



# *Project Summary*

*Texas Department of Transportation*

## 0-5549: Horizontal Cracking in Concrete Pavements

### *Background*

In continuously reinforced concrete pavement (CRCP), transverse and longitudinal cracks were the only types of cracks known to exist. Proper design and construction techniques and features were developed to make transverse cracks harmless and to keep longitudinal cracks from developing. In 1999, a different type of cracking in CRCP was observed on IH 35 in Hillsboro in the Waco District. At that time, a CRCP section was under construction and being evaluated due to curing-related issues. During the pavement evaluation, horizontal cracking (HC) was observed at the depth of the longitudinal steel. At that time, HC was not known to exist in CRCP. Since the section was still under construction and not open to traffic except for occasional construction traffic, it was considered that HC was caused by environmental loading (temperature and moisture variations) only, not by wheel loading. What was not known at that time was whether HC would eventually develop into distress, and if it did, how long it would take before distress developed. This research study was initiated to investigate the causes and mechanisms of HC and what needs to be done to prevent or minimize HC in CRCP.

### *What the Researchers Did*

To identify the causes and mechanisms of HC in CRCP, a numerical model was developed first to investigate the behavior of CRCP under environmental loading. The stress distribution of concrete at the depth of steel, where the horizontal crack generally occurs, was analyzed in the model. Laboratory and field testing were performed, where the results from the developed numerical model were validated with testing results. The variations of strain in concrete during temperature changes were measured and compared with those from the numerical analysis. The development of vertical stress in concrete near the steel was also measured and compared. The accuracy of the numerical modeling was confirmed and a factorial experiment was developed for a comprehensive numerical analyses to assess the HC potential for the factors related to the materials, design and construction of CRCP. The variables included in the factorial experiment were concrete material properties (coefficient of thermal expansion (CTE), modulus of elasticity), steel design variables (longitudinal steel amount, number of steel layer), and construction variables (curing effectiveness, temperature variations through the slab depth and consolidation of concrete).

#### *Research Performed by:*

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## What They Found

HC in CRCP is caused by vertical stress in concrete at the depth of longitudinal steel. HC potential was evaluated in terms of the effect of each variable on the vertical stress.

### Concrete Material Properties:

- Concrete CTE: CTE has consistent effects on HC potential; the larger the CTE, the greater the potential for HC, even though the effects are dependent on the level of other input variables.
- Effect of concrete modulus of elasticity: Higher modulus of elasticity in concrete results in larger vertical stress in concrete, and thus increases the potential for HC.

### Steel Design Variables:

- Longitudinal steel amount: As more longitudinal steel is used, the potential for HC increases. However, this could mislead in that, as the longitudinal steel amount increases, crack spacing decreases and concrete vertical stress is reduced. It should be kept in mind that in this analysis, constant crack spacing was used.
- Number of steel layer: Currently, TxDOT requires the use of two-mat steel when the slab thickness is greater than 13 inches. In all combinations of inputs investigated in this study, two-mat steel results in lower concrete vertical stress and HC potential.

### Construction Variable:

- Curing effectiveness and temperature variations through slab depth: In this study, curing effectiveness was incorporated in terms of temperature variations through slab depth. In general, a larger degree of nonlinearity of temperature gradient results in higher concrete vertical stress and consequently, a higher potential for HC.
- Consolidation of concrete: Since HC potential increases as concrete tensile strength decreases at the depth of longitudinal steel, proper consolidation of concrete at the depth of longitudinal steel is important.

## What This Means

HC potential in CRCP depends on pavement design, materials, and construction practice. To minimize HC in CRCP, best practices should be exercised in these three areas. The most efficient way to promote best practices is the development of guidelines and their implementation. Guidelines were developed from this research to encompass the three areas – pavement design (steel design), selection of concrete materials, and construction quality. The implementation of these guidelines is expected to minimize the occurrence of HC in CRCP.

### For More Information:

0-5549-1 Horizontal Cracking in Portland Cement Concrete Pavements: Literature Review

0-5549-2 Horizontal Cracking Mechanism in CRCP

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