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MAP Brief July 2019

Best practices and promising technologies that can be used now to enhance concrete paving

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

for Low-Volume Roads

July 2019

ROAD MAP TRACK 6

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

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Introduction

Iowa has the highest number of miles (over 2,200) of concrete overlays in the United States, mainly on county roads (typically in the range of 750 Annual Daily Traffic [ADT] with 75 Annual Average Daily Truck Traffic [AADTT]), with some on state and city roadways. Concrete overlays were thought to be successful; however, until recently there was not a clear understanding of their overall performance. In response, the Iowa Highway Research Board (IHRB) funded TR-698, Concrete Overlay Performance on Iowa’s Roadways. This was the first phase of a two-phase study, which consisted of a comprehensive and quantitative evaluation of concrete overlay performance. Concrete overlay performance was measured by analyzing the Pavement Condition Index (PCI) and the International Roughness Index (IRI). This study was completed in July 2017 and showed that the majority (89%) of overlays in Iowa were in good to excellent condition.

The second phase was the Optimized Joint Spacing for Concrete Overlays With and Without Structural Fibers. The purpose of the second phase was to try to determine why some contraction joints in concrete overlays on low volume roads (75AADTT) did not activate (crack did not deploy under the saw cut), in some cases for years.

Background

Once Phase 1 of the study was concluded, it was apparent that the design, joint spacing, and construction practices instituted years ago are correct for overlays greater than 6 in., as outlined in the 2014 Guide for Concrete Overlays. The 2014 Guide recommends joint spacing in feet from 1.5 to 2 times the overlay thickness in inches, which typically results in nominal 6 ft by 6 ft joint spacing for overlay thicknesses in the 4 in. to 6 in. range. However, it was documented in the Phase 1 report that not all small spacing of transverse contraction joints had activated for thin (4 in. to 6 in.) overlays and in some cases did not activate until years after construction. Contraction joints that do not activate may be considered an inefficient design. If less than the majority of joint activation does not occur in a reasonable period, then the joint spacings may be too close together, which results in unnecessary joints, increases the costs of installation and maintenance, results in the formation of highly spaced predominant joints that widen up over time, and promotes loose load transfer. At the same time, long joint spacing can lead to an increase in shrinkage and curling stresses in the overlay, which can cause additional cracking and higher IRI (lower rideability). If 100% joint activation occurs soon after construction, it normally indicates the joint spacings are too large and other mid-panel cracking could be forthcoming.

The objective of the Phase 2 study was to provide guidance on the optimum joint spacing for thin concrete overlays based on traffic loading, concrete overlay thickness, support system, presence of fibers, and concrete overlay types. In this study, optimum joint spacing means having as close to 100% joint activation as possible over a reasonable period (less than a year).

Work Plan

The database developed in Phase 1 was also used for Phase 2. The Phase 2 study was conducted in three steps:

Step 1: Analytical Investigation

An analytical investigation was performed using pavement design programs (AASHTOWare, Pavement ME, and BCOA-ME) to analyze the impact of joint spacing on predicted concrete overlay performance.

The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by the Federal Highway Administration.

Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The July 2019 MAP Brief provides information relevant to Track 6 of the CP Road Map: Concrete Pavement Construction, Reconstruction, and Overlays.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefJuly2019.pdf.

AASHTOWare Pavement ME Analysis

AASHTOWare Pavement ME Design (version 2.3.1) supports a minimum longitudinal joint spacing of 12 feet (full-lane width) and a minimum transverse joint spacing of 10 feet as design parameters. For this study, the climate station city was set to be Des Moines, Iowa, and the annual average daily truck traffic (AADTT) was 75. The reason for also using BCOA-ME is to cover limits of the AASHTOWare Pavement ME Design for thin bonded overlays.

The overlays selected in the analytical investigation included bonded concrete overlays on asphalt (BCOA) and unbonded concrete overlays on concrete (UBCOC). Overlay thicknesses of 6 in. and less were placed in the bonded category, which is consistent with the Iowa DOT definition. It was noted that a majority of overlays in the Iowa secondary road system were designed with a 6 in. thickness without relying on a bond between the new overlay and the existing pavement (Gross et al. 2017).

Table 1 presents the design parameters of two concrete overlay types: jointed plain concrete pavement (JPCP) over JPCP and JPCP over asphalt concrete (AC).

Table 1. Parameters used in Pavement ME design for this study

Design parameters	JPCP over AC (BCOA)	JPCP over JPCP (unbonded) (UBCOC)
Traffic (ADT)	750	
Truck Traffic (AADTT)	75	
Climate station	12 × 12	12 × 12
Joint spacing (ft)	12 × 15	12 × 15
Thickness (in.)	12 × 20	12 × 20
Existing AC or concrete	4 to 6	5 to 6
layer thickness (in.)	4 and 6	6
Interlayer thickness (in.)	N/A	1

These parameters were utilized in the analytical investigations with Pavement ME. A 30-year designed service life with a 50% reliability was utilized.

In the analysis, a predicted IRI of 170 in./mi was considered as an upper limit for acceptable performance (AASHTO 2012; AASHTO 2013). No local calibration of Iowa concrete overlays (bonded or unbonded) was available; therefore, the national performance prediction models were utilized. The AASHTOWare Pavement ME Design IRI prediction model for designing JPCP and concrete overlays includes transverse cracking, joint faulting, joint spalling, and a site factor, along with the calibration coefficients.

BCOA-ME Analysis

The BCOA-ME design procedure was developed at the University of Pittsburgh, Pennsylvania (Li et al. 2016). This software is used for designing thin concrete overlays. Unlike Pavement ME Design software, BCOA-ME does not model predicted performance of the overlay. Instead, the BCOA-ME procedure provides an overlay thickness based on design parameter inputs and includes an input variable for fiber type and content.

In this case, to analyze and compare the predicted performance of concrete overlays with different joint spacing, the design thickness was calculated and plotted as a function of maximum allowable percentages of cracked slabs. Table 2 shows the design parameters of concrete overlay types used in these analytical investigations using BCOA-ME design.

