with a PG 64-22. Two additional mixtures were designed using a highly polymer-modified asphalt, PG 64-40, to provide low modulus (stiffness) but high recovery (elasticity). A summary of the twelve mixtures is shown in Table 1.

The main objectives of this research project were to:

♦ Evaluate the applicability of the simple performance tests for measuring permanent deformation in HMA mixtures;
♦ Compare results from the dynamic modulus test with those from the SST-FSCH and APA;
♦ Evaluate the ability of the SPTs to properly characterize highly polymer-modified HMA mixtures and
♦ Conduct indirect tensile strength and indirect tensile creep tests to evaluate how the SPTs characterize the cracking potential of the mixtures.

FINDINGS

The same stress and temperature levels were used for mixtures with a wide range of binder grades (PG 64 to PG 82) in order to compare them on an equal basis. This could only be done at the expense of some sensitivity of the tests.

The different test parameters ranked the mixes in different orders, as shown in Table 2. Since there...
was no quantitative field rutting performance, the APA rut depth and APA creep slope were used as indicators of rutting performance.

Indirect tension tests were also conducted to rank the mixtures in order of their susceptibility to cracking. The stiffer mixes were more prone to cracking.

Conclusions and Recommendations
- Flow time slope and flow number value provided the best correlations with the APA rut depth.
- The correlation between flow time value and APA rut depth was better than that between flow number value and APA rut depth.
- Correlations of the APA test parameters with dynamic modulus and FSCH tests were not as good as correlations of the APA test parameters with the flow time and flow number test parameters.
- Correlations of |E*|/sin δ or G*/sin δ with the APA test parameters were better than correlations of E* and G* alone with the APA. This difference is likely because the phase angle captures some of the viscoelastic behavior of the mix.
- Correlations of E* or G* with the APA parameters were better at lower test frequencies than at higher frequencies.
- The overall rut depth from the APA test at 8000 strokes correlated better with all other parameters as compared to the APA creep slope.
- Flow number value, flow time slope, |E*|/sin δ at 1 Hz, flow number slope, and flow time value were among the best five correlations with the APA rut depths.
- Flow time slope and flow number slope categorized the PG 64-40 mixes in statistically equivalent groups similar to APA rut depth. Based on this finding and assuming that APA relates well to pavement rutting, flow number slope and flow time slope appear to relate well to predicted rutting in a pavement.
- The mixtures containing the PG 64-40 binders ranked best for resisting cracking by almost all the test parameters considered.
- Mixtures containing high PG grade binders and shown to be relatively very stiff by the permanent deformation tests performed poorly in terms of cracking resistance. However, the |E*|sin δ parameter indicated that these mixtures should exhibit good cracking resistance.
- The mixtures containing PG 64-40 binder exhibited relatively higher viscoelastic and viscoplastic strains than most other mixes. However, these mixtures also performed fairly well with respect to permanent deformation (as demonstrated by the flow time, flow number and the APA test).

Simple Performance Tests continued

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Conclusions and Recommendations

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M-E Design Guide To Be Released Soon

The long awaited mechanistic-empirical pavement design guide should be available in the near future, according to speakers at a workshop during the 2004 Annual Meeting of the Transportation Research Board (TRB). The guide developed under National Cooperative Highway Research Program (NCHRP) project 1-37a, Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures, will be published by TRB as a research report.

Eventually the guide is expected to be the basis for pavement design for the next 25 years or more. According to Danny Dawood, PennDOT, however, there are some remaining issues that need to be addressed before AASHTO formally adopts the guide. (Dawood is vice chair of the AASHTO Joint Technical Committee on Pavements (JTCP), which is ultimately responsible for the guide as an AASHTO product.) These issues will be addressed through a multi-pronged approach including additional review by the JTCP, leading to a white paper on implementation issues; an FHWA website for review and comment, planned for Summer 2004; and a follow-up study by NCHRP to focus on implementation issues.

Amir Hanna, NCHRP Program Manager for project 1-37a, added that the follow-up project 1-40, Facilitating the Implementation of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures, is intended to help familiarize DOTs with the guide, support educational/training workshops for the DOTs, and provide an independent assessment of short and long term needs for additional work.

