Transportation Literature Search
RESEARCH & LIBRARY SERVICES
research@dot.state.wi.us
library@dot.state.wi.us

Flow Number and Mechanistic Evaluation of HMA

Prepared for
WHRP Flexible Pavements
Technical Oversight Committee

Prepared by
CTC & Associates LLC
WisDOT Research & Library Unit

January 30, 2008

Transportation Literature Searches are prepared for WisDOT staff and investigators to identify completed research and other authoritative information in an area of interest. The citations below are representative, rather than exhaustive, of available English-language studies on the topic. Primary online resources for the literature searches are OCLC's WorldCat and TLCat, U.S. DOT's TRIS Online, the National Transportation Library (NTL), TRB's Research in Progress (RiP) database, and other academic, engineering and scientific databases as appropriate.

To request a literature search, contact the WisDOT Library at library@dot.state.wi.us or (608) 264-8142, or WisDOT Research at research@dot.state.wi.us or (608) 261-8198.

Topic/Problem Statement: Document literature from 2000 to the present relevant to evaluating the relationship of flow number and flow characteristics to mechanistic properties of hot-mix asphalt.

Keywords: Flow, number, mechanistic, evaluation.

Summary

We located seven citations of published research and one research project in progress. The published research spanned three years, including a Wisconsin study and two TRB articles or presentations in 2007, two TRB reports in 2006, and one Texas study and an asphalt industry journal article in 2005. A research project in progress is sponsored by Iowa DOT.

Citations

Results are listed chronologically, with the most recent citations shown first. Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Using the Superpave gyratory compactor to estimate rutting resistance of hot-mix asphalt
Author(s): Hussain U. Bahia, Ahmed F. Faheem
Date: December 2007
Source/URL: *Transportation Research Circular* E-C124, 2007: 45-61.
http://onlinepubs.trb.org/onlinepubs/circulars/ec124.pdf
Description: 17 pp.
Contents: Several approaches have been introduced lately to characterize the performance-related properties of asphalt mixtures. The majority of these efforts are focused on developing special equipment to test mixtures at conditions similar to those acting on pavements due to moving traffic. Because the Superpave gyratory compactor (SGC) is used routinely for compaction, and because it has components to measure load and densification, this study investigated its use for estimating the stability of asphalt mixtures as a surrogate or an estimate for results of the proposed method for the simple performance test. Several asphalt mixtures were produced using four different aggregate sources, different asphalt contents, and different gradations. Each mixture was compacted using the SGC.

To evaluate if the results from the SGC can be related to rutting, mixtures were also tested using the new repeated compression test procedure recommended by the NCHRP Project 9-19 and used in the "Mechanistic–Empirical Pavement Design Guide." Densification curves produced by the SGC were used to determine volumetric properties of the mix and to calculate the traffic densification index (TDI), which is the value of the area under the densification curve from 92% density to 98% density and which represents the densification experienced due to traffic loading during the pavement service life. One more index, the traffic force index (TFI), is calculated. The TFI is the amount of work done to change the density of the mix from 92% to 98% measured using a special accessory added to the SGC called the pressure distribution analyzer (PDA). The results from the mixture rutting tests were used to estimate the rutting rate and the flow number (FN), which is the point at which the mixture starts to exhibit tertiary flow. The FN, which is considered an important mixture property, is shown to have a strong correlation to the TFI derived from the mixtures' resistance behavior measured in the SGC and the PDA. The TFI was found to be strongly correlated to the TDI, giving the opportunity to estimate the mixture resistance to compaction forces using its volumetric behavior. The main finding of the study is that the SGC gives information that can be used to characterize the stability of asphalt mixtures. Such information could be used as an initial screening criterion to select mixtures for various traffic levels.

Title: Testing Wisconsin Asphalt Mixtures for the AASHTO 2002 Mechanistic Design Procedure
Author(s): R. Christopher Williams, Christopher J. Robinette, Jason Bausano, Tamer Breakah
Date: July 2007
Source/URL: WHRP 0092-04-07, Final Report, 2007.
http://www.whrp.org/Research/Flex/flex_0092-04-07/0092-04-07%20Final%20Report.pdf
Description: 267 pp.
Contents: The intent of this project was to examine typical hot mix asphalt (HMA) pavements that are constructed in the state of Wisconsin. The analysis compares the suggested pavement structures based on the 1972 pavement design guide currently used in Wisconsin and the same ones based on the new Mechanistic-Empirical Pavement Design Guide. In order to develop the pavement structure as outlined by the new Design Guide, the mechanical properties of the HMA layers were measured from 21 field sampled mixtures. These properties include dynamic modulus and flow number, which have been found to be significant predictors of rutting and fatigue by Witczak et al. (2002). Properties of the other layers in the system have been obtained from the Wisconsin Department of Transportation pavement design inputs. The objective was to account for typical construction variability that occurs and to determine its impact upon both mechanical tests. Further, the authors examined these mechanical test results on pavement design to determine if the performance tests and new Design Guide, as they currently exist, are ready for implementation by owners/agencies.