Table 2. Parameters used in BCOA-ME design for this study

Design parameters	BCOA
Traffic (AADTT)	75 (ADT: 750)
Climate station	Des Moines
Existing AC/concrete layer thickness (in.)	4 and 6
HMA fatigue	Adequate
Composite Modulus of Subgrade Reaction, k-value (psi/in.)	150
Does the existing HMA pavement have transverse cracks?	Yes
Fiber type and content	No fiber or 4 lb/yd^3 synthetic structural fibers
Maximum Allowable Percent Slabs Cracked (%)	5, 10, 15, 25, 50
Joint spacing (ft)	6 × 6 12x12 12x15

Step 2: Field Reviews

Field reviews of existing bonded and unbonded overlays were performed using nondestructive testing to measure joint activation in existing 4 in. to 6 in. overlays (figure 1).

The MIRA test method (figure 2) was used to analyze 52 existing in-service Iowa concrete overlays (see table 3 on page 3).

Figure 1. Joint activation data collected on an existing overlay in Worth County, Iowa using a MIRA device placed over saw cuts

Figure 2. MIRA ultrasonic shear-wave tomography device being used to collect joint activation data

Table 3. Breakdown of test sections evaluated

The MIRA test method was used to analyze 52 existing in-service Iowa concrete overlays (Table 2).		Number of joint samples
Type of concrete overlay	BCOA	420
	UBCOC	232
Thickness (in.)	4	87
	5	95
	6	431
	7	39
Joint spacing (ft)	5.5 to 7.5	148
	11 to 12.5	236
	14 to 15	159
	20 to 40	109
Age (year)	0 to 5	371
	6 to 10	45
	11 to 15	93
	>15	144
ADT	0 to 500	241
	501 to 1,000	246
	1,001 to 1,500	83
	>1,500	112

Step 3: New Test Sections

New test sections were constructed in conjunction with new concrete overlay projects (Mitchell Co. and Buchanan County) to analyze a wider range of variables and study early-age joint activation behavior (figure 3). The parameters of the study included overlay thickness, joint spacing, and use of structural macro-fibers (4 lb/yd^3) within BCOAs and UBCOCs.

Key Findings

Analytical Investigation

- An analytical investigation was performed, using the American Association of State Highway and Transportation Official's (AASHTO) AASHTOWare pavement mechanistic-empirical (ME) pavement design and the University of Pittsburgh's bonded concrete overlay of asphalt-ME (BCOA-ME) design procedure (Li et al. 2016). The investigation analyzed the impact of joint spacing on predicted concrete overlay performance. The overlay types selected in the analytical investigation included BCOA and UBCOC. One or both of two design tools, AASHTOWare Pavement ME and BCOA-ME, were used where they were most applicable to analyze the different combinations of overlay type, thickness, and joint spacing that were considered as part of this investigation.
- A thin concrete overlay on an existing asphalt pavement is predicted to serve longer before reaching the established IRI performance threshold than an unbonded concrete overlay on an existing concrete pavement.

Figure 3. Mitchell County test section construction showing addition of fibers at the batch plant and overlay paving

- 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 ft to 12 ft/15 ft, additional thickness may be required to handle the same amount of traffic.

Joint Activation of Existing Overlays

Field reviews were performed using MIRA ultrasonic shear-wave tomography on existing 4 in. to 6 in. concrete overlays.

The results of the nondestructive testing demonstrated the following key findings:

- Joint activation did not depend or vary based on overlay type (BCOA vs. UBCOC). Within the parameters of this study, bond between layers was not observed to affect joint activation over the studied time period.
- Holding other variables constant, in general,
  - concrete overlays with longer joint spacing exhibited increased joint activation.
  - concrete overlays with greater thickness achieved increased percentages of joint activation.
  - joint activation rates did not vary with low traffic volumes (750 ADT).
  - for a given overlay thickness, longer joint spacing increased the number of joints that were activated.
  - for a given joint spacing, greater overlay thickness increased the number of joints that were activated.
- Pavements that were 10 years or older had most joints activated. Joints that did not activate were mostly observed in short slab sections that were less than 10 years old.
- In concrete overlays with greater than 6 in. thickness and 12 ft or greater joint spacing, activation rates were high, often approaching 100%. Rates were lower in overlays that were thinner (4–5 in.) and with shorter joint spacing, often falling in the range of 60%–80%.

Age

After 10 years of service, most of the joints were activated (see figure 4). However, joints that did not activate were mostly confined to short slab sections that were 10 years old or younger.

Overlay Types

As shown in figure 5, joint activation did not vary with overlay type (BCOA vs. UBCOC).

Low volume Traffic

As shown in figure 6, joint activation was not affected much for low traffic volume.

Overlay Thickness

In general, concrete overlays with greater thickness achieved increased percentages of joint activation. As shown in figure 7, higher overlay thickness led to increased joint activation.

Joint Spacing

As shown in figure 8, longer overlay joint spacing led to increased joint activation. For a given overlay thickness of 6 in., longer joint spacing increased the number of joints that were activated.