Hanna noted other on-going and proposed projects that will likely provide findings for eventual inclusion in the design guide. These projects include ongoing 1-42, Top-Down Fatigue Cracking of Hot Mix Asphalt Layers, and 1-39, Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design; and the proposed 1-41, Selection, Calibration and Validation of a Reflective Cracking Model for Asphalt Concrete Overlays.

Dave Newcomb, National Asphalt Pavement Association, summarized the hot mix industry’s reaction to the proposed design guide. He supported the concept of mechanistic-empirical design to relate material properties to design and performance. The current models, however, need improvement, especially relative to rutting, top-down cracking and reliability. Validation of the models is needed, as is a better understanding of how variability in the input parameters affects the reliability of performance. Newcomb also noted that a simple design can take 45 minutes to complete the computations, which is too slow for routine use.

Mike Ayers, American Concrete Pavement Association, spoke on behalf of the concrete industry, which also supports the mechanistic-empirical design approach. He commented that the guide represents a great leap forward in pavement technology and a platform for future improvements.

FHWA is planning to help states implement the design guide. To that end, they have formed a Design Guide Implementation Team (DGIT). Among other activities, the DGIT will host a number of workshops around the country to help states plan implementation programs. Workshops are currently scheduled from May to October in various places around the country. Check out the website at www.fhwa.dot.gov/pavement/dgit.htm for more information and to register for a workshop.

For more information on the guide itself, see www.2002designguide.com/.
Louisiana Hosts AAPT

Baton Rouge, Louisiana, was the site of the 79th Annual Meeting of the Association of Asphalt Paving Technologists in March. The meeting began with a Government Engineers’ Forum focusing on Training Tools for the 21st Century and other issues.

Government Engineers Forum

Dave Newcomb, National Asphalt Pavement Association, demonstrated Xpactor, a virtual roller simulator being developed by Joe Mahoney from the University of Washington for NAPA. This training tool allows an operator to control the movement of a roller to compact a pavement before it cools. Newcomb also previewed the Virtual Superpave Lab that NAPA and UWA are also developing.

Tom Harman, FHWA, reported on mixless internal angle calibration of the SGC. (See page 3 for a related article.)

Vivek Tandon, University of Texas at El Paso, updated the group on the status of Superpave implementation. He indicated that 47 states have implemented the PG binder specifications and two more are in the process of implementing; mix design implementation is not as far along. Current costs for Superpave are about 3% higher than conventional mixes, but Superpave mixes offer many direct and indirect benefits leading to improved performance.

Workshop Session

In the Workshop session, Gordon Airey, from the University of Nottingham, reported on a laboratory evaluation of secondary aggregates, including waste glass (cullet), blast furnace slag and oxygen furnace steel slag. The study looked at the effects of these materials on mechanical mixture properties and durability.

The Florida DOT has been working on development of a test method for evaluating the bond strength of tack coats, as reported by Greg Sholar. FDOT developed a direct shear test apparatus that they used to assess the bond strength on several field projects. The device showed the effects of water, tack coat application rate, size of mix placed over the tack and effect of base layer texture on the resulting bond strength.

Gerry Huber, Heritage Research Group, then summarized the development of the Superpave Gyratory Compactor and the effects of changing gyrations on mix volumetrics. He and co-author Mike Anderson of the Asphalt Institute concluded that changing N-design changes the mix stiffness but not the binder content. Changing VMA however, does affect the binder content. They also concluded that the current N-design levels are appropriate.

First Technical Session

Combi-layer is a surface used in the Netherlands for intersections, airports and industrial floors. It is a unique combination of a porous asphalt concrete layer impregnated with a fluid cement mortar to fill the voids and improve the high temperature stiffness, and rut resistance, of the pavement. Martin van de Ven reported on a study of the mechanical properties of this material, concluding that it behaves similarly to asphalt concrete.

Bjorn Birgisson, University of Florida, described a study evaluating the rut resistance of a variety of Florida mixes. The research team suggested an approach for measuring rut resistance in the Superpave Gyratory Compactor by increasing the gyrations angle after initial compaction. The higher angle causes rearrangement of the aggregate particles, and analysis can indicate whether the mix is brittle, plastic or optimal in terms of rut resistance.

The use of x-ray computed tomography (CT) to evaluate asphalt mixtures has demonstrated its great potential over the last few years. Laith Tashman, Texas A&M, reported on using CT to examine the evolution of damage in hot mix during deformation. The study shows that the damage is localized in a critical region due to inhomogeneity of the mixture.