Title: Statistical development of a flow number predictive equation for the Mechanistic-Empirical Pavement Design Guide
Author(s): Andrea Kvasnak, Christopher John Robinette, R. Christopher Williams
Date: 2007
Source/URL: 2007 TRB Annual Meeting Paper 07-1000.
Description: 18 pp.
Contents: Over the past few years there has been significant interest in establishing a test method that could be employed universally to evaluate the material properties of a hot mix asphalt design, such that it would be indicative of field performance. The majority of interest has centered around dynamic modulus with primary efforts on refining associated predictive equations. However, some researchers feel that an additional test should be employed in conjunction with dynamic modulus within the Mechanistic-Empirical Pavement Design Guide. Currently, there is interest in incorporating flow number as the additional test method. If flow number is to be incorporated into the Mechanistic-Empirical Pavement Design Guide, a predictive equation relating flow number will need to be developed. In this paper, an initial predictive equation for flow number is presented. Seventeen mixtures were sampled around the State of Wisconsin, each with unique mix parameters. The flow number of these mixtures were evaluated at different air void and asphalt contents. Using the flow number test data, several statistical tools were employed to develop a model based on the given information. Aggregate characteristics were believed to affect flow number, hence the inclusion of aggregate characteristics in variable selection. The final model selected is based on six factors with a coefficient of determination greater than 0.90. The six factors found to be important for estimating flow number are number of gyrations, bitumen viscosity, voids in the mineral aggregate, percent passing the 4.75-mm sieve, percent passing the 1.18-mm sieve, and percent passing the 0.075-mm sieve.

Title: Permanent deformation analysis of hot-mix asphalt mixtures using simple performance tests and 2002 Mechanistic-Empirical Pavement Design software
Author(s): Louay N. Mohammad, Zhong Wu, Sandeep Obulareddy, Sam Cooper, Christopher David Abadie
Date: 2006
Source/URL: *Transportation Research Record 1970*, 2006: 133-142.
Description: 10 pp.
Contents: A complex laboratory study in characterization of permanent deformation resistance of hot-mix asphalt (HMA) mixtures is presented. Six plant-produced HMA mixtures were selected for this study. The main objective was to characterize the permanent deformation characteristics of HMA mixtures based on four laboratory tests, namely, the dynamic modulus |E*|, flow number, frequency sweep at constant height (FSCH), and Hamburg-type loaded wheel-tracking tests. The secondary objective was to evaluate the sensitivity of the dynamic modulus |E*|-test results in pavement rutting performance prediction with the 2002 mechanistic–empirical (M–E) pavement design software. Test results indicate that the |E*|-test was sensitive to the nominal maximum aggregate size in an HMA mixture. Larger aggregates combined with aged materials tend to have high |E*|-values at high temperatures. However, both the |E*|- and FSCH tests could not correctly rank the permanent deformation characteristics for the six HMA mixtures considered in this study. However, test results from the flow number and Hamburg tests correlated fairly well, and both tests were sensitive to the permanent deformation characteristics for the mixtures evaluated. The mixture ranking order obtained from the flow number tests was consistent with the use of those mixtures in the field. The predicted rut depths from the 2002 M-E pavement design software basically followed the same trend found in the |E*|-test results at high temperatures.

Title: Pavement design analysis with 2002 Design Guide software
Author(s): Christopher J. Robinette, R. Christopher Williams
Date: 2006
Source/URL: *Transportation Research Record 1970*, 2006: 143-150.
Description: 8 pp.
Contents: There has been a continuous evolutionary process in hot-mix asphalt (HMA) pavement design. In the beginning it was primarily based on past experience. Through research, empirical methods were developed on the basis of the materials' response to specific loading in the AASHO Road Test. Today pavement design has progressed to a mechanistic–empirical method. This methodology takes into account the mechanical properties of the individual layers and uses empirical relationships to relate material properties to performance. The mechanical tests that are used as part of the current methodology include dynamic modulus and flow number, which have been shown to correlate with field pavement performance. The use of the dynamic modulus test and its impact on pavement design with the current design guide (2002) and its associated software are examined here. The three pavement structures that are examined were derived from the 1972 AASHTO design guide approach and were constructed in Wisconsin during the 2004 construction season. Through iterative changes in the HMA layer thickness, the major distresses of permanent deformation and fatigue were examined. Included in the examination were changes in air voids and asphalt binder content over ranges that were believed to be typical of HMA production and paving. All three pavements were predicted to perform well in terms of permanent deformation for the as-designed layer thicknesses. The 2002 design guide software, however, indicates that two of the three pavements considered may be prone to fatigue cracking, specifically at higher air void contents (+7.0%).

