Southeastern Superpave Center News

Volume 6, Number 1 Spring 2007

Inside this issue

Electronic Version of the Newsletter Now Available

The Southeast Superpave Center is now offering an electronic version of this newsletter. If you would like to receive the newsletter electronically, please go to the SESC Newsletter electronic subscription page at the following website:

https://engineering.purdue.edu/ECN/mailman/listinfo/sesc-newsletter-list

Please indicate if you wish to receive the electronic version only or if you would also like to receive a hard copy in the mail.

If you have any questions, please call the North Central Superpave Center office at (765) 463-2317, extension 224, or e-mail ncsc@ecn.purdue.edu.

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

EVALUATING N_{design} FOR SMA MIXTURES IN GEORGIA

By Randy West, NCAT

Stone Matrix Asphalt (SMA) has been increasing in popularity in the United States, and 28 states now utilize SMA, which has been reported to provide a 20 to 30 percent increase in pavement life over conventional pavements. In 1994, the Georgia Department of Transportation (GDOT) initiated a policy to use SMA on all interstates and other highways with average daily traffic (ADT) greater than 50,000 over a twenty-year design period.

In Georgia, current specifications allow SMA mixtures to be designed either by Marshall hammer or with 50 gyrations in a Superpave Gyratory Compactor (SGC). Various previous studies have recommended gyratory compaction levels from 70 to 100 gyrations for SMA mix design. However, in the second cycle of the NCAT test track, three new SMA sections were placed using a 75 gyration mix design, and three SMA sections were designed with 50 gyrations in the SGC. All of these sections performed very well with negligible rutting and no signs of cracking or raveling. The excellent test track performance is evidence that 50 and 75 gyrations can be used to satisfactorily design SMA mixtures.

The purpose of this project was to evaluate the compaction requirements for SMA using Georgia aggregates. Project work consisted of conducting SMA mix designs with various aggregates using four compactive efforts: 50-blow Marshall compaction, and 50, 75, and 100 gyrations with a Superpave gyratory compactor. Performance tests were performed on both laboratory and field-produced mixes.

Five granite aggregate sources were used in the laboratory phase of the study. These aggregates cover a range of Los Angeles (LA) Abrasion values from 16 to 44 percent loss. In the field phase of the study, three SMA projects in Georgia were sampled for verification of the laboratory results.

To compare the compactive effort between the Marshall hammer and the Superpave gyratory compactor, bulk specific gravity (Gmb) ratios were analyzed. A regression for all the mixture data combined indicates that 35 gyrations, on average, in the SGC yields the same density as 50 blows with a Marshall hammer. This result is much lower than expected. Other studies have found that 60 to 80 gyrations in the SGC typically yield equivalent specimen densities to the 50 blow Marshall hammer. To investigate the reason for the relatively low and wide range of equivalent gyrations, several mix and aggregate characteristics were evaluated. The factor that had greatest influence on the equivalent gyrations was the L.A. abrasion of the coarse aggregate. A strong relationship (R^2=0.9783) between LA. abrasion and the number of gyrations to achieve a density equivalent to the Marshall hammer .

Each of the SGC mix designs was tested in the Asphalt Pavement Analyzer (APA) for rutting susceptibility. Test samples were compacted in the SGC to the three gyration levels at their respective design asphalt contents.

GDOT specifications require APA rut depths not to exceed 5 mm for mixtures placed on

Continued on page 11

Performance Modeling of Asphalt Concrete Pavements

By Y. Richard Kim

Editor's note: *Space did not permit printing the entire document Dr. Kim wrote. The full text and graphics are online at http://bridge.ecn.purdue.edu/~spave/Newsletters/Newletters.htm*

Asphalt concrete pavement, one of the largest infrastructure components in the United States, is a complex system that involves multiple layers of different materials, various combinations of irregular traffic loading and varying environmental conditions. Therefore, a realistic prediction of the long-term service life of asphalt pavements is one of the most challenging tasks for pavement engineers. In recent years, research efforts by the Asphalt Materials Analysis and Computational Mechanics Group at North Carolina State University (NCSU) have resulted in some key advances in pavement performance modeling. One such accomplishment is the development of the viscoelastoplastic continuum damage (VEPCD) model.