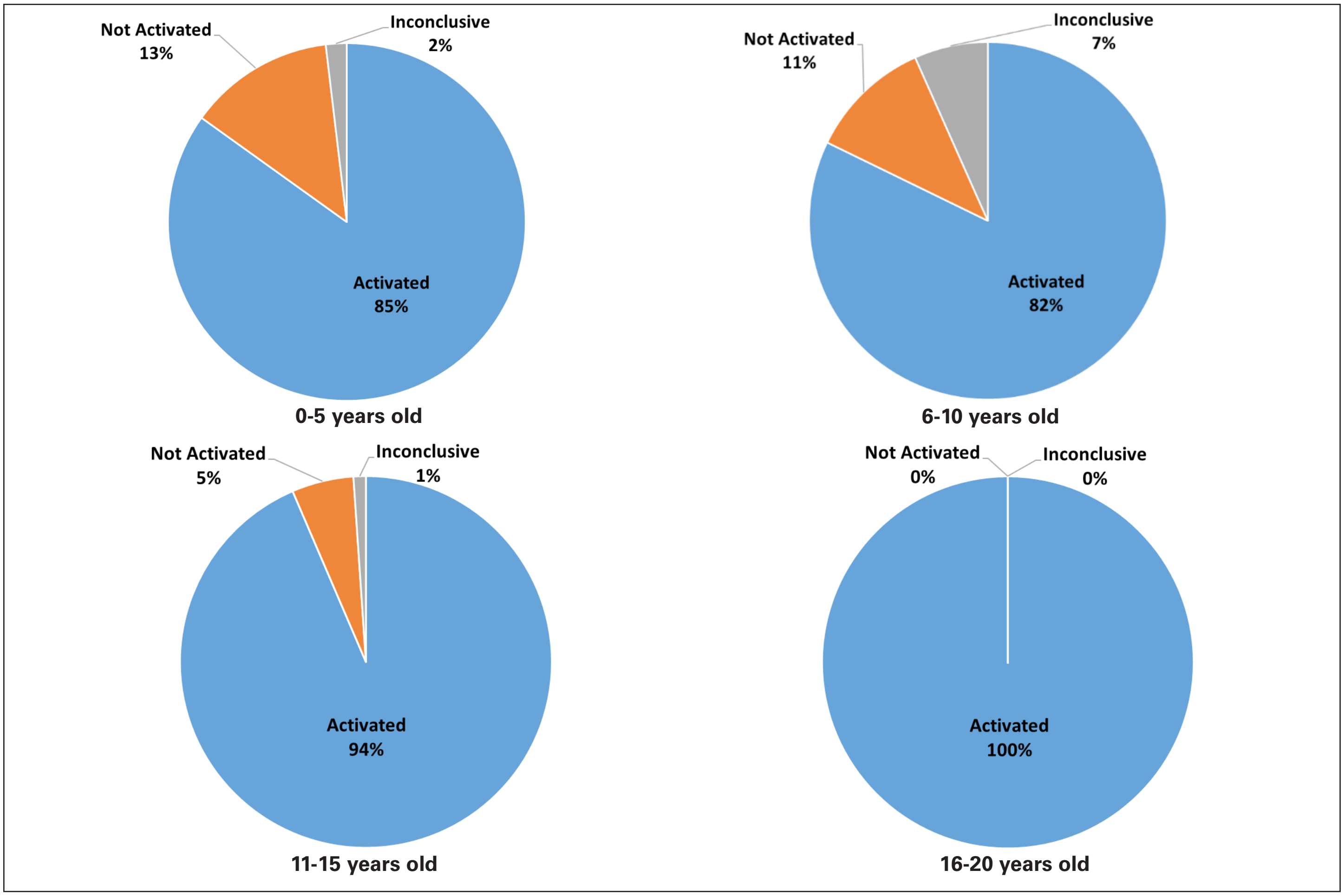

Figure 4 . Percentage of joints activated for different overlay ages

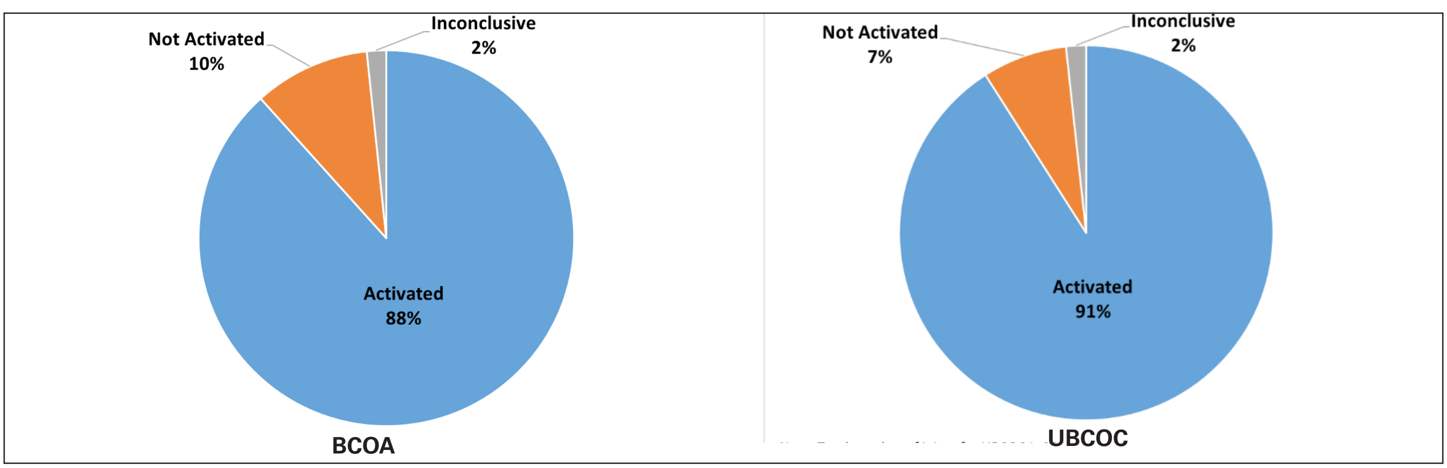

Figure 5. Percentage of joints activated for different concrete overlay types

