Flexible Pavement Design- State of the Practice

RESEARCH SYNOPSIS 14-04

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Background

The empirical AASHTO pavement thickness design procedure developed in the 1960s and currently used by many agencies across the U.S. has recently been replaced by more modern and mechanistic-based approaches. The new Mechanistic-Empirical Pavement Design Guide (MEPDG) and corresponding design software, AASHTOWare™ Pavement ME Design, represents the new AASHTO standard for pavement design in the U.S. In addition, perpetual pavement approaches offer methods for achieving high-performing, long-life pavements as an alternative to conventional design. These new approaches are a radical shift in design, and for many agencies implementation will replace decades of experience in the old system. The new approaches have the potential to optimize pavement structures through modern characterization of materials, traffic and performance prediction. The purpose of this research synopsis is to present the various approaches to asphalt pavement thickness design and summarize their current use across the U.S.

Pavement Design Methods

Prior to the 1960's, pavement design in the U.S. was primarily based on experience. Recognizing the need for a more widely-applicable scientific approach, the AASHO Road Test (*1*) was conducted in northern Illinois from 1958-1960 and formed the basis for the AASHTO Design Guides published through 1993 (*2*). These procedures were empirically-based and essentially correlated a set of properties (e.g., thickness, strength of materials, strength of subgrade) to the amount of traffic the pavement could withstand before reaching a terminal level of serviceability. These design approaches were developed from an experiment with a limited range of conditions, and as a result are not easily updated. As advances in materials and construction are made over time, designers are often forced to extrapolate, which may result in overly conservative designs.

In the 1990's, AASHTO became interested in developing a mechanistic-empirical pavement design procedure, and several research projects were conducted through the National Cooperative Highway Research Program (NCHRP) with this goal in mind. The outcome of these efforts was the MEPDG and AASHTOWare™ Pavement ME Design software, which became commercially available in 2013 (*3*,*4*). This new design approach represents a dramatic leap forward in pavement design and analysis. The procedure relies on sophisticated materials characterization, load characterization and climate modeling to simulate the response of pavement cross-sections under various conditions in a mechanistic-based model. The model predicts the pavement responses (e.g., stress and strain) from which empirical predictions of pavement performance (e.g., cracking, rutting, ride quality) are made through transfer functions. These transfer functions were developed and nationally calibrated based on in-service pavements obtained mostly from the Long Term Pavement Performance (LTPP) program. However, state specifications, practices, materials and climatic conditions vary across North America and can significantly affect pavement performance. These differences are not considered in the nationally calibrated transfer functions but through local calibration. Thus, AASHTO strongly recommends local calibration of these transfer functions prior to implementation.

Perpetual pavement design is also mechanistic-empirical with two important distinctions in design philosophy. First, the goal of perpetual design is to achieve long life with no deep structural distresses that would require costly deep structural repairs or reconstruction. In contrast, the methods described above generally result in pavements reaching a terminal distress condition at some predefined time. Second, perpetual design recognizes that all materials have