The structure of the VEPCD model is based on the principle that strain may be separated and modeled by component, i.e., elastic, linear viscoelastic, viscoplastic, etc. For the VEPCD model, elastic and linear viscoelastic strains as well as strains due to microcracking damage are combined in a single term (ε_{ve}) while plastic and viscoplastic strains are combined in another (ε_{vp}).

The underlying principles of the VEPCD modeling approach are linear viscoelasticity, continuum damage mechanics and strain-hardening viscoplasticity. Linear viscoelastic (LVE) materials exhibit time- and temperature-dependent behavior. That is to say, the response is dependent on both the current input and all past input (i.e., input history). Continuum damage mechanics considers a damaged body with some stiffness as an undamaged body with a reduced stiffness. Continuum damage theories thus attempt to quantify two values, damage and effective stiffness, and further find the relationship between the two.

In the VEPCD modeling approach these two concepts, linear viscoelasticity and continuum damage mechanics, are combined and result in a robust material model that is easy to characterize. For viscoplasticity, the approach thus far has been to utilize a strain-hardening viscoplastic model.

The major strength of the VEPCD model is in the simplicity of the calibration testing. The calibration testing program is composed of three phases: (1) LVE characterization; (2) VECD characterization; and (3) VP characterization. The complex modulus test at varying temperatures and frequencies is used for LVE characterization. For the VECD and VP model characterization, constant crosshead rate monotonic tests at 5° and 40°C, respectively, are used.

The accuracy of the VEPCD model has been assessed in a number of different ways. One of the most robust assessments includes the application of randomly selected cyclic loadings at a temperature (25°C) not used in characterization. For such tests the loading amplitude, frequency and number of cycles for a given loading are randomly selected.

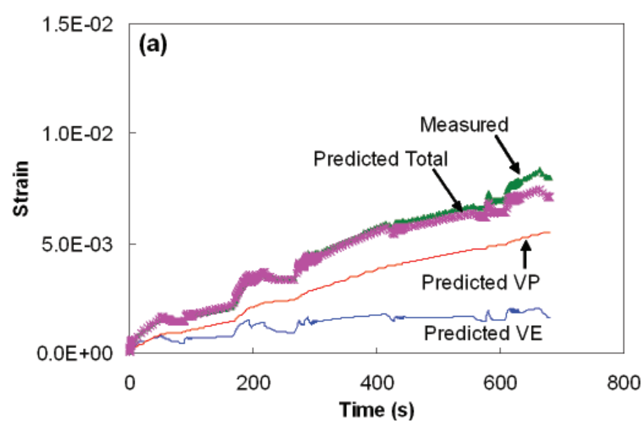
Figure 1 presents results of the model prediction for this loading history for two of the mixtures tested in the study. An examination of this figure shows that the measured and modeled behaviors closely agree. The same prediction accuracy was found with two other mixes evaluated: SBS and Terpolymer. The same loading history results in a different fatigue life for each of the mixtures. (Note the difference in scale on the y-axis.)

An even more rigorous validation of the VEPCD model involves the prediction of Thermal Stress Restrained Specimen Tests (TSRSTs). The TSRST verification is particularly important because these tests were not used in the model development. In addition, stresses in TSRSTs are thermally induced whereas mechanically induced stresses are used in the characterization process.

Using specimen dimensions, initial temperature, and cooling rates, predictions of stress-time history, stress-temperature history and stress, time, and temperature at failure have been made. These predictions were modeled with three levels of complexity: (1) LVE; (2) VECD; and (3) VEPCD. The predictions are shown in Figure 2 with the model predictions. As with the random load tests, the VEPCD predictions are in agreement with the measured responses.

