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#### RESEARCH PROJECT TITLE

Prevention of Longitudinal Cracking in Iowa Widened Concrete Pavement

#### SPONSORS

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The Program for Sustainable Pavement Engineering and Research (PROSPER) is part of the Institute for Transportation (InTrans) at Iowa State University. The overall goal of PROSPER is to advance research, education, and technology transfer in the area of sustainable highway and airport pavement infrastructure systems.

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# Prevention of Longitudinal Cracking in Iowa Widened Concrete Pavement

tech transfer summary

This study examined the factors contributing to the longitudinal cracking observed in the widened jointed plain concrete pavements (JPCPs) that Iowa has used since the 1990s and provides recommendations for preventing its occurrence.

## Background and Problem Statement

Over the past 10 to 15 years, Iowa has used 14 ft widened concrete slabs (as opposed to the standard 12 ft wide slabs) in jointed plain concrete pavement (JPCP). The wider slabs are intended to reduce stresses and deflections at the critical concrete pavement edges, reduce shoulder maintenance costs, and minimize the exposure of maintenance crews on high-volume roadways.

Many widened concrete pavements in Iowa are approaching 20 years of service life, and some are experiencing sudden occurrences of significant longitudinal cracking within 2 to 3 ft from the pavement edges.

Field observations have indicated that random longitudinal cracks in widened JPCPs typically start as 4 to 6 in. long cracks from the joint but eventually grow in degree and severity. Additionally, these cracks appear not at saw cut locations but at unexpected locations, resulting in random cracking, especially during early ages.

This distress pattern has never been reported before in Iowa, and an investigative study was needed to better understand the causes of this distress pattern. Although there is strong evidence for the occurrence of random longitudinal cracking in JPCPs in many states, few studies have documented the causative factors and prevention or mitigation strategies.



*Longitudinal cracking observed in widened concrete pavement with a skewed transverse joint on US-65 in Polk County, Iowa*

## Objectives

- Conduct a field investigation to survey longitudinal cracking in widened JPCP in Iowa
- Identify the causes of longitudinal cracking in widened JPCP in Iowa
- Perform finite element analyses (FEA) to simulate the responses of widened JPCP to axle loads under various temperature gradients
- Develop recommendations for widened JPCP design features and construction practices to prevent and minimize longitudinal cracking

## Research Description

### Field Investigation

Field surveys were performed in 2017 at 12 existing sites in Iowa, including 4 control sites and 8 other sites undergoing different levels of longitudinal cracking. These sites represent widened concrete pavements of various ages, mix design aspects, construction conditions, shoulder types, and traffic levels.

Slab geometry was checked, and existing longitudinal and other types of cracking were also documented. The extent and pattern of longitudinal cracking were linked to pavement age, mix design aspects, construction conditions, and traffic levels to determine potential factors contributing to the cracking.

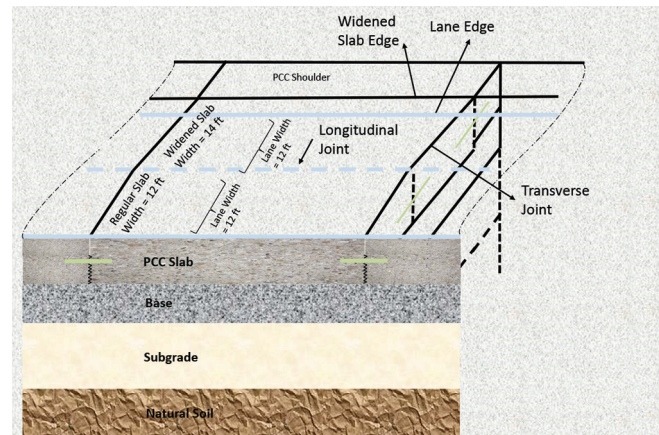
Concrete core samples were taken by Iowa Department of Transportation (DOT) crews at six of the longitudinal cracking locations.



*Longitudinal cracking observed on IA-163 with widened slabs in Mahaska County, Iowa*

### Numerical Modeling

Numerical analysis using ISLAB2005 and EverFE 2.25 FEA software was conducted to understand the underlying mechanisms of longitudinal cracking failures in JPCP. A typical Iowa widened JPCP slab was modeled using a six-slab setup (three widened slabs in the traffic direction and three regular slabs adjacent to the widened slabs).