The next AAPT meeting will be held March 7-9, 2005, in Long Beach, California.

Kitae Nam outlined a method to directly measure the thermal coefficient of contraction of mixture specimens. This allows estimation of the glass transition temperature of the mixture, which is related to thermal cracking. The method was developed at the University of Wisconsin under Hussain Bahia.

Haleh Azari, FHWA, summarized a study of the effects of vertical inhomogeneity on mechanical properties of a mixture. Vertical segregation of mixes can occur in the lab when heavier aggregates settle to the bottom of a specimen during preparation and compaction. These variations were found to have no significant impact on results of the candidate simple performance tests (dynamic modulus or flow number).

Second Technical Session

Lorena Popescu, University of California at Berkeley, reported on the development of performance-based pay factors for rutting and fatigue. The approach hinges on establishing penalties that represent the cost of inferior performance to the agency and bonuses that reflect the benefits of improved performance. By considering rutting and fatigue together, changes to improve one distress must be balanced against the effects on the other distress.

Since pay factors and pavement performance depend on in-place density, accurately measuring that density is critical. Shane Buchanan, Mississippi State University, has studied density determination using the nuclear gauge and coring. He determined that using a surface filler with the nuclear gauge was very effective at improving accuracy and precision. He also found that correlating the nuclear gauge to core density based on a running average of ten tests resulted in better correlations.

Rey Roque, University of Florida, then described the results of a study to develop and verify criteria related to top-down cracking. Based on evaluation of 22 field sites in Florida, the researchers identified energy-based criteria to distinguish mixes that exhibited top-down cracking from those that did not. Roque noted that no one mixture property could be used to predict if top-down cracking would or would not occur.
Zhong Wu reported on a study at the Louisiana Transportation Research Center relating laboratory performance to mix properties and field performance for eight Superpave mixes. The study found that coarse graded mixes designed for high traffic volumes had higher rutting and cracking resistance than the mixes designed for low traffic, in general. The study pointed out the need for a performance test, however, because meeting the aggregate and volumetric criteria alone did not ensure good rutting resistance.

Ray Brown presented a paper on findings from the NCAT test track. None of the test sections have developed significant rutting, and no rutting occurred when the temperature dropped below 28°C (82°F). The sections with PG76–22 binder densified less under traffic than those with PG64-22, suggesting that perhaps more binder can be added to improve the durability of the mixes with “bumped” grades.

HMA for Airfield Pavements

The symposium session focused on the use of Hot Mix Asphalt for Airfield Pavements. Three consultants, Stan Herrin, Tim Murphy and Maggie Broten, and one FAA representative, Jeff Rapol, summarized the heavy demands placed on airfield pavements, current specifications and materials, best practices for design and construction and typical distresses.

Herrin pointed out that the amount of mix used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change used on airfields is a small percentage of the total hot mix produced, so they have to change.
Determining Air Void Content of Compacted SMA Mixtures
Hongbin Xie and Don Watson, NCAT

The standard method currently used to measure the SMA bulk specific gravity is AASHTO T166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens, commonly known as the saturated surface dry (SSD) method. The major error of this method typically comes during \( G_{mb} \) testing when water can quickly infiltrate into the sample. Then, after removing the sample from the water bath to obtain the SSD condition, the water can also drain from the sample quickly. This results in an incorrect SSD weight, and usually results in \( G_{mb} \) being higher than it should.

Another alternative method recently used is the CoreLok method. The CoreLok method utilizes an automatic vacuum chamber with a specially designed, puncture resistant, plastic bag. Under vacuum, the bag tightly conforms to the sides of the sample and prevents water from infiltrating into the sample. The volume of the specimen encapsulated by the bag is considered as the bulk volume of the sample.

The objective of this study was to compare the CoreLok and SSD methods for determining the density of SMA mixtures, and consequently the mix design volumetric properties. Also the critical air voids content for an impermeable SMA sample was to be determined by the two methods.