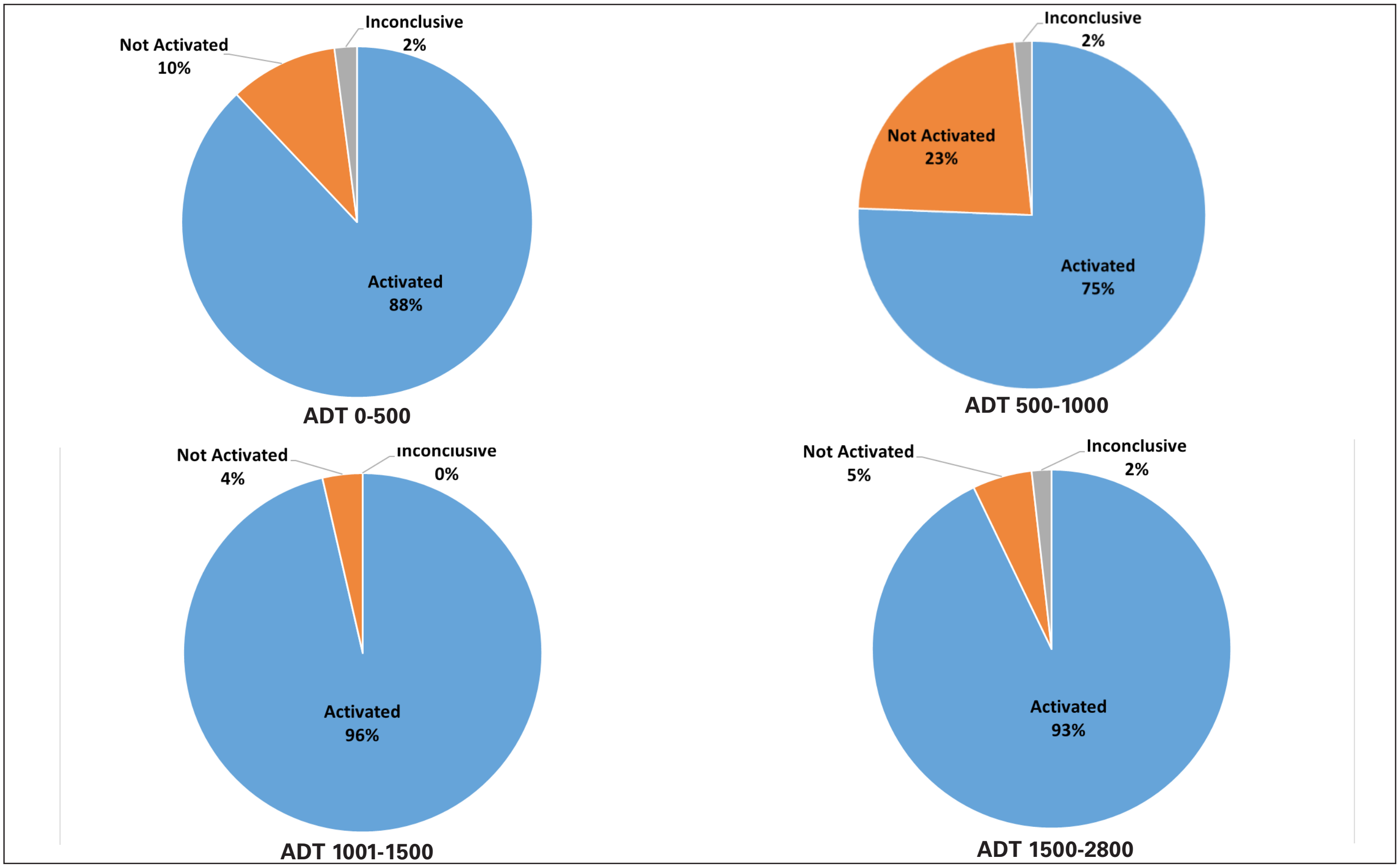

Figure 6. Percentage of joints activated for different traffic volumes

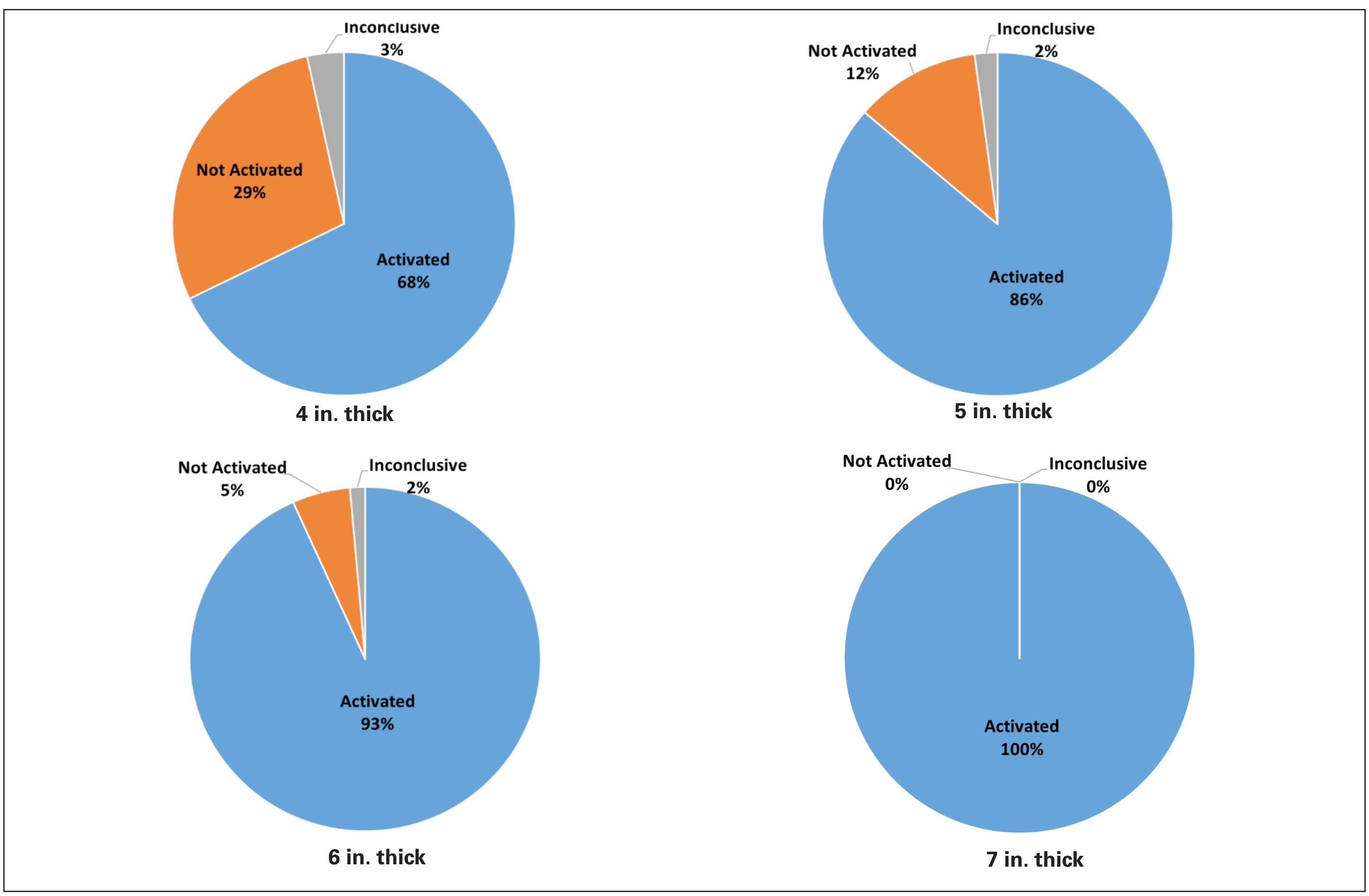

Figure 7. Percentage of joints activated for different concrete overlay thickness