*Finite element model definitions*

Numerical modeling analyses were conducted for four cases:

- Case 1 study: single axle load simulations using ISLAB 2005 to understand critical loading cases, including both mechanical and temperature loading, that increase longitudinal cracking potential
- Case 2 study: truck load simulations using ISLAB 2005 to simulate longitudinal crack initiation on transverse joints
- Case 3 study: skewed joint simulations using EverFE 2.25 to compare the effects of rectangular and skewed joints on longitudinal cracking potential
- Case 4 study: simulation of shoulder design alternatives using ISLAB 2005 to compare different paved (tied PCC and hot mix asphalt [HMA]) and granular shoulder alternatives in terms of their contributions to mitigating longitudinal cracking potential

## Key Findings

### Field Investigation

- Longitudinal cracks occurred mainly in the traffic lane about 2 to 4 ft away from the slab edge parallel to traffic direction, and some arc-shaped longitudinal cracks were also observed.
- Most observed longitudinal cracks were initiated from slab joints
- A few low-severity longitudinal cracks were found at one control site and no longitudinal cracks were observed at a different control site even though both sites experienced relatively higher traffic volumes. Both sites have tied PCC shoulders.
- Sites with tied PCC shoulders performed better than sites with HMA and granular shoulders in terms of the observed level of longitudinal cracking.
- Concrete core samples indicated top-down longitudinal cracking.

## Numerical Modeling

- Top-down longitudinal cracking potential for JPCP with widened slabs was demonstrated consistently, and longitudinal cracks were initiated from the transverse joints between the lane edge and wheel path. Longitudinal cracking potential increased with a higher negative temperature gradient.
- Skewed jointed widened slabs have greater potential for developing longitudinal cracking than rectangular joints.
- Higher (1) top-to-bottom tensile stress ratios and (2) top tensile stresses were observed when a widened slab (14 ft wide) with a tied PCC shoulder alternative was used than when a regular slab (12 ft wide) with a full-depth tied PCC shoulder was used.
- Higher top-to-bottom tensile stress ratios were observed when a regular size slab (12 ft wide) with a HMA or granular shoulder was used than when a widened slab (14 ft wide) with a HMA or granular shoulder was used.

## Recommendations

- Shorter joint spacing can result in reduced curling and warping and possibly offer less of a chance for longitudinal cracking.
- Dowel bars can restrain vertical deflection at joints, so proper dowel bar installation will help mitigate longitudinal cracking because most longitudinal cracks were observed to start from slab transverse joints.
- Use of rectangular joint design instead of a skewed joint design is recommended.
- A tied PCC shoulder can perform better than other shoulder alternatives. Additionally, a regular slab (12 ft wide) with a full-depth tied PCC shoulder rather than a widened slab (14 ft wide) with a full-depth tied PCC shoulder is recommended.
- A width-to-thickness ratio of 1.2 (12 in. thickness) to 1.5 (9.5 in. thickness) should be used to minimize the severity and extent of cracking for 14 ft widened slabs.
- Increased coarse aggregate content, use of aggregates with a low coefficient of thermal expansion, a moderate water/cement ratio, and proper curing can lessen the potential for longitudinal cracking.
- Paving at night or in late fall could help reduce the potential for longitudinal cracking, and paving during cloudy weather is preferred because less solar radiation results in less built-in curling.

## Future Research

Based on the findings from this study, the project Technical Advisory Committee (TAC) and the Iowa DOT recommended an expanded Phase II study to address the following additional research needs:

- Identify and evaluate the effectiveness of various JPCP and shoulder design options, including current Iowa highway and county road practices for preventing longitudinal cracking, through three concurrent research efforts:
  1. Numerical investigation through finite element modeling
  2. Field implementation, instrumentation, and monitoring for a set of test sections, including regular size (12 ft wide) slabs with full-depth tied PCC shoulders and current Iowa widened JPCPs
  3. Forensic evaluations of Iowa highway and county concrete pavements with longitudinal cracking problems
- Understand the mechanisms of longitudinal cracking failures and quantify longitudinal cracking potential for various JPCP design options, including current Iowa practices
- Evaluate the effectiveness of different JPCP design features and shoulder design options through real field implementation projects
- Identify the causes of longitudinal cracking in Iowa county concrete pavements
- Evaluate the in situ performance of rectangular slabs utilized in Iowa widened JPCP construction since 2005
- Develop implementation recommendations for the Iowa DOT, Iowa counties, and contractors for preventing and repairing longitudinal cracking on Iowa's concrete pavements
- Identify rehabilitation options for portland cement concrete slabs suffering from longitudinal cracking
- Conduct economic analyses for various JPCP and shoulder design options that are used to prevent longitudinal cracking



## Implementation Readiness and Benefits

The results from this study will benefit the Iowa DOT and local highway agencies by providing information on how to prevent or minimize longitudinal cracking as they plan for and build long-lasting concrete pavements.

Most of the sites with longitudinal cracking observed during the field investigations were built with skewed

joints before 2000, so they were approaching 20 years of service life. A follow-up study using a larger number of sites is needed to evaluate the performance of widened JPCPs in Iowa with rectangular joints (most constructed after 2005) and to verify the effectiveness of these design features in preventing or minimizing longitudinal cracking.