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WISCONSIN DEPARTMENT OF TRANSPORTATION

PUTTING RESEARCH TO WORK

BRIEF

Identifying effects of concrete component variations using MEPDG

The Wisconsin Department of Transportation (WisDOT) is exploring implementation of the Mechanistic-Empirical Pavement Design Guide (MEPDG) for more efficient and cost effective concrete pavement designs. Factors influencing the behavior and durability of a pavement include site conditions, climate, traffic and material characteristics. These factors are integrated within a set of mechanistic and empirical models to obtain a prediction of the pavement's performance over the course of its design life. The empirical relations contained within the MEPDG provide alternative approaches to the selection of concrete modulus of rupture and modulus of elasticity for pavement distress and response calculations.

What's the problem?

The parameters required by the MEPDG for the prediction of new or reconstruction design of Jointed Plain Concrete Pavement (JPCP), Continuously Reinforced Concrete Pavement (CRCP) and Portland Cement Concrete (PCC) overlay include compressive strength, flexural strength, modulus of elasticity, indirect tensile strength, coefficient of thermal expansion, Poisson's ratio and unit weight. Performance of pavement with respect to type of concrete components is not well known.

Research Objective

This research evaluates the effects of different concrete component materials in Wisconsin on key concrete mechanical and thermal properties used in the MEPDG model. The researchers updated the MEPDG model empirical relationships from the results of comprehensive laboratory tests on concrete specimens made from aggregate and cementitious materials found in Wisconsin. The sensitivity of concrete pavement thickness with respect to change in type of concrete components was investigated.

Methodology

The research plan involved four main tasks:

Task 1: Evaluate prior research and reports regarding the MEPDG design process and the effects of the concrete constituents on design properties and relationships.

Task 2: Characterize the concrete component materials used. Testing included chemical composition, scanning electron microscope (SEM) analysis, particle size distribution (PSD), and X-ray diffraction (XRD) of all the cementitious materials, and Blaine fineness of the two Type I Portland cements. For the coarse and fine aggregates, testing included gradation, absorption and materials finer than the No. 200 sieve. The microfines of the coarse aggregates were also analyzed with PSD, XRD, reactivity, and leaching tests.

Task 3: Collect data from each mixing matrix designed to sufficiently reflect the effects of different concrete component materials on concrete mechanical and thermal properties.

Task 4: Evaluate the accuracy of the default empirical relationships in MEPDG for concrete mixed with Wisconsin materials.

For tasks 3 and 4, a total of 15 sources of coarse aggregates were selected to be mixed with one source of sand using each of the three different mix proportions: Type I ordinary Portland cement (OPC) only, OPC with slag cement, and OPC with fly ash composing 45 different mix designs. Five selected coarse aggregates were mixed with another source of cement, slag cement, fine aggregate and two different sources of fly ash composing 65 additional mixes. These materials were selected to represent a range of typical pavement design in the state of Wisconsin.

Investigator

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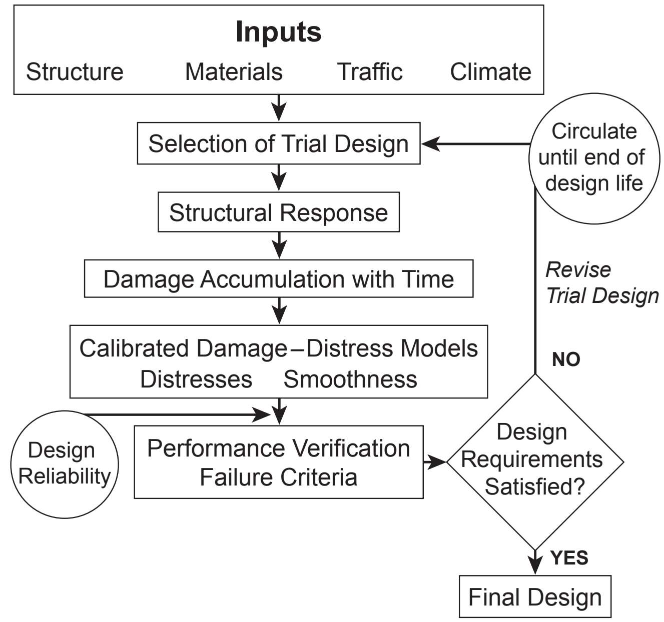


Mechanistic Empirical Pavement Design Guide procedure diagram

Results

The researchers found that the effects of changing concrete components on concrete properties vary with the amount and the type of each specific component changed. The type of coarse aggregate had the greatest effect on all concrete properties compared to the rest of the components changed in this study. However, the magnitude of that effect varied with each property. Coarse aggregate type affected concrete modulus of elasticity with much larger magnitude compared to other concrete properties. Modulus of rupture and splitting tensile strength were most significantly affected by changing cementitious material composition. Therefore, it was observed that the effect of cementitious material composition on concrete tensile strength associated with tensile failure was larger than its effect on other concrete properties not associated with tensile failure, including compressive strength, Poisson's ratio, dynamic modulus and coefficient of thermal expansion (CTE).

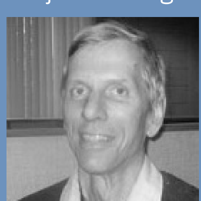
Researchers found pavement thickness varies with coarse aggregate source and the use of supplementary materials, especially slag, which improved pavement performance by decreasing the critical thickness required. For most cases, using different sources of Portland cement, slag cement, and fine aggregate did not have a large effect on the pavement thickness. The pavement's critical thickness varied with the source of fly ash. However, this effect was not as large as that associated with cementitious material type or coarse aggregate type.

Implementation

The researchers recommend replacing two new sets of empirical relations to correlate concrete compressive strength values to concrete modulus of rupture and modulus of elasticity values in the level 2 MEPDG model. One set of the relations are used for concrete mixed with granite and quartzite coarse aggregates and the other set for concrete mixed with dolomite, basalt and gabbro coarse aggregates.

The limitations on certain variables' ranges of the default empirical relations within MEPDG which prevent the software from running should be modified. The upper limit for the concrete's flexural strength unput in the MEPDG model is 950 psi. However, many concrete mixes have their 90-day flexural strength values greater than 950 psi within the research of this project. WisDOT will continue to examine MEPDG sensitivity to inputs as the MEPDG is implemented for concrete pavement design.

Project Manager



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This brief summarizes Project 0092-10-11, "Laboratory Study of Concrete Properties to Support Implementation of the new AASHTO Mechanistic-Empirical Pavement Design Guide."

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