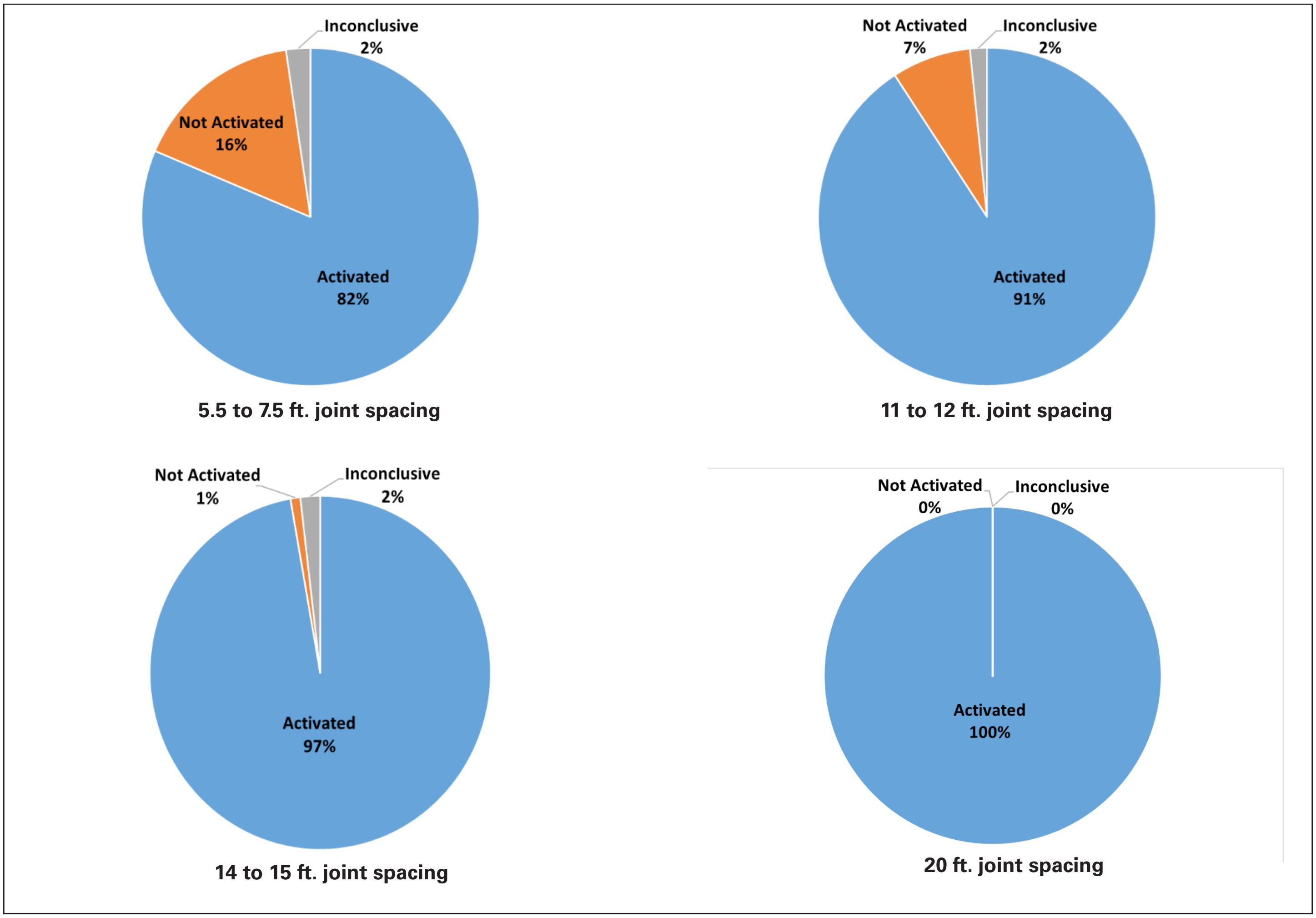

Figure 8. Percentage of joints activated for different joint spacing for a 6-inch thick concrete overlay

Joint Activation of New Overlays

The construction of new concrete overlay test sections offered the ability to study joint spacing and its relationship with different design variables and compare results with the testing of existing overlays. Constructing new overlays also allowed for continuous monitoring of the development of joint activation in the early stages of overlay service life. Additionally, since use of synthetic macro-fibers in concrete overlays was not widespread in Iowa at the time of this study, the construction of these test sections allowed for a study of fiber-reinforced concrete and its impact on joint behavior and optimized joint spacing in concrete overlays.

Development and Construction of Test Sections

The test sections were designed and built as part of two new concrete overlay projects in Iowa: a bonded concrete overlay of a composite pavement constructed in Mitchell County, west of St. Ansgar, in August 2017, and an UBCOC, with geotextile fabric interlayer built in Buchanan County, east of Dunkerton, in August 2018. Table 4 on page 8 lists the design parameters for these two projects. Many of the design parameters chosen for the test sections were the same as those analyzed as part of the analytical and field investigations, including overlay type, thickness, and joint spacing. Additionally, fiber reinforcement (4 lbs/cu yd) was considered as part of this test section study. Although neither project was designed with fibers in the typical section, they were able to be incorporated into the test sections.

There was also a desire to evaluate the impact of interlayer type for unbonded projects, but the study was ultimately limited to the Buchanan County project, where a geotextile was used as the interlayer. Table 4 lists the full test matrix of test sections considered across the two projects.

The construction of new concrete overlay test sections in Mitchell and Buchanan Counties offered the opportunity to study joint spacing and its relationship with different design variables. Constructing new overlays also allowed for continuous monitoring of the development of joint activation in the early stages of overlay service life. Additionally, since use of synthetic macro-fibers in concrete overlays was not widespread in Iowa at the time of this study, the construction of these test sections allowed for a study of fiber-reinforced concrete and its impact on joint behavior and optimized joint spacing in concrete overlays. The test sections were de-

Table 4. Design parameters for experimental test sections

Project/ Overlay Type	Thickness (in.)	Joint spacing (ft.) (Transverse x Longitudinal)	Fiber-reinforcement (lb.yd^3)
Mitchell County BCOA (constructed August 2017)	4	6x6	0
			4
		12x12	0
			4
		15x12	0
			4
		20x12	0
			4
	6	6x6	0
			4
		12x12	0
			4
		15x12	0
			4
		20x12	0
			4
Buchanan County UBCOC (constructed August 2018)	6	5.5x5.5	0
			4
		11x11	0
			4
		15x11	0
			4
		20x11	0
			4
		30x11	0
			4
		40x11	0
			4

signed and built as part of two new concrete overlay projects in Iowa: a bonded concrete overlay of a composite pavement constructed in Mitchell County, west of St. Ansgar, in August 2017, and an UBCOC built in Buchanan County, east of Dunkerton, in August 2018.

