The Ohio Department of Transportation
Office of Research & Development
Executive Summary Report

Truck/Pavement/Economic Modeling and In-Situ Field Test Data Analysis Applications Volume 4: Effects of Slab Shape and Load Transfer Mechanisms on Portland Cement Concrete Pavement

Start date: February 9, 2001

Duration: 76 months

Completion Date: August 9, 2007

Report Date: September 2007

State Job Number: 147700-SP2(203)

Report Number: FHWA/OH-2006/3D

Funding: $682,774

Principal Investigator:
Shad M. Sargand

ODOT Contacts:
Technical:
Roger Green

Administrative:
Monique R. Evans, P.E.
Administrator, R & D
614-728-6048

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or call 614-644-8173

Ohio Department of Transportation
1980 West Broad Street
Columbus OH 43223

Problem

Environmental factors have a major impact on both the initial response and long term performance of Portland Cement Concrete (PCC) pavements. Past research has shown the significant influence environmental factors have on the longevity of PCC pavement. However, additional research is needed to determine how to incorporate environmental factors into the PCC design process.

Additionally, the transfer of load from slab to slab by the use of dowel bars is critical for maintaining the quality of PCC pavement. The importance of this dynamic effect has long been recognized, but additional research is needed to determine the most effective dowel bar configuration.

The New York State Department of Transportation constructed test sections in Interstate 490 near Rochester, New York with the objective of evaluating the effects of environmental factors and dynamic loading on PCC pavements. This report describes the research methods used and the results obtained from this study of environmental and dynamic effects on the PCC pavement.

Objectives

In order to increase the research-based knowledge on the dynamic and environmental effects on PCC pavement and on dowel bar diameter and spacing, the objectives for this project were:

- Present descriptions of pavement instrumentation and data acquisition systems for measuring environmental and dynamic effects on PCC pavement sections.
- Evaluate the loss of support for PCC during the curing process and service.
- Investigate the effect of three variations of dowel bar diameter and spacing on load transfer efficiency (LTE) and pavement performance.

- Recommend layout design for dowel bars in transverse joints.
- Determine the environmental and dynamic effects on the pavement

Description

This test pavement was located on I-490, approximately 16 km (10 mi) south-east of Rochester, New York including both the eastbound and westbound lanes. The jointed plain concrete pavement (JPCP) slab dimensions were 5 m (16.4 ft) long, 4.60 m (15.0 ft) wide, and 250 mm (10 in) thick and made of NYSDOT Class C mix. The slabs rested on a 75 mm (3 in) thick permeable concrete treated base on top of a 300 mm (11.8 in) thick aggregate base. The two 4.27 m (14.0 ft) wide traffic lanes were constructed first, with the 3.6 m (11.8 ft) exit ramp lane and 3.0 m (9.8 ft) concrete shoulders installed later. The typical dowel bar spacing was 305 mm (12 in) on center, with a dowel bar diameter of 32 mm (1.25 in). The eastbound dowel bar diameters and spacings were varied as part of this study: the standard (STD) configuration used size 32 bars spaced 300 mm (11.8 in) apart, the E1 configuration used size 28 bars spaced 240 mm (9.45 in) apart, and the E2 configuration used size 25 bars spaced 190 mm (7.48 in) apart.

The westbound sections were instrumented with LVDTs to measure slab displacement, thermocouples to measure slab temperature, and vibrating wire strain gages to measure strains in the slab. The strain gages had built-in thermistors and air temperatures were also measured using a temperature probe.

Data were taken from the instruments at the time of construction, and at 37 days (after curing), 12 months, 16 months, and 28 months after construction. In addition to instrumentation readings taken over an approximately 24-hour period, each visit included slab shape measurements made with a Dipstick®, and deflections measured with a falling weight deflectometer (FWD) on the westbound sections. The final data collection visit, in October 2004, also included FWD testing and profilometer measurements on the eastbound sections.

Conclusions

PCC Pavement: A significant component of the loss of support observed in this pavement is built-in curling. The resulting loss of support may lead to top-down cracking in the pavement when a heavy load, such as a truck, runs over the inadequately supported area, providing additional tensile stress. The observed loss of support due to built-in curling is so significant that even with the most favorable temperature gradients observed, the pavement will not come into complete contact with the base.

The loss of support measurements based on the LVDTs at selected temperature gradients were validated by the FWD measurements taken during the same visit. The deflection due to load, such as that measured from the FWD, was significantly smaller than that resulting from environmental factors. A realistic and rational design approach for rigid pavement must account for the environmental factors that cause warping and curling and the resulting loss of support and top-down cracking.

Dowel Bars: Throughout the testing period the E2 slabs, with the smallest dowel bar diameter, narrowest spacing, and least proportion of steel in the slab cross section, warped and curled the least.

After the air temperature rose and the pavement gradient became positive, the LTEs were about the same, with the E2 sections having highest LTE. However the E1 sections had lower load deflections. In this state the slab experiences less loss of support and improved load transfer due to aggregate interlock.

One could conclude that dowel bars play a key role in controlling the loss of support as well as assisting in load transfer. This research suggests that the E2 configuration will perform better and result in better slab support than the STD configuration.

Implementation Potential

New York should design rigid pavements taking into account the mechanisms causing loss of support and top-down cracking. The resulting design process can then be validated via the Mechanistic-Empirical design process. A number of smaller equally-spaced dowel bars, such as the E2 configuration, should result in improved performance of rigid pavements.