Figure 1. Air Voids Difference by the Uncorrected Corelok And SSD Method Versus Air Voids by SSD Method

Figure 2. Relationship between Permeability and VTM for 12.5 mm NMAS
This result indicates that there may be a system error, or calibration error, for the CoreLok method, as used here, which may be due to the bag stiffness, sample geometry, surface texture, vacuum pressure, or moisture in the samples. Another error may be introduced into the procedure if samples are not tested immediately or within a reasonable time frame. After vacuum sealing, the bags may relax and allow air to leak into the bags.

The average difference between the two methods for three NMAS was determined to be about 0.49 percent when the air voids content by the SSD method approached zero. Based on this calibration difference, a correction factor of 0.5 percent was applied for the CoreLok device used in this study since it was assumed the system error was similar for all the NMAS and air voids levels.

### Effect on Volumetric Properties

The difference in measured air void content results in a difference in mix design volumetric properties. The difference in mix design volumetrics by these two methods is summarized in Table 1 (shown on Page 8). This table shows that there was as much as 0.9 percent difference in optimum asphalt content between the SSD and corrected CoreLok method. The average difference in optimum asphalt content for the two methods was 0.3 percent.

Table 1. Mix Design Volumetric Properties* Summary

<table>
<thead>
<tr>
<th>Aggregate Type</th>
<th>NMAS</th>
<th>AASHTO T166</th>
<th>Corrected CoreLok</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Opt. AC VMA</td>
<td>Opt. AC VMA</td>
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<tr>
<td>Crushed Gravel</td>
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<td>17.3</td>
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<td>5.4</td>
<td>16.2</td>
</tr>
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<tr>
<td>9.5</td>
<td>7.2</td>
<td>20.5</td>
<td>7.4</td>
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</tbody>
</table>

* Optimum asphalt content and VMA are based on 4.0 percent air voids.

Materials

Five aggregate sources with a range of material properties and three nominal maximum aggregate size (NMAS) mixtures were selected: 19 mm, 12.5 mm and 9.5 mm. All the samples were compacted by a Superpave gyratory compactor (SGC) at 100 gyrations. The same gradations were used for all five aggregates.

Air Voids Comparison

The air void content measured ranged from 1.14 to 7.13 percent by the SSD method, and from 1.64 to 10.86 percent by the CoreLok method. For all the test results, the difference between these two methods ranged from 0.39 to 4.60 percent. The CoreLok method yielded an average of 1.26 percent higher air voids than the SSD method. The difference between the CoreLok and SSD method for the three NMAS versus air voids content by SSD method is shown in Figure 1. It is noticeable that at the lowest air void level (1.13 percent by SSD method), the difference between the two methods was still as high as 0.5 percent. It is believed that at low air voids content, when mixtures are impermeable, these two methods should give similar results.

This result indicates that there may be a system error, or calibration error, for the CoreLok method, as used here, which may be due to the bag stiffness, sample geometry, surface texture, vacuum pressure, or moisture in the samples. Another error may be introduced into the procedure if samples are not tested immediately or within a reasonable time frame. After vacuum sealing, the bags may relax and allow air to leak into the bags.

Permeability Comparison

If the threshold value for permeable SMA mixtures is set at 125×10^{-5} cm/s, which is a value that has been recommended for Superpave dense-graded mixes, the critical air void values by both methods can be determined using a falling head permeability test. For 9.5 mm NMAS, none of the tested samples were considered permeable, and the differences between the corrected CoreLok and SSD results were all within one percent. For the 12.5 mm NMAS, the critical air void content at which the mix is considered to become permeable (by the SSD method) was 5.7 percent. For the 19 mm NMAS, the critical air voids were 4.5 percent by the SSD method, which corresponds to the corrected air voids by the CoreLok method of 5.9 percent. An example of the comparison for critical air voids in 12.5 mm SMA mixes in this study is shown in Figure 2 (left). For air voids higher than the critical value, the SSD method was considered not accurate because of the problem of water draining out of the specimen during the SSD procedure.

Based on the air voids and permeability comparison information, both the SSD and CoreLok methods can be used for 9.5 mm SMA mixtures with similar results to be expected. For 12.5 mm SMA mixtures with about 6.0 percent or more air voids and for 19 mm SMA mixtures with more than about 4 percent air voids, there is a greater potential for error by the SSD method than when the CoreLok method is used.

Recommendations

SMA mixtures may become permeable at a relatively low air void content for 19 mm and 12.5 mm NMAS. Based upon the conclusions of this study, the following recommendations are made.