Thickness was varied between 4 in. and 6 in. for the test sections in Mitchell County, while thickness was held at 6 in. in Buchanan County. Transverse joint spacing was varied from shorter slab design (5.5 ft to 6 ft) to slab sizes (12 ft to 20 ft). In Buchanan County, extended joint spacings of 30 ft and 40 ft were also tested. Longitudinal joint spacing was reduced (5.5 ft to 6 ft) for the short slab test sections and maintained at the lane width (11 ft or 12 ft) for the rest of the sections.

A fiber dosage rate of 4 lb/yd^3 was chosen based on the typical dosage rate used on fiber-reinforced concrete overlays in Illinois (Illinois DOT 2019). The type of fiber incorporated in both projects was FORTA-FERRO, a blend of micro- and macro-synthetic fibers.

Results

Figures 9 through 14 present joint activation percentages measured for the various test sections over time, organized by thickness and joint spacing.

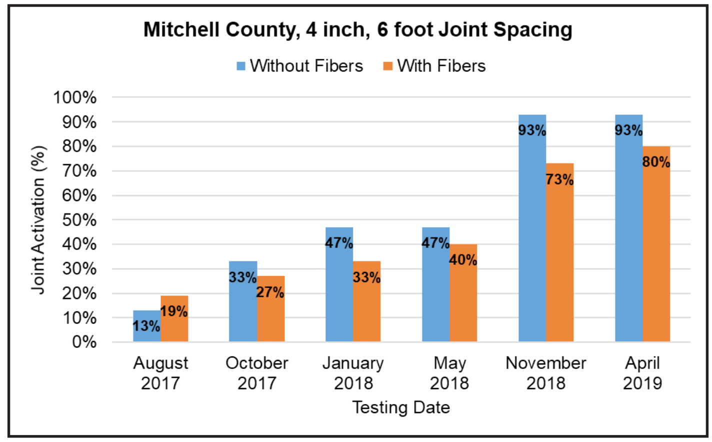

Figure 9. Joint activation results for Mitchell County, 4-inch, 6-foot joint spacing

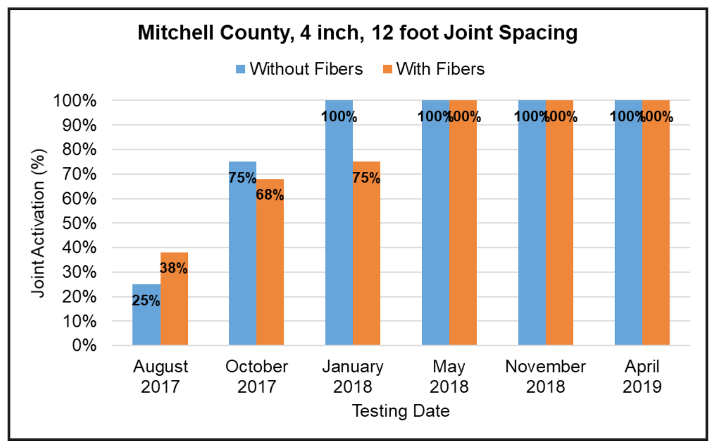

Figure 10. Joint activation results for Mitchell County, 4-inch, 12-foot joint spacing

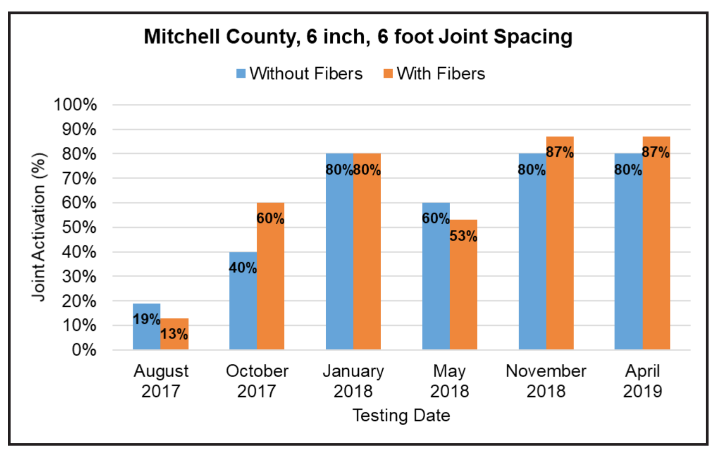

Figure 11. Joint activation results for Mitchell County, 6-inch, 6-foot joint spacing

Note: May 2018 Results. The measurement of cracking under the transverse saw cuts for May, 2018, were difficult to read accurately since the cracks had closed under May warmer weather temperatures (high 62o F.) as compared to the adjacent January, 2018 and November, 2018 when the high temperatures were below freezing and the cracks had opened more through contraction.

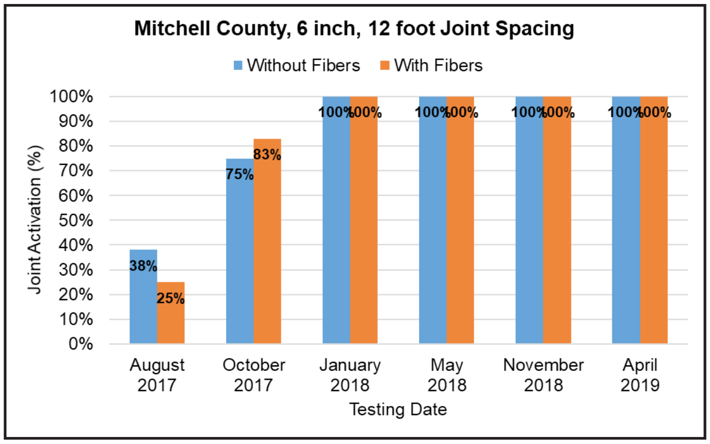

Figure 12. Joint activation results for Mitchell County, 6-inch, 12-foot joint spacing