Modeling the material behavior alone is not sufficient for pavement performance predictions, however. Experience has shown that the performance of asphalt concrete pavements is also strongly influenced by boundary conditions, such as tire-pavement interaction, temperature gradient along the layer thickness, pavement structural design, etc. To account for these influences, a structural model must be included in the performance prediction process. This need has led to the development

Continued on page 11



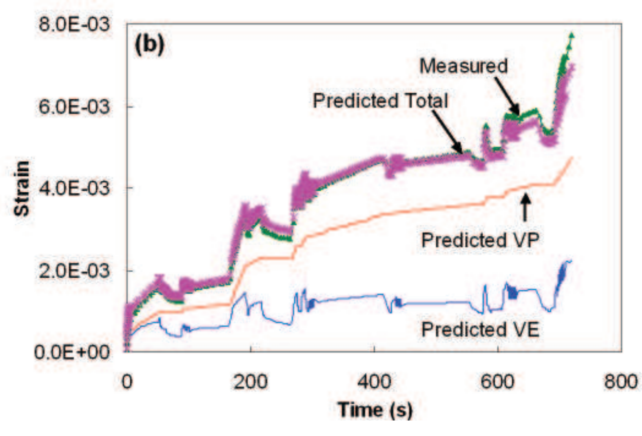


Figure 1. Random load prediction results for ALF mixtures: (a) Control, (b) CR-TB

Continued from page 2

of VEPCD-FEP++, performance modeling software written in C++ that integrates both the fundamental VEPCD material model and a robust finite element model.

Typical analysis results using VEPCD-FEP++ (shown in the on-line article) show that the degree of damage increases with load applications, as one would expect. For the thick pavement used in this example, damage initiates from both the bottom of the asphalt layer and the top of the layer right under the tire edge, and propagates simultaneously to form a conjoined damage contour. This conjoined damage contour supports the findings from field studies of top-down cracking. Also, the conjoined damage contour suggests that the through-the-thickness crack may develop as these bottom-up and top-down microcracks propagate further and coalesce together. VEPCD-FEP++ is currently used in the NCHRP 1-42A project, *Models for Predicting Top-Down Cracking of Hot-Mix Asphalt Layers*, to evaluate the top-down cracking mechanism of various asphalt mixtures and pavements.

Pavements with different materials and boundary conditions might not necessarily behave in a similar manner and their performance might be notably different. To the pavement engineer, knowing how a given material will perform in a selected structure is of great importance for selecting the appropriate solution. Such a tool has both national and international implications, as evidenced by two of the current NCSU projects, one funded by the Federal Highway Administration (FHWA) and the other by the Korea Highway Corporation (KHC).

The FHWA project incorporates full-scale Accelerated Loading Facility (ALF) testing on various asphalt mixtures, including polymer-modified mixtures. The KHC Test Road project involves continuous measurement of environmental conditions and traffic loading on a 7.7 km section of instrumented test road on the Jungbu Inland Expressway, as well as periodic measurements of pavement responses under moving loads with the Falling Weight Deflectometer. Both of these projects offer opportunities for validation and calibration of VEPCD-FEP++. Further, the FHWA and several states have also expressed interest in validating and calibrating VEPCD-FEP++ using perpetual pavements in China as well as pavements in those states.

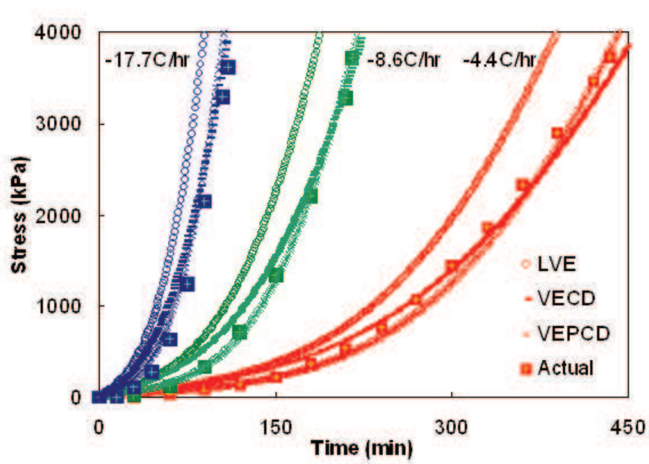


Figure 2: Average measured and predicted stress histories for different material models and cooling rates

Continued from page 1

high traffic volume facilities. All of the SMA mixtures designed in this study easily met this criterion. The data also indicates that there is not a trend of increased rutting potential as asphalt content increases or as compactive effort in the SGC decreases. This finding is supported by field experience with SMA mixtures, which has indicated that as long as an SMA mixture retains stone-on-stone contact within the aggregate skeleton, its rutting resistance is not sensitive to asphalt content.

