Material Selection Guidance for Asphalt Pavement Design

RESEARCH SYNOPSIS 18-01

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Background

Innovation and sustainability have been hallmarks of the asphalt pavement industry for many years. Technologies such as warm mix asphalt (WMA), recycled asphalt shingles (RAS), reclaimed asphalt pavement (RAP), recycled tire rubber (RTR), stone matrix asphalt (SMA), and cold recycled (CR) mixtures offer economic, engineering, and environmental advantages when their use in structural pavement design is carefully considered to arrive at optimized structures. A primary challenge to this effort has been that these technologies often outpace the structural design procedures that may rely solely on more conventional materials and performance characterization.

Objective

The objective of this investigation was to provide guidance for flexible pavement design methods to arrive at optimized pavement structures when innovative and sustainable materials are used, and to identify the challenges when trying to incorporate these materials. This investigation also provides a basic understanding of different materials and technologies, mix design considerations, material properties, performance, and possible applications.

Structural Pavement Design Methodologies

The study first evaluated methods for flexible pavement design primarily used in the U.S. These methods include, but are not limited to, the empirical AASHTO pavement design method (1993 AASHTO Design Guide), the more recent AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG), and perpetual (long-life) pavement design.

The 1993 Design Guide relies primarily on structural coefficients to characterize materials, and their use, in thickness design. For many years, most states have used a layer coefficient of 0.44 or lower to represent conventional dense-graded hot-mix asphalt. Recent studies in Washington State and Alabama have found values of 0.50 and 0.54, respectively, to better represent performance and structural value of conventional materials. As described in this synopsis and detailed in the full report, accurately quantifying structural coefficients of new materials is key to optimized pavement design within the 1993 AASHTO Design Guide.

The MEPDG relies on mechanistic pavement modeling and empirical predictive equations for thickness design. Mechanistic modeling requires characterizing the master curves of the binder dynamic shear modulus (|G*|) and mixture dynamic modulus (|E*|). There is generally an abundance of |E*| data available for both conventional and new asphalt materials following the AASHTO T 378-17 procedure with the Asphalt Mixture Performance Tester (AMPT). However, |G*| is sometimes more difficult to quantify, especially for materials that require extraction of a binder after mixing for testing (e.g., RAP, RAS, and RTR mixtures).

Empirical performance prediction in the MEPDG can prove more difficult than master curve determination as it requires actual field performance, measured over many years, to calibrate the prediction equations. This step is not limited to the use of new materials, but rather recommended for any agency considering using the MEPDG in practice, regardless of material type. Local calibration is strongly recommended by AASHTO, but it may be prohibitively costly and time-consuming for a new material that is not in widespread use. At the same time, not adjusting the performance predictions for the new material may lead to over or under designed structures. Currently, there is no formalized procedure for overcoming this difficulty. Designers have to rely on their engineering judgment based on an assessment of the material to determine whether the pavement performance predictions will be accurate. In most cases, this may be done by examining previous lab and field studies of the various materials.

Perpetual (long-life) pavement design is a subset of mechanistic-empirical (M-E) design that limits pavement responses below critical thresholds to prevent distresses deep in the structure. Again, the mechanistic pavement modeling relies on master curve determination. There are established procedures, as explained in the report, for finding the threshold in the laboratory or field, and there are existing recommendations for conventional materials. However, there is a need to develop thresholds for new and innovative materials.

Warm Mix Asphalt (WMA)

Warm mix asphalt has been used for over a decade in the U.S., and numerous studies have indicated that it can be used in design with few (if any) changes when compared to conventional HMA. It is recommended that WMA mixtures have similar structural coefficients to HMA mixtures in the 1993 AASHTO Design Guide. In M-E systems, treating WMA in the same fashion as HMA with respect to material properties and performance prediction equations also is supported by lab and field data.

Reclaimed Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS)

Increased RAP and RAS contents tend to increase mixture moduli and potentially decrease strain tolerance when all else is held equal. Using softer virgin binders can offset this effect and result in high-performing materials nearly indistinguishable from virgin HMA. Laboratory testing should be conducted to determine |E*| for specific mixes to be used in the MEPDG. Adjustments to performance prediction transfer functions will also be needed to account for changes in cracking and rutting potential. For AASHTO 1993, there are data to support using structural coefficients for RAP mixtures similar to virgin mixtures, but no data or guidance was found pertaining to RAS mixtures. This deficiency requires further investigation.

Recycled Tire Rubber (RTR)

Recycled tire rubber has a very long history and the benefits of the material are well-documented, but there is little guidance available regarding its use in structural design procedures. The recommendation, based on available data, is to use structural coefficients at least equal to that of conventional materials for AASHTO 1993 Design. For M-E design, |E*| should be measured in the laboratory, but further research is needed regarding transfer function calibration.

Stone Matrix Asphalt (SMA)

Many field studies have confirmed excellent performance from SMA mixtures used as surface layers. SMA mixes at the NCAT Test Track were found to have structural coefficients comparable to conventional materials and a value of 0.54 was recommended. Again, laboratory |E*| testing is needed for M-E design and the various transfer functions should be adjusted to reflect the actual performance of SMA mixtures in the field.

Cold Recycling (CR)

Though CR has been widely used across the U.S., the long-term performance of pavements constructed with these techniques has not been widely documented, especially when they are used on highways with relatively high traffic levels. Recent studies have estimated layer structural coefficients for one type of CR, cold central-plant recycle (CCPR), in the range of 0.36 to 0.48. Further research is needed to quantify structural coefficients for a wider range of CR materials. For M-E design, |E*| should be measured on a mixture-specific basis, and calibration of transfer functions is required.

Polymer-Modified Asphalt (PMA)

Polymer modified asphalt includes a wide range of materials resulting in a wide range of mixtures whose properties depend on the mix design and the amount and type of polymer modification. These materials tend to have improved cracking and rutting resistance, which suggests that the M-E transfer functions should be calibrated accordingly to optimize their use. Also, |E*| should be directly measured in the laboratory for M-E design. As documented at the NCAT Test Track, there was insufficient evidence found to support using a structural coefficient for PMA different than that of conventional mixtures. This was likely due to the limited nature of the study and perhaps a conservative recommendation.

Summary

This investigation provides guidance for flexible pavement design methods when innovative and sustainable materials are used. Specific layer coefficients were found in past studies and are recommended for some of these materials in the AASHTO 1993 Design Guide. For M-E design, a direct measurement of |E*| is recommended, and calibration of transfer functions is required for these mixtures, as their stiffness and strain tolerance are different from the conventional mixtures used in past calibration.

Authors: Dr. Carolina Rodezno, Dr. David H. Timm, P.E., Dr. Mary Robbins, Dr. Nam Tran, P.E.

Acknowledgements and Disclaimer: Funding for this study provided by the National Asphalt Pavement Association under the research project "Optimizing Flexible Pavement Design and Material Selection". This document is for general guidance and reference purposes only. NCAT, Auburn University, and the listed sponsoring agency assume no liability for the contents or their use.