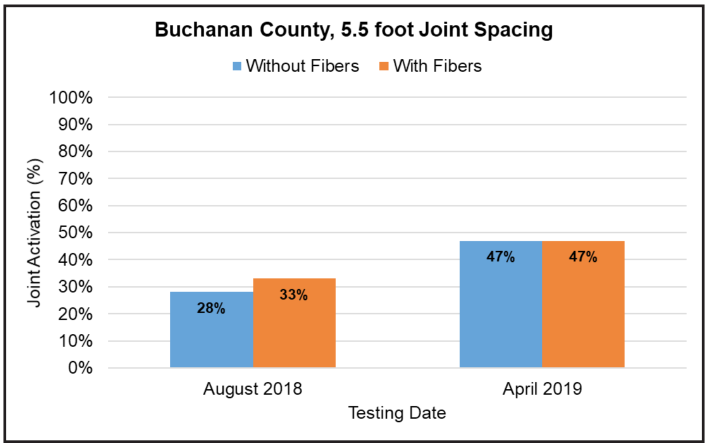

Figure 13. Joint activation results for Buchanan County, 5.5-foot joint spacing

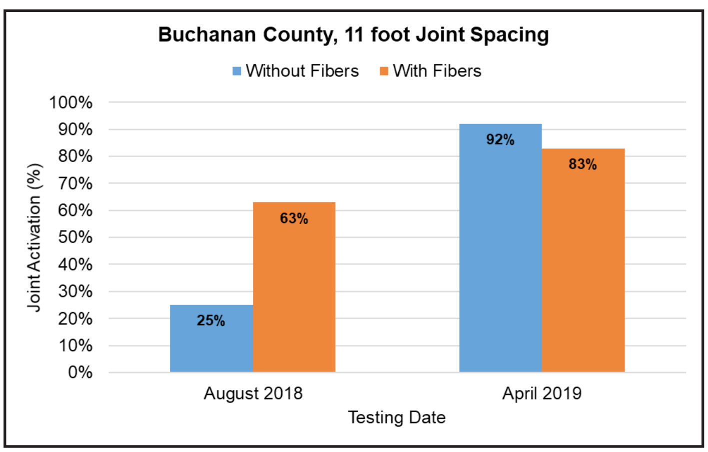

Figure 14. Joint activation results for Buchanan County, 11-foot joint spacing

Observations

In virtually all cases, the number of activated joints increased with time. In a few instances, mainly in the Buchanan County sections with extended joint spacing, 100% of joints had activated. The progression of joint activation and percentage activated (at the time of this report) depended primarily on slab size. Rate of activation was slowest in the short slab sections, and remaining un-activated joints were mostly confined to those sections. Comparing the short slab sections in Mitchell County, joints activated slightly more quickly and to a slightly greater extent in the thicker 6 in. sections than in the 4 in. sections. Fiber reinforcement was not observed to have a significant impact on the rate of joint activation or ultimate activation rates.

Effect of Slab Size on Joint Activation

Slab size was found to be the predominant factor affecting joint activation. In general, as joint spacing increased, the ultimate rate of joint activation increased. Joints also tended to activate more quickly in sections with longer joint spacing relative to those with shorter joint spacing. For the most part, un-activated joints remained only in the shorter slab sections, as highlighted in figures 11 and 13.

Joint activation in the short slab sections in both Mitchell and Buchanan Counties did increase steadily with time, but these increases lagged behind those of the longer joint spacing sections. To date, activation rates remained lower in Buchanan County than in Mitchell County, but they were on a similar trend given that the Mitchell County pavement has been in service for one year longer. In Mitchell County, about one year post-construction, virtually all joints in sections with 12 ft joint spacing or greater went on to crack. The Buchanan County 11 ft sections appeared to be on a similar trend—they had not quite reached 100% activation at the time of this report, but were well on their way, and activation rates were substantially higher than those in the 5.5 ft sections.

Implications for Optimized Joint Spacing Design

Although 100% joint activation is desirable, it should be noted that longer joint spacing can lead to larger joint openings and increase the risk of random cracking and increased curling stresses (Darter and Barenberg 1977; Zhang and Li 2001; Harrington and Fick 2014). Although no random or mid-panel transverse cracks were observed to date in the test sections, these factors should be kept in mind when considering the impact of slab size on joint activation.

Ride quality is another factor that could be compromised by joint spacing that is too long, due to increased curling. In the future, ride quality should be monitored in these test sections and could be helpful in determining optimized joint spacing.

Ultimately, an optimized joint spacing design for concrete overlays may seek to balance the benefits of maximum joint activation with potential problems caused by slabs that are too long.

In the last 25 years, the common approach to determining joint spacing was not based only on the type of overlay, but mainly on overlay thickness. Table 5 shows past conventional thinking regarding the approximate maximum joint spacing as it pertains to thickness, as outlined in the 2014 Guide to Concrete Overlays. The overlays constructed in the past generally followed this approach in Iowa with good results.

Table 5. Conventional joint spacing compared to study activation

Conventional joint spacing design approach			Study activation (IHRB 7R-648)	
Overlay thickness (in.)	Multiplier of max. joint spacing in ft. times overlay thickness in inches	Max suggested spacing in feet	Approx. % activation (5 months)	Approx % activation (12 months)
4	1.5	6.0	50%	80%
5	1.5	7.5		
6	1.5 to 2.0	9.0 to 12	90-100%	100%
7	15ft. maximum spacing	14 to 15		

Thin overlay joint spacings do not activate as quickly as they should, typically when the joints are too close together, and can influence dominant joint behavior, sometimes leading to opening of the dominant joint and loss of load transfer. In addition, unnecessary joints are more expensive and cost more to maintain. Conversely, joints which are too far apart typically activate early, and can influence the formation of intermediate uncontrolled cracks, due to shrinkage and curling stress. Ride quality is another factor that could be compromised by joint spacing that is too long, thanks to increased curling and larger joint openings. In the future, ride quality should be monitored in these test sections and could be helpful in determining optimized joint spacing. Given the above, it would be reasonable to increase the multiplier of the maximum joint spacing in feet times overlay thickness in inches from 1.5 to 2.0 for thin (6 in.) overlays with low traffic counts (750 ADT) to allow faster joint activation. This also would fit closer to the test results from this study. A 4 in. thick overlay could use the same multiplier, but consideration should be given to a 6 ft longitudinal joint spacing to avoid placing a joint in the wheel path.