Three SMA projects in Georgia were sampled in the field validation phase. Samples of the plant produced SMA from each project were taken from four consecutive lots to include typical material variability in the field phase. The collected samples from each lot were compacted to 50 blows with the Marshall hammer and 50, 75, and 100 gyrations with the SGC. The bulk specific gravities of compacted samples using 50 blows with the Marshall hammer were compared to the gyratory compacted samples. The G_{mb} ratio was examined for this comparison. The range of equivalent gyrations for the field produced mixes was from 30-48. The G_{mb} ratio versus gyrations for all of the field data combined indicates that an average of 34 gyrations provided an equivalent density to the Marshall hammer.

APA tests were performed on samples from two lots for each project. The two samples were selected which had the greatest range in quality control results. All of the rut depth results from the APA testing easily met the 5.0 mm maximum rut depth requirement. There was no significant difference in APA rut depths found between samples of the same mixture compacted to different gyrations. The low APA rut depths for the field samples also indicate that the mixtures are not sensitive to normal mixture variations which occur during SMA production.

SMA mix designs using the Marshall method of specimen compaction have performed very well in Georgia for over a decade. With this history of success, the goal of this research was to change the type of compactor without changing SMA mixtures. The results from this study indicate that the relationship between gyrations in the SGC and the 50 blow Marshall hammer is significantly influenced by the resistance of the aggregate to degradation. Based on Georgia's successful use of aggregates with relatively high L.A. abrasion values in SMA, it is recommended that the design number of gyrations (N_{design}) for SMA mix designs be set at 50 gyrations using a Superpave gyratory compactor.

Editor's note:
The full text of this article, with supporting graphs, is available online at http://bridge.ecn.purdue.edu/~spave/Newsletters/Newletters.htm

National Center for Asphalt Technology (NCAT)
Southeastern Superpave Center
Auburn University
277 Technology Parkway
Auburn, AL 36830

Don Watson (334) 844-6228
Manager, Superpave Center ext. 108
watsode@eng.auburn.edu

E. Ray Brown (334) 844-6228
Director, NCAT ext. 113
rbrown@eng.auburn.edu

Brian Prowell (334) 844-6228
Assistant Director ext. 111
prowebd@eng.auburn.edu

Randy West (334) 844-6228
Assistant Director ext. 109
westran@eng.auburn.edu

Andre Smit (334) 844-6228
Research Engineer ext. 105
smitade@eng.auburn.edu

Andrea Kvasnak (334) 844-6228
Research Engineer ext. 103
ank0004@eng.auburn.edu

FAX (334) 844-6248

Website: http://www.ncat.us

Linda Pitstick (765) 463-2317
Coordinating Editor ext. 224
lmp@ecn.purdue.edu

Calendar of Events

2007

March 12-14	Association of Asphalt Paving Technologists 82nd Annual Meeting San Antonio, TX Website: www.asphalttechnology.org
March 19-22	World of Asphalt 2007 Show and Conference Atlanta, GA Website: www.worldofasphalt.com
March 26-29	Superpave Mix Design NCAT Research Facility, Auburn, AL Website: www.ncat.us
April 2-3	6th International Symposium on Asphalt Binder Rheology and Pavement Performance Tampa, FL Website: www.asphalt-technology.com/sym.htm
April 16-18	New Directions in Airport Technology Atlantic City, NJ Website: www.airporttech.tc.faa.gov/naptf/att07/
June 19-28	Professor Training Course NCAT Research Facility, Auburn, AL Website: www.ncat.us
June 24-27	9th International Conference on Low-Volume Roads Austin, TX Website: www.trb.org/conferences/9lvr/
Sept. 27-Oct. 2	AASHTO Annual Meeting Milwaukee, WI Website: www.transportation.org/aashto/calendar.nsf

National Center for Asphalt Technology
Southeastern Superpave Center
Auburn University
277 Technology Parkway
Auburn, AL 36830

Non-Profit Organization
U.S. Postage
PAID
Purdue University