1. Both the SSD and corrected CoreLok methods can be used for 9.5 mm SMA mixtures with similar results to be expected.
2. For 12.5 mm SMA mixtures with about 6.0 percent or more air voids and for 19 mm SMA mixtures with more than about 4 percent air voids by the SSD method, there is a greater potential for error, and the corrected CoreLok method should be used.
3. The correction factor for each machine used in the CoreLok method should be determined by testing a solid metal sample that is approximately the same size and shape as the asphalt specimen to be tested.
LATEST DEVELOPMENTS OF LABORATORY TESTS TO PREDICT HMA MOISTURE DAMAGE  
Mansour Solamanian, NECEPT

INTRODUCTION

The performance of hot mix asphalt in the presence of water is a complex issue that has been the subject of numerous research studies during the past four decades. The great number of different aggregate sources, the numerous types of unmodified and modified asphalt binders, and varied environmental conditions, traffic, and construction practices across the United States have made testing to accurately predict HMA moisture susceptibility a difficult task. It has remained a challenge to the pavement industry to improve the current moisture damage tests for better and more reliable distinction between poor and good performers.

With the implementation of Superpave, use of AASHTO T283 and its companion ASTM D4867 to determine the Tensile Strength Ratio (TSR) became common. There have been questions, however, on how well these procedures simulate the mechanisms that cause moisture damage in the field. State highway agencies report mixed success with the TSR. While some agencies have expressed relative satisfaction with this method for determination of moisture damage, some others have found it not very reliable.

The National Cooperative Highway Research Program (NCHRP) is sponsoring project 9-34 to investigate whether an improved moisture sensitivity test can be developed by integrating the Environmental Conditioning System (ECS) with one of the NCHRP 9-19 simple performance tests. NCHRP 9-34 is being conducted at Penn State University.

THE ENVIRONMENTAL CONDITIONING SYSTEM (ECS)

The ECS was developed at Oregon State University during the Strategic Highway Research Program (SHRP) to determine the moisture sensitivity of compacted HMA specimens under conditions of temperature, moisture saturation, and dynamic loading in an attempt to simulate those found in pavements. The equipment and test procedure were described in the AASHTO Provisional Standard TP34.

The system includes three major components: a fluid conditioning subsystem, an environmental conditioning chamber, and a loading subsystem. The fluid conditioning subsystem maintains a constant flow of water and supply of vacuum to the specimen. The environmental conditioning chamber maintains the temperature during the test. The load frame is contained in the environmental chamber. The loading subsystem simulates traffic by applying a repeated haversine loading on the specimen while load and deformation are measured for determination of the resilient modulus. The change in resilient modulus as a result of water conditioning is used in the ECS procedure as a measure of damage in the test. If the ratio of the conditioned $M_r$ to the unconditioned $M_u$ falls below a certain level, the mixture is considered moisture susceptible.

The procedure is too long and complicated and must be shortened and simplified before it can be adopted for routine mixture design or quality control testing. One advantage of the ECS is that it does include the influence of traffic loading and the resulting effect of pore water pressure, a significant consideration if the mechanism that causes moisture damage in the pavement is to be duplicated.

THE EXPERIMENT AND THE RESULTS

Phase I of the NCHRP Project 9-34 research has been completed, and Phase II is at its early stages. In Phase I, three aggregates with known stripping performance were included in the study. One limestone, one sandstone, and one granite aggregate were selected. The binder used in the mixes for all three aggregates was from the same source that had been used with the granite mix showing failed field performance. Mixes with limestone had demonstrated the best field performance and the sandstone had demonstrated good moisture resistance but not as good as the limestone in an earlier laboratory study of moisture damage.

The results obtained from the dynamic modulus tests were encouraging. These results follow the same trend observed for the tensile strength ratio from ASTM D4867, as presented in Figure 1. The results match the observed field performance of the limestone and granite mixes. However, the sandstone mix has demonstrated better performance than expected both in ASTM D4867 as well as the ECS/dynamic modulus test, possibly because the binder used here was different from the one used when the sandstone showed somewhat higher moisture damage than the limestone.

The research is continuing using the integrated ECS/Dynamic Modulus under the second phase of the project considering a larger number of mixes with known field performance.