Title: Evaluation of Selected Laboratory Procedures and Development of Databases for HMA
Author(s): Amit Bhasin, Joe W. Button, Arif Chowdhury
Date: January 2005
Source/URL: FHWA/TX-05/0-4203-3, Technical Report 0-4203-3.
Description: 163 pp.
Contents: The objectives of this research project were to develop and validate laboratory test protocols for measuring rut susceptibility of hot mix asphalt (HMA) mixtures; to identify the best available laboratory test protocol(s) for predicting moisture susceptibility of HMA paving mixtures; and to develop a TxDOT HMA test database to be used for evaluating and/or validating the proposed AASHTO mechanistic-empirical pavement design guide. Twelve field mixes and three lab mixes were tested using Asphalt Pavement Analyzer (APA), Hamburg, Dynamic Modulus, Flow Time, Flow Number, and Simple Shear at Constant Height for the evaluation of rutting tests. Mixture parameters resulting from different tests were ranked and compared with APA rut depth as a base. Rankings of the different parameters were analyzed using statistical techniques. Findings indicate that flow time and flow number tests capture fundamental material properties and should be considered for inclusion in the mixture design and selection processes. Caution must be exercised in interpreting rut susceptibility of mixes based on the E* parameters, especially when evaluating mixtures containing polymer-modified asphalts. Nine mixtures were tested using the Hamburg. Their individual aggregates and binders were tested for surface energy measurement using

Universal Sorption Device and Wilhelmy plate method, respectively. Mixtures with and without antistripping agents like hydrated lime and commercially available liquid antistripping agents were tested. Within groups of controlled mixes, the calculated bond strength based on surface energy measurements relates well with the deformation data from the Hamburg test. About 30 plant-produced mixes and 50 lab-produced field mixes were tested using the Hamburg and dynamic modulus devices. Plant-produced mixes were tested for production verification and lab-produced mixes were tested to develop a mixture database for future use, especially for the AASHTO design guide.

Title: A practical look at the simple performance tests: Louisiana's experience
Author(s): Louay N. Mohammad, Zhong Wu, Leslie Myers, Sam Cooper, Christopher Abadie, Ghassan Chehab, Richard Davis
Date: 2005
Source/URL: *Asphalt Paving Technology*, Vol. 74, March 2005: 557-600.
Description: 4 pp.
Contents: The Superpave volumetric mix design procedure developed during the Asphalt Research Program of the Strategic Highway Research Program did not include a mechanical "proof" test similar to the ones commonly used in the Marshall mix design or Hveem mix design such as the Marshall stability and flow tests or the Hveem stabilometer method, respectively. The Superpave mix design method, however, did use strict requirement to material specifications and volumetric mix criteria to ensure satisfactory performance of mix designs that were intended for low volume traffic. In addition, the original Superpave mix design protocol required mix verification for intermediate and high volume traffic through advanced materials characterizations tests utilizing the Superpave Shear Tester test protocols. It was quickly recognized the complexity of those test protocols for routine mix design application and that a simple performance test is needed to complement the Superpave volumetric mix design procedure. In response to this need, NCHRP Project 9-19, Superpave Support and Performance Models Management, recently recommended three candidate Simple Performance Tests (SPTs) to complement the Superpave volumetric mixture design method. These are flow time (F_T), flow number (F_N), and dynamic modulus |E*| tests. In addition, the dynamic modulus test was selected for the HMA materials characterization input utilized in the 2002 Empirical and Mechanistic Guide for Design of New and Rehabilitated Pavement Structures, developed under NCHRP Project 1-37A. This paper presents a practical look at the results of a cooperative evaluation of similar Superpave mixtures utilizing two tests of the SPTs: the Dynamic Modulus and Flow Number. Two different dynamic modulus predictive models, Witczak and Hirsch, were also evaluated.

Research in Progress

Results are listed chronologically, with the most recent citations shown first. Links to research project Web sites or TRB Research in Progress listings are provided when available.

Title: Evaluation of Hot Mix Asphalt Moisture Sensitivity Using the Nottingham Asphalt Test Equipment, Phase II
Principal Investigator(s): Christopher Williams, (515) 294-4419 or rwilliams@iastate.edu
Start Date: 4/1/2006
RIP URL: http://rip.trb.org/browse/printview.asp?ids=11971
Sponsor Organization: Iowa Department of Transportation
Contents: The objectives of this research project are to: 1. Compare the test results for materials tested in both a moisture saturated environment and dry environment. The research plan will integrate a range of Iowa DOT asphalt mixtures. 2. Use the results obtained from the dynamic modulus and flow number tests to develop a new test protocol for determining moisture susceptibility.