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PUTTING RESEARCH TO WORK

BRIEF

Predicting Low-Temperature Cracking in Asphalt Pavements

In Wisconsin's winter climate, low temperatures can cause asphalt pavements to contract and crack, reducing their ride quality and service lives. To help engineers more accurately determine how well certain pavement designs will fare in such conditions, AASHTO has developed the Mechanistic-Empirical Pavement Design Guide, or MEPDG. Pavement designers can use this manual and accompanying software to predict how pavement distresses will accumulate over time by inputting information about pavement materials, climate and expected traffic levels.

What's the Problem?

To use this methodology effectively, engineers must accurately establish certain properties of mixtures used in asphalt pavements so they can be used as inputs to the MEPDG. Three important inputs for predicting the susceptibility of pavements to cracking at low temperatures are creep compliance, or how a material deforms as it is subjected to a given stress; tensile strength, or the force required to break a material; and the coefficient of thermal contraction, or how a material changes in volume with changes in temperature. Research was needed to establish the value of these inputs for asphalt mixtures commonly used by WisDOT.

Research Objectives

The objective of this study was to evaluate the low-temperature creep compliance and tensile strength of asphalt mixtures commonly used in Wisconsin in order to recommend values for use with the MEPDG and suggest mixture specification changes if necessary. Researchers also evaluated methods for estimating the coefficient of thermal contraction.

Methodology

Researchers evaluated the low-temperature creep compliance and tensile strength of 16 asphalt mixtures commonly used in Wisconsin, with mixtures varying by:

- Aggregate source. The pit or quarry that served as the aggregate source was varied to evaluate the effects of aggregate mineralogy and differences in performance between the crushed rock or gravel used in a mixture.
- Aggregate gradation. This refers to the particle size distribution of the aggregate. Coarser and finer aggregates are blended together to achieve a gradation meeting specification requirements and affecting layer thickness.
- Design Traffic Loading: HMA mixture characteristics are selected for a certain traffic level, measured in equivalent single-axle loads from vehicles over a given period of time, or ESALs. A pavement with a design traffic level of E3 is expected to withstand up to 3 million ESALs in a 20-year projected service life.
- Binder performance grade. This gives the temperature range in which the asphalt cement that binds the aggregate particles together is expected to perform well. For example, under this grading system a binder with a performance grade of PG 58-34 is designed for use between –34 and 58 °C.

The mixtures used various combinations of four aggregate sources, mix designs for traffic levels E3 and E10, two RAP contents (0% and 25%), and four binder grades: (1) PG 58-34, (2) PG 58-28, (3) PG 58-34 with 25 percent binder replacement from recycled asphalt pavement, or RAP, and (4) PG 58-28 with 25 percent binder replacement from RAP.

To test the mixtures, researchers first conducted the indirect tensile test, which is used to measure creep compliance by applying a load to a cooled cylindrical specimen and measuring the resulting deformations. To measure tensile strength, the load is increased until the specimen fractures. Researchers

Investigator

"With this study, WisDOT now has a complete set of data representing a wide range of asphalt mixtures used in Wisconsin, which will allow the department to evaluate the use of the MEPDG to build more cost-effective pavements."

–Ramon Bonaquist
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The indirect tensile test uses a hydraulic system to apply a vertical load across the diameter of a cylindrical specimen of hardened asphalt. Sensors measure the resulting deformations for creep compliance and tensile strength.

measured creep compliance at –20, –10 and 0 °C, and tensile strength at –10 °C. They then compared the measured values to the MEPDG's default values, and evaluated two equations for predicting the coefficient of thermal contraction.

Results

The test results showed that Wisconsin mixtures and specifications do not require changes to improve low-temperature cracking performance, with aggregate source and design traffic level having a minimal impact on cracking.

However, the low temperature performance grades of binders had a significant effect on the creep compliance of mixtures. As the low temperature grade increased, so did thermal stresses, with the PG 58-34 binder having lower thermal stresses. Compared with those measured for PG 58-34, thermal stresses for the temperature range of –34 to –28 °C for the other binders were about 10 to 60 percent higher.

Using this data, researchers developed an equation to estimate the creep compliance of mixtures as a function of the low temperature grade of the binder. They also recommend a constant value for tensile strength, based on results at –10 °C, which did not significantly vary with low temperature binder grade, aggregate source or design traffic level. Finally, researchers estimated a value range for the coefficient of thermal contraction.

Benefits and Implementation

WisDOT can use the creep compliance and tensile strength values developed in this project to predict the low-temperature cracking of asphalt mixtures using the MEPDG, instead of using the software's less accurate default values. Using this information, WisDOT will continue to evaluate the use of MEPDG on projects by comparing its predictions for current pavements to their actual performance. If the MEPDG can be used to predict the service lives of pavements more accurately, engineers can design them to be more cost-effective and reliable.

Further Research

Researchers recommend further research to establish a more accurate value for the coefficient of thermal contraction, which will likely vary significantly with mixture composition and aggregate source. Moving forward, WisDOT plans to evaluate this and other thermal characteristics of mixtures for a wider range of aggregates currently being used in Wisconsin.

Project Manager

"This study shows that WisDOT's asphalt binder selection criteria are on target, and will also help us move forward in making practical use of the MEPDG in a way that will ultimately impact our specifications."

–Judie Ryan
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