



May 2019

RESEARCH PROJECT TITLE

Concrete Overlay Performance on Iowa's Roadways Phase 2B: Optimized Joint Spacing for Concrete Overlays with and without Structural Fiber Reinforcement – Field Demonstration and Verification

SPONSORS

Iowa Highway Research Board
(IHRB Project TR-698)
Iowa Department of Transportation
(InTrans Project 15-559)

PRINCIPAL INVESTIGATOR

Peter Taylor, Director
National Concrete Pavement Technology
Center, Iowa State University
515-294-9333 / ptaylor@iastate.edu
(orcid.org/0000-0002-4030-1727)

MORE INFORMATION

cptechcenter.org

National CP Tech Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-3230

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Optimized Joint Spacing for Concrete Overlays with and without Structural Fiber Reinforcement

tech transfer summary

Optimum joint spacing design for concrete overlays may need to be determined based on factors different from those that are currently considered.

Problem Statement

In thin concrete overlays (4-inch to 6-inch), field observations have sometimes shown that not all contraction joints activate initially and, in some cases, do not activate until many years after construction. Contraction joints that do not activate may be considered an inefficient design that leads to unnecessary maintenance efforts, unnecessary costs, and negative impacts on concrete overlay performance.

Objective

The objective of this study was to determine the optimum joint spacing for thin concrete overlays based on traffic loading, concrete overlay thickness, support system, presence of fibers, and concrete overlay types.

Work Plan

In the beginning of the study, an analytical investigation was performed using pavement design software (AASHTOWare Pavement ME and BCOA-ME) to analyze the impact of joint spacing on predicted concrete overlay performance. From there, field reviews were performed using nondestructive testing to measure joint activation in existing concrete overlays.



Joint activation data being collected on an existing overlay in Worth County, Iowa using a MIRA device placed over the sawcuts

Finally, new test sections were constructed in conjunction with new concrete overlay projects to analyze a wider range of variables and study early-age joint activation behavior. The parameters of study included overlay thickness, joint spacing, and use of structural macro-fibers (4 lb/yd³) within bonded concrete overlays on asphalt (BCOAs) and unbonded concrete overlays on concrete (UBCOCs).



Mitchell County test section construction showing addition of fibers at the batch plant and overlay paving

Key Findings

The analytical investigation using the American Association of State Highway and Transportation Officials' AASHTOWare pavement mechanistic-empirical (ME) design and the University of Pittsburgh's bonded concrete overlay of asphalt-ME (BCOA-ME) design procedure have shown the following:

- A thin concrete overlay on an existing asphalt pavement is predicted to serve longer before reaching the established International roughness index (IRI) performance threshold than an unbonded concrete overlay on an existing concrete pavement.
- The predicted IRI performance of 4-inch to 6-inch thick concrete overlays is very similar for 12-foot to 20-foot transverse joint spacing.
- The IRI outputs based on a 50% reliability parameter are similar to data from Iowa concrete overlays (Gross et al. 2017).
- Using BCOA-ME, for the same set of design parameters, a shorter joint spacing design provides better performance than longer joint spacing designs and potentially allows a reduction in thickness. Conversely, when increasing the joint spacing design from 6-foot to 12-foot/15-foot, additional thickness may be required to handle the same amount of traffic.

Field reviews were performed using MIRA ultrasonic shear-wave tomography on existing 4-inch to 6-inch concrete overlays. The results of the nondestructive testing demonstrated the following:

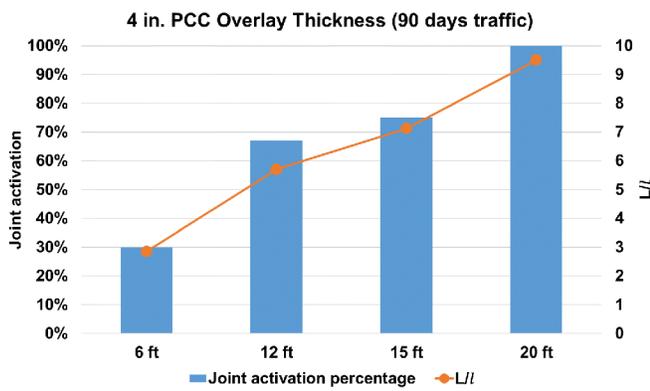
- Observed joint activation did not vary based on overlay type (BCOA vs. UBCOC).
- Holding other variables constant, concrete overlays with longer joint spacing exhibited increased percentages of joint activation.
- Holding other variables constant, concrete overlays with greater thickness exhibited increased percentages of joint activation.
- Joint activation did not vary with traffic volumes.
- Un-activated joints were mostly confined to short slab sections that were 10 years old or younger.
- In concrete overlays with >6-inch thickness and >12-foot joint spacing, activation rates were high, often approaching 100%. Rates were lower in overlays that were thinner and had shorter joint spacing, often falling in the range of 60–80%.



MIRA ultrasonic shear-wave tomography device being used to collect joint activation data

Testing of newly-constructed concrete overlay test sections indicated the following:

- Joint spacing was the predominant factor affecting joint activation behavior. Greater joint spacing led to more rapid development and a higher ultimate rate of joint activation.
- Within the first two years of service life, in both Mitchell and Buchanan Counties, test sections with conventional joint spacings achieved near 100% joint activation. Un-activated joints were confined mainly to short slabs.
- The ratio of slab length to radius of relative stiffness, L/ℓ , appears to be a good indicator for joint activation behavior and can be used to help optimize joint spacing design for concrete overlays.



Joint activation vs. L/l and joint spacing for Mitchell County concrete overlay test sections

- Designing joint spacing to achieve L/l between 4 and 7 may provide the desired balance between maximum, timely joint activation and good overlay performance.
- For short slab test sections in Mitchell County, thinner overlays demonstrated slightly slower joint activation rates than thicker overlays. However, these effects were not as significant as those observed with joint spacing, and ultimate rates of joint activation achieved by April 2019 were similar for both thicknesses.
- Fiber-reinforcement at 4 lb/yd³ and overlay type did not have significant effects on joint activation behavior.

Implementation Readiness and Benefits

The results of this study are beneficial to the Iowa Department of Transportation (DOT) and local agencies. The results appear to show a correlation between joint activation and the ratio of slab length to radius of relative stiffness (L/l). Designing joint spacing to achieve L/l between 4 and 7 may provide the desired balance between maximum, timely joint activation, and good overlay performance.

The findings of this study are being shared with cities, counties, the Iowa DOT, and consultants through various programs including concrete pavement lunch forums, Iowa Concrete Paving Association (ICPA) workshops, and other seminars. Publications are being distributed via the National Concrete Pavement Technology (CP Tech) Center website and other newsletters.

Future Research

The adaptation of ultrasonic shear-wave tomography for determination of joint activation provides opportunities to measure joint behavior using nondestructive testing. Additional study may be warranted using nondestructive testing on concrete overlays with higher traffic volumes.

Long-term study of the Mitchell County and Buchanan County test sections to address ride quality, curling behavior, and joint performance may help provide further insight into factors that should be considered for optimized joint spacing design.

Reference

Gross, J., D. King, D. Harrington, D., H. Ceylan, Y.-A. Chen, S. Kim, P. Taylor, and O. Kaya. 2017. *Concrete Overlay Performance on Iowa's Roadways*. National Concrete Pavement Technology Center, Iowa State University, Ames, IA. https://intrans.iastate.edu/app/uploads/sites/7/2018/08/Iowa_concrete_overlay_performance_w_cvr-1.pdf.