PUTTING RESEARCH TO WORK

BRIEF

Strategies to Prevent Early Concrete Joint Distress

During the 1991 through 1993 construction seasons, a 15-mile section of jointed plain concrete was constructed on Interstate 90/94 near Wisconsin Dells. The section featured randomly spaced, skewed joints on slabs as long as 20 feet and a 12-inch layer of doweled portland cement concrete over a 4-inch layer of open-graded base course. In 1998 a WisDOT report on early distress at the site identified cracking in panels, especially at corners; loose chunks of concrete; and potholes where pulverized concrete was being pumped up to the surface after rainfalls.

What's the Problem?

Expected life spans for concrete pavement are measured in decades, so serious damage after only five or six years is unusual. The types of distress that developed in this section were also unusual, particularly corner cracking, which is atypical for layers this thick. Examination of slabs removed during rehabilitation showed corroded dowels with epoxy coating worn away and delamination in the slabs at the dowel line, separating portions of the concrete into two layers.

An internal WisDOT technical group identified a number of factors that could have contributed to the pavement's susceptibility to damage, including the use of open-graded base course, long panels and skewed joints in the pavement's design. Clogged drains and poor concrete consolidation were also identified as potential contributors. WisDOT initiated this study to confirm the design and construction factors that likely contributed to the pavement distress.

Research Objectives and Methodology

This project pursued three primary objectives. Investigators sought to:

- Investigate distress through field observations and methods such as finite-element modeling.
- Identify maintenance or restoration activities to prevent or slow distress.
- Review WisDOT design standards and specifications and suggest changes as necessary to prevent distress.

To achieve these objectives, researchers took the following steps:

- Reviewed information provided by WisDOT, the Wisconsin Concrete Pavement Association and Marquette University, including photographs, deflection and profile data, and test results.
- In August 2006, observed rehabilitation of damaged pavement in the field and inspected removed slabs at a refuse yard.
- Employed finite-element methods to model pavement sensitivity to parameters that were considered likely contributors to distress, including slab length, joint skewness and strain gradients.
- Identified probable factors in poor pavement performance.
- Developed recommendations for maintenance and repair.
- Reviewed design standards and specifications, and recommended changes to prevent similar poor performance.

Results

Based on forensic investigation and modeling, researchers identified several factors that likely contributed to the distress. Analysis suggested that acute joint angles, curling and unstable base support led to weakness at slab corners, higher than normal deflections in the slabs, and high stress concentrations at the dowels and slab corners. Primary factors contributing to this distress included:

- Skewed joints, which increase corner stress, deflection, curling and warping effects, and dowel bearing stress during loading.

Investigator

"WisDOT has already turned back to square joints, shortened its panels, and gone to more stable base courses. All of these changes will minimize the chance of this unique distress happening again."

–Robert Rasmussen
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This project identified the causes of premature corner cracking and pumping of pulverized concrete, left, on a section of I-90/94. A significant number of dowels from this section showed corrosion and loss of epoxy coating, right, reducing their effectiveness at transferring loads (Fig. 12 of the final report).

- Long panels of over 16 feet, which induce higher slab stresses and lower load transfer over wider joints.
- Open-graded base course, which provides little shear strength, poor support at slab corners and poor drainage, as well as an unstable construction platform.
- Dowel size and spacing. Dowels contribute to a cantilever effect during warping and curling, transferring loads between slabs and creating a prying effect of one slab upon another. This suggests a need for fewer dowels or wider spacing, as well as smaller dowel sizes. Larger dowels create larger voids at joints and increase susceptibility to damage.

Researchers' recommendations included reducing slab length, revising dowel size and placement specifications, targeting concrete strength to 28-day values (the level of compression strength achieved after 28 days of curing), controlling the temperature of mixes during construction, revising curing methods and timing, and using coarse aggregates with lower thermal coefficients of expansion.

Effective repair methods were limited to the standard practices of cutting and replacing damaged slabs. Maintenance included regular drain cleaning, which WisDOT practices.

Benefits

Researchers expect that the design recommendations resulting from this project will prevent similar premature stress in concrete pavements. Durable, long-lasting pavements will result, and early rehabilitation will remain an anomaly.

Implementation and Further Research

WisDOT has already discontinued three of the four major design practices that influenced the premature distress of this roadway. The department no longer employs the open-graded base course used in this construction, instead using a finer grade of aggregate for bases. Panel length was reduced to 15 feet in 2006, and designers now specify perpendicular joints that create no acute angles.

Several of this project's findings may warrant further research. Related research topics include temperature control of mixes, curing temperatures and techniques, and use of coarse aggregate with low thermal coefficients of expansion. Investigators also recommended that WisDOT continue to gather deflection and profile data for concrete pavement similar to the section studied in this project.

Dowel size and spacing has drawn considerable national interest in recent years, and the potential to reduce dowel diameters to 1 inch or less, as well as identify optimal placement and spacing—such as in wheel paths of truck lanes—may be considered in future research.

This brief summarizes Project 0092-05-05, "Analysis of Concrete Pavement Joints to Predict the Onset of Distress," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

Nikki Hatch, WisDOT Research and Communication Services

Rigid Pavements TOC Chair

"This research gave us analytical confirmation of the failure mechanisms in this stretch of highway. The findings were in line with what we suspected."

–James Parry
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