Characterization of Asphalt Concrete Dynamic Modulus in South Carolina

In Cooperation with:

U.S. Department of Transportation

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P.O. Box 191

Columbia, SC 29202-0191

Overview

Many states around the country still use the 1972, 1986, or 1993 AASHTO Design Guides, which rely on empirical relationships between paving material properties and the structural performance of pavement layers that were developed based on the 1950's AASHO Road test data. However, during the implementation of 1986 Design Guide, the need for and benefits of a mechanistically-based pavement design procedure were recognized. In 2004, the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) was completed and ultimately released to the public for review and evaluation.

For many years, South Carolina Department of Transportation (SCDOT) officials have considered adopting AASHTO's new mechanistic-empirical design guide; however, this would require extensive local calibrations. The major objective of this research was to characterize currently-used South Carolina (SC) asphalt mixtures and to develop a catalog for dynamic modulus value inputs to be used in the MEPDG software.

Literature Review

Dynamic modulus (|E*|) is the ratio of stress to strain under vibratory conditions. The |E*|, commonly used for flexible pavement design, is one of the most important parameters needed for the MEPDG. In addition, |E*| is also one of the key parameters employed to evaluate both rutting and fatigue cracking distress predictions in the MEPDG. Phase angle (δ) is the angle in degrees between a sinusoidal applied peak stress and the resulting peak strain in a controlled stress test and is useful in the prediction of permanent deformation.

The repeated load flow number (FN) test is a dynamic creep test where a haversine type of loading is applied with rest periods between loadings (AASHTO TP79-13). A higher load repetition results in a higher FN, which indicates that the asphalt pavement exhibits a better rutting resistance.

With the |E*| and FN being significant inputs required for flexible pavement design/evaluation in the MEPDG, numerous researchers have explored the various factors affecting these properties, which include aggregate gradation, asphalt binder stiffness, and mixture volumetrics.

Results

In this study, all SCDOT Surface mixture types (A, B, C, D, and E), all SCDOT Intermediate mixture types, (A, B, and C), and two SCDOT Base mixture types (A and B) were evaluated at multiple temperatures and frequencies for dynamic modulus, phase angle, and flow number. Variables included seven aggregate sources in various regions of SC, two asphalt binder sources, two RAP contents (0% RAP and job mix formula % RAP), two warm mix asphalt (WMA)

technologies (foaming and a chemical additive), two liquid anti-stripping additives (LASA), and two aging conditions (unaged and long-term aged). Later in the project, a few samples from some newly-approved mixture types were also tested, including Intermediate Type B Special; Surface Type A with updated gradation requirements and corrected optimum asphalt content (COAC); and Surface Type B with COAC. Figures 1 and 2 show that aggregate source affected both |E*| values and FN values of various Surface Type A mixtures containing RAP.

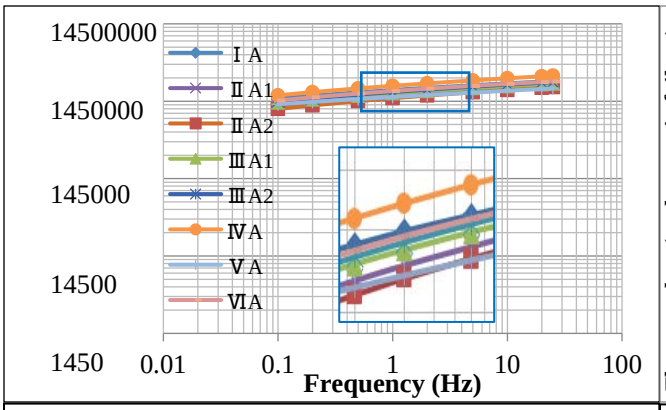

Figure 1. Dynamic Modulus Values of Surface Type A Mixtures with RAP in Terms of Aggregate Source at 4 °C (39.2 °F)

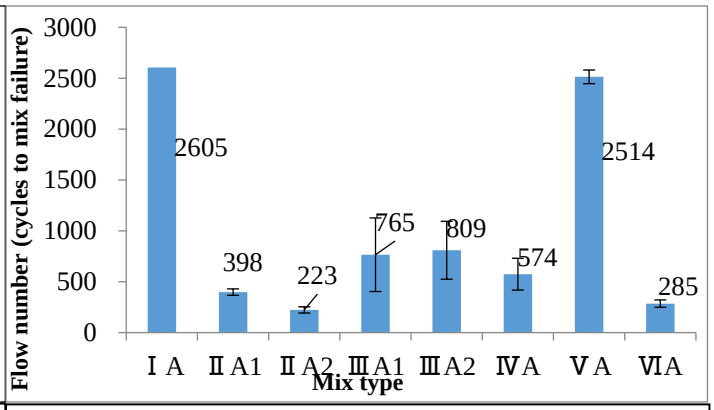

Figure 2. Flow Number Values of Surface Type A Mixtures with RAP in Terms of Aggregate Source at 59 °C (138.2 °F)

Legend for Figures 1 and 2
I, II, III, IV, V, and VI = Aggregate source
A = Surface Type A mix
1* = Mix design used Feb. 2013 SC-M-402 gradation specifications (in effect when study began)
2* = Mix design used July 2017 SC-M-402 gradations specifications + COAC
*Note: Mixtures not labeled “1” or “2” used Feb. 2013 SC-M-402 gradation specifications (in effect when study began).

Conclusions

Mixtures containing the following variables exhibited higher |E*| and lower δ values (which predict greater resistance to rutting) than the corresponding mixtures to which they were compared: aggregate sources I and V, PG 76-22 asphalt binder grade, and RAP. Surface and Intermediate course mixture types designated for higher volume pavements also generally produced higher |E*| and lower δ compared to lower volume mixtures. Base mixture type, asphalt binder source, and WMA type only slightly affected |E*| and δ values, while LASA type and aging had little to no effect.

Mixtures containing the following variables exhibited higher FN values (which predict greater resistance to rutting) than the corresponding mixtures to which they were compared: aggregate sources I and V, PG 76-22 asphalt binder grade, and no WMA. Surface and Intermediate course mixture types designated for higher volume pavements also generally produced higher FN values compared to lower volume mixtures. Several variables had differing results depending upon the aggregate source and/or mixture type. Those variables included asphalt binder source, use of LASA, aging, and use of RAP. Base mixture type only slightly affected FN values, while WMA type and LASA type had little to no effect. Although several mixtures in this study did not meet the minimum flow number values recommended by AASHTO, the scope of this study did not allow for further investigation of the causes of those results. More in-depth studies of some of the individual variables from this study are recommended.

Tables were developed for every material combination tested in this project that contain the necessary input data for pavement design using these materials in the MEPDG software program.

Serji Amirkhanian, Feipeng Xiao and Mary Corley were the Principal Investigators for this research project. For further information, please contact Mr. Terry Swygert at SC DOT: 803-737-6652 or swgerttl@scdot.org