Project Summary
Texas Department of Transportation

0-1700: Improving Portland Cement Concrete Pavement Performance

Background

Both directly and through sponsored research, the Texas Department of Transportation (TxDOT) has been monitoring the condition of the state's rigid pavements for more than 30 years. Thanks to that effort, it is now well established that portland cement concrete (PCC) pavements will provide 25-50 years of service on high-volume roadways with minimum maintenance if designed and built correctly. However, it is also equally clear that some PCC pavements have suffered a high rate of failure development for various reasons, causing them to fail far short of their design life. Unfortunately, despite all the efforts made in the past to address premature failures, they still take place in some PCC pavements, resulting in unnecessary expense and inconvenience to the traveling public.

Much work has been done over the past decades to determine the causes for these premature failures. What had to be done to prevent or minimize premature pavement failures was to conduct an in-depth study for the causes of premature pavement failures and develop a comprehensive array of recommendations for TxDOT's implementation.

What the Researchers Did

The study developed mitigation techniques to control the in-place temperature development of early-age concrete. A general hydration model for cementitious materials and a model to predict the temperature gain in hardening concrete were developed and calibrated for field conditions with data collected from seven concrete paving projects. The effects of concrete temperature, different cements, and mineral admixtures on the initial and final setting times were characterized.

Mathematical models were developed for the calculation of moisture and temperature profiles to help investigate the effect of different combinations of climate, construction, and materials on the development of the moisture and temperature profiles and their subsequent effects on early-age cracking.

The sensitivity of the design variables to the behavior of continuously reinforced concrete pavement (CRCP) has been investigated using mechanistic models of CRCP. The practical ranges of the design variables have been selected and the typical values of the variables have been determined.

The effect of early opening to traffic on the life of portland cement concrete pavement systems was evaluated using experiments and mathematical models. A series of laboratory fatigue tests was performed to develop appropriate fatigue relationships for TxDOT's typical Class P concrete.

After completion of the laboratory testing, accelerated fatigue tests on full-scale concrete slabs were performed under constant cyclic loading. An analytical linear damage model for the prediction of the loss of life of a PCC pavement due to early opening was developed and examined.

Research Performed by:

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What They Found

Longer-lasting PCC pavements will be produced if the assumptions made during pavement design development are achieved in the field. The temperature prediction model will enable the development of performance-based specifications to guard against premature concrete failures.

The calculated moisture and temperature profiles using the moisture diffusivity and thermal conductivity models correspond to the measured data. Spalling distress is strongly correlated with pre-existing horizontal delaminations that occur within 1 inch. of the pavement surface. The cause of these shallow horizontal delaminations is primarily early-age nonlinear shrinkage strains in addition to temperature variations through slab depth.

The relationships between the design variables and the CRCP behavior have been obtained from the sensitivity analysis of the CRCP computer program. The zero-stress temperature and the coefficient of thermal expansion of concrete are the most sensitive design or materials variables, and the steel bar diameter and the stiffness of underlying layers are the least sensitive variables.

The concept of equivalent fatigue life was applied to correct the effect of the different stress ratios between field and laboratory testing. The laboratory beams and full-scale field slabs showed an almost identical fatigue relationship after the correction for the variance of stress ratio.

What This Means

The developed temperature prediction model will further provide the designer, contractor, and specification developer with the means to evaluate and quantify the effect of most of the various complex interactions that affect the concrete temperature development during early ages. This model was further validated in a subsequent implementation project, and shadow specifications developed and applied to a TxDOT paving project. The specifications could be implemented to TxDOT's CRCP construction projects.

The important factors responsible for spalling are those related to the effectiveness of the curing medium in minimizing moisture loss during the hydration of the concrete and the bond strength between the aggregate and the paste. By increasing the effectiveness of the curing system, moisture gradients near the surface are substantially reduced and delamination stresses and spalling potential minimized.

Further studies for the CRCP computer program including field experiments should be conducted to identify the actual steel stresses. The mechanistic models should be calibrated and validated with field data. The additional fieldwork to calibrate/validate the CRCP-10 will also increase its acceptance by pavement engineers.

The current opening criteria used by TxDOT appear to be reasonable based on the sensitivity analysis results. Therefore, it is also recommended that no modifications be made to the current specifications on early opening to traffic.

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