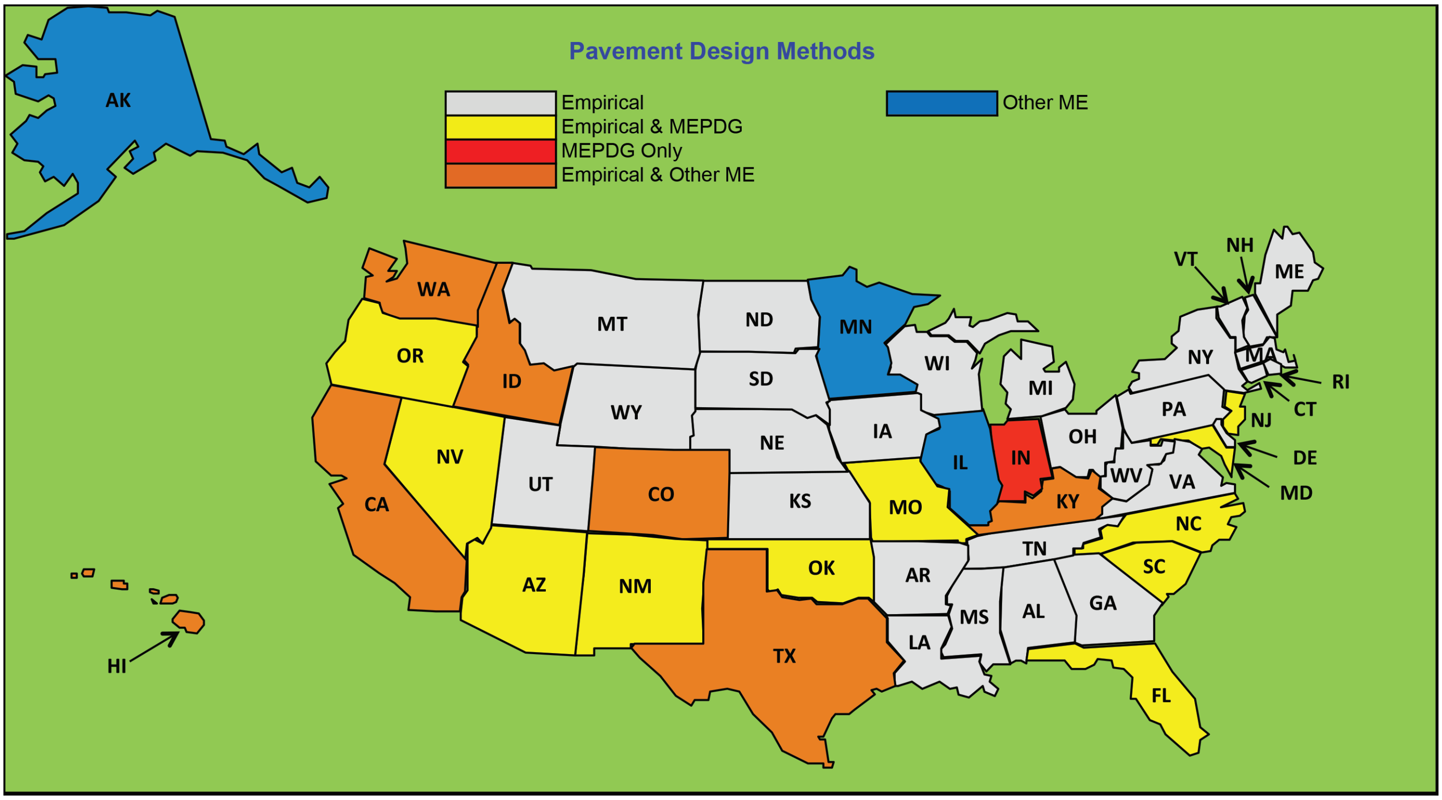

Figure 1 Pavement Design Methodologies by State (*data from 7*)

inherent endurance limits below which no damage will occur. Perpetual pavement design works toward determining layer thicknesses that will keep the materials below their respective endurance limits to prevent structural damage. The Pavement ME Design software can accommodate perpetual design, though other programs and procedures are available such as PerRoad and PerRoadXPress, the Illinois Department of Transportation (DOT) (*5*) and Texas DOT (*6*) procedures.

Asphalt Pavement Design in the U.S.

Twenty-eight states are currently using some form of empirically-based design, as shown in Figure 1. Eleven states have begun using both their pre-existing empirical method and the MEPDG while seven are using an empirical method along with some other form of M-E design.

A key input to the AASHTO empirical design procedure is the asphalt structural coefficient that describes the relative contribution of the asphalt layer to the overall pavement structure and is used to determine the required asphalt thickness. Currently, thirty-eight states use a value that is equal to or less than the value of 0.44 originally recommended by AASHTO in 1962. This means that all the advances made in the asphalt paving industry since then are not taken into account when determining the required thickness. Two states, Alabama and Washington, have recently revised their structural coefficients to reflect actual flexible pavement performance in their states. Alabama (*8*) increased its value to 0.54 while Washington (*9*) increased its value to 0.50, which translates to 18.5% and 12% thinner cross-sections, respectively.

Many states are working toward implementing the MEPDG to take advantage of the potential benefits M-E design offers. Figure 2 shows the results of a recent survey by Pierce and McGovern (*7*). Three states currently have the method implemented, while fourteen are working toward implementation in the next two years. Half the states expect to implement within the next two to five years with two states

