Ahmed Shalaby

Thesis

Analytical and Experimental Investigation of Thermal Cracking in Asphalt Pavements

Abstract

The problem of thermal cracking in asphalt pavements is a serious concern in cold regions in Canada and the northern parts of the United States. This study involves the structural analysis of asphalt pavement systems and the prediction of pavement performance at low temperatures. The Strategic Highway Research Program, SHRP, has proposed new measures and concepts affecting asphalt technology. The shift towards performance based specifications of pavements resulted in a growing necessity for reliable performance models. At the present time, development of performance models for thermal cracking follows one of two approaches. The first is a phenomenological approach, in which the pavement response is represented by a mechanistic or empirical simplified formula, and therefore detailed material properties, the interaction between layers, or existing cracks cannot be simulated. On the other hand, the fracture mechanics approach utilizes a numerical method, such as the finite element method, to examine the propagation of a crack under a set of defined boundary conditions. In this thesis, a review of the state-of-the-art on prediction of thermal cracking and cracking mechanisms is presented. A novel approach for the analysis of asphalt pavements behaviour at low temperatures is demonstrated. Based on the fracture mechanics approach, a finite element analysis for the transient thermal field and corresponding stress field is performed. Different crack configurations and multiple cracks are considered. The results are used to evaluate the cracking potential for a wide range of transverse cracks. An experimental program is implemented to determine the material parameters required for the numerical analysis. The direct tensile test, tensile fatigue and repeated tensile strain test are used, and damage indicators are obtained at three test temperatures. Advanced reliability methods are used to extend an existing thermal cracking prediction model. A sensitivity analysis of the improved model is used to determine the effect of each parameter on the extent of cracking. The model is applied to field data in order to verify its predictive abilities. The results of the finite elements analysis, the developed laboratory test methods and the prediction model are useful fools for defining the factors and mechanisms causing thermal cracking. The thesis presents three methods of examining thermal cracking at three different levels. While, the analytical approach is applicable to the study of specific cracks with known geometry and boundary conditions, the experimental approach is suitable for exploring project-level alternatives. The reliability-based model can be used at network-level for decision making and prediction of thermal cracking.

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Supervisors

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