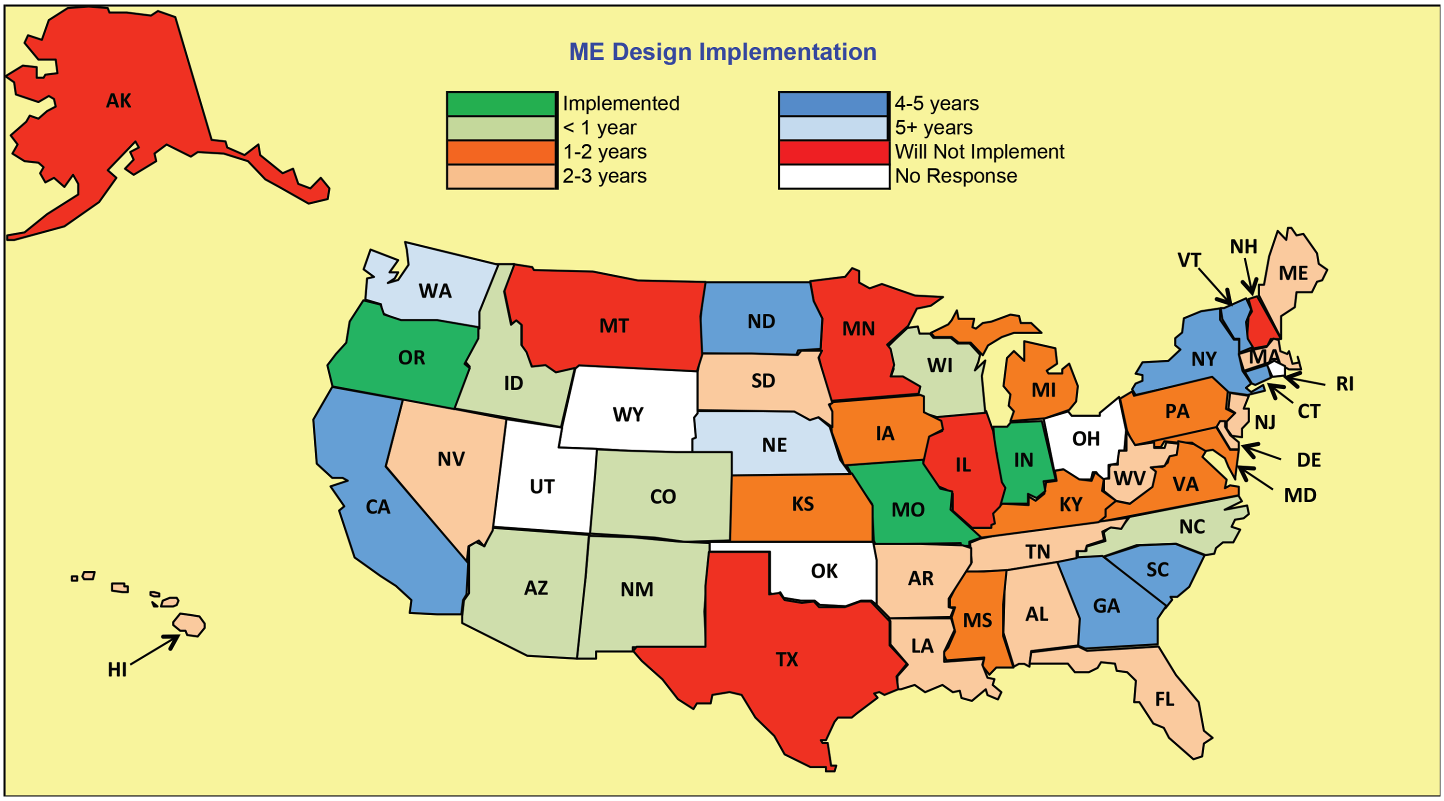

Figure 2 MEPDG and ME Design Software Implementation (*data from 7*)

projecting at least five years until implementation. Six states do not currently plan to implement the new design approach (*7*). It should be emphasized that these implementation plans are estimates from a single survey of state agencies and may certainly change as states progress further into the implementation process. Eleven states have begun transitioning from empirical to mechanistic-empirical where both methodologies are used concurrently, and one state (Indiana) uses the MEPDG approach exclusively. Two other states (Oregon and Missouri) have fully implemented the MEPDG but use it in combination with an empirical approach. Each of the fully-implemented states have documented their implementation process, and it is of note that each of them use a combination of local and national (default) input data and transfer function calibration factors in their design procedures.

Very few states have an established perpetual pavement design procedure. Illinois' procedure involves evaluating the pavement structure under the warmest conditions and designing for the heaviest expected load to find maximum pavement thickness (*5*). The approach in Texas is similar, using the flexible pavement system software to evaluate the pavement section under critical conditions to find the perpetual pavement thickness (*6*). Both states have published recommended design thicknesses for a range of conditions. Illinois ranges from 14 to 17 inches of full-depth asphalt concrete (*5*), while the Texas approach recommends at least 8 inches of aggregate base beneath 14 to 17 inches of asphalt concrete (*6*). The PerRoad and PerRoadXPress procedures are also available for perpetual pavement design, though they are not currently in widespread use by state agencies. These programs rely upon modeling the pavement variability and loading variation to determine the appropriate perpetual pavement cross-section given a set of input conditions.

Summary

M-E and perpetual pavement design, if implemented properly, have the potential to optimize pavement thickness design through the optimal use of materials. Many states are currently using the older empirically-based AASHTO method, though fourteen are expecting to implement the new M-E procedure in the next few years. Careful consideration of the transfer functions that includes verification, calibration and validation, is critical to successful implementation as recommended by AASHTO (*3*). Agencies may also consider provisions for perpetual pavement design approaches, either through the new AASHTO method or other various approaches, to achieve long-life, high-performing asphalt pavements. Finally, in situations where adopting M-E or perpetual pavement design is not feasible, agencies should consider re-evaluating the asphalt structural coefficient to take advantage of the vast improvements in asphalt materials engineering and construction practices since the original AASHO Road Test to achieve optimized designs through their existing procedures.

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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."