Effect of Thickness on Joint Activation

In Mitchell County, where test sections were built at both 4 in. and 6 in., thickness did not appear to have a large impact on joint activation, particularly when looking at sections with 12 ft joint spacing and greater. However, some differences were observed when comparing the 6 ft slab sections. During the first winter of service in (January 2018), just 33%–47% of joints had activated in the 4 in. thick sections, while 80% of joints had activated in the 6 in. sections. These findings reflect similar differences observed in the analysis of existing overlays, where all 4 in. overlays had a slightly lower joint activation rate (68%) compared to 5 in. (86%) and 6 in. (93%) overlays.

One factor that might help explain why joints may activate more quickly and to a greater extent in thicker overlays is that as concrete slab thickness increases, the magnitude of the temperature differential between the top and bottom of the slabs increases (Shoukry et al. 2007). This, in turn, increases the amount of curling stress in the slab, which also impacts joint activation behavior in concrete overlays (Roesler and Wang 2009).

Ultimately, the rates of activation between the 4 in. and 6 in. test sections at the time of the last observation in April 2019 appear to be similar (80%–90%). However, a slower rate of activation may still influence the development of dominant joint behavior. Relative to thickness, joint spacing had a far more significant impact on joint activation in the test sections. The magnitude of impact of thickness on joint activation at short joint spacing is small compared to that of joint spacing.

Effect of Fiber

Macro-fibers are generally considered to be able to reduce the number of required joints or extend joint spacing in certain concrete slab applications (American Concrete Institute 2010). Although fibers may not have an impact on the stress required to crack the concrete, they can help control crack widths (Altoubat and Lange 2001; Bischoff 2003)(see figure 15).

In general, the addition of 4 lb/yd^3 of synthetic macro-fibers did not appear to have a significant effect on the rate of joint activation. This is not surprising, because the fibers used here have a relatively low modulus of elasticity, meaning that considerable strain has to be applied before they carry much load. However, they will, as observed, help to limit the width of the cracks over time.

Effect of Overlay Type on Joint Activation

The major design difference between the Mitchell and Buchanan County test sections was that the Mitchell County overlay was a BCOA project, while the Buchanan County overlay was a UBCOC project. Accounting for the fact that the Mitchell

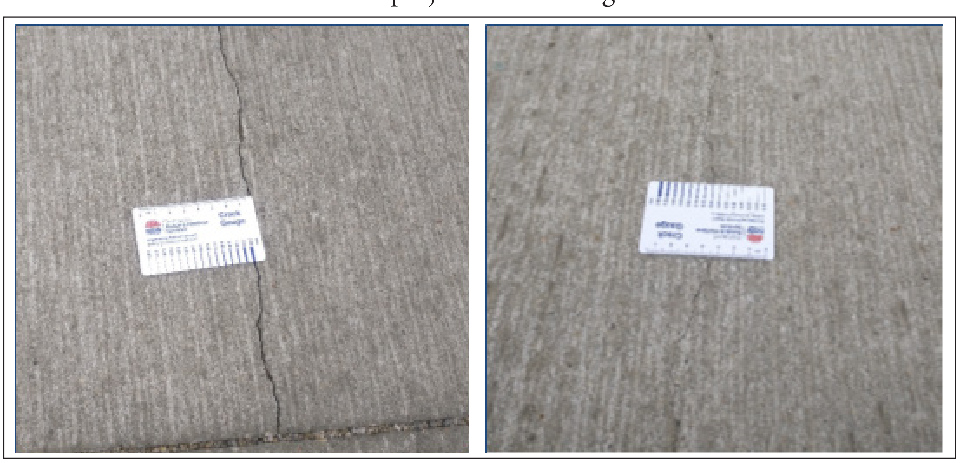

Figure 15. Comparison of reflective cracks developed in test sections without fibers (left) to those with fiber reinforcement (right)

County project was built one year before the project in Buchanan County, joint activation rates for the same thickness, joint spacing, and fiber content appeared to be similar.

The only notable difference observed between the two projects was that, in Buchanan County, some of the extended joint spacing sections (20+ feet) achieved 100% joint activation immediately after construction, confirmed by visual observation. In Mitchell County, it was not until the following winter (about 6 months after construction) that 100% activation was confirmed by MIRA testing.

Detailed Analysis of Slab Size Effects

Bradbury (1938) provided insight into the parameters influencing pavement curling stresses, which depend on the radius of relative stiffness, ℓ, between the slab and foundation, defined by Westergaard (1927) as:

$$\ell = \sqrt[4]{\frac{E\quad{}^{3}}{12k\ \ 1-\mu\ \ )}}$$

where, E is the modulus of elasticity, h is the slab thickness (including the effective thickness of the portion of the bonded asphalt), μ is Poisson's ratio, and k is the modulus of subgrade reaction.

In the range of L/ℓ from 1 to 8, slab proportions impact curling stresses related to joint activation. Figure 16 shows the relationship between joint activation and L/ℓ in the Mitchell County test sections at both the time of construction and at the time of the first follow-up testing in October 2017. As shown in figure 16, for a given thickness, L/ℓ will increase with increasing joint spacing. L/ℓ decreases slightly with increasing thickness, but the magnitude is small. For the 4 in. thick test sections, L/ℓ ranges from 2.9 and 9.5, while for the 6 in. sections, L/ℓ ranges from 2.5 to 8.4. As seen in figure 16, as L/ℓ increases, the rate of joint activation increases, especially with increasing time after construction.

Conclusions

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 Mitchell County, and 10 months in Buchanan County, sections with conventional joint spacing achieved nearly 100% joint activation. Un-activated joints were confined mainly to short slab sections.
- For short slab test sections in Mitchell County, thinner (4 in.) overlays demonstrated slightly slower joint activation rates than thicker (6 in.) 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 and overlay type did not have significant effects on joint activation behavior. However, fiber-reinforcement may provide other benefits to joint performance and crack mitigation.
- The ratio of slab length to radius of relative stiffness, L/ℓ, was a good indicator for joint activation behavior and can be used to help optimize joint spacing design for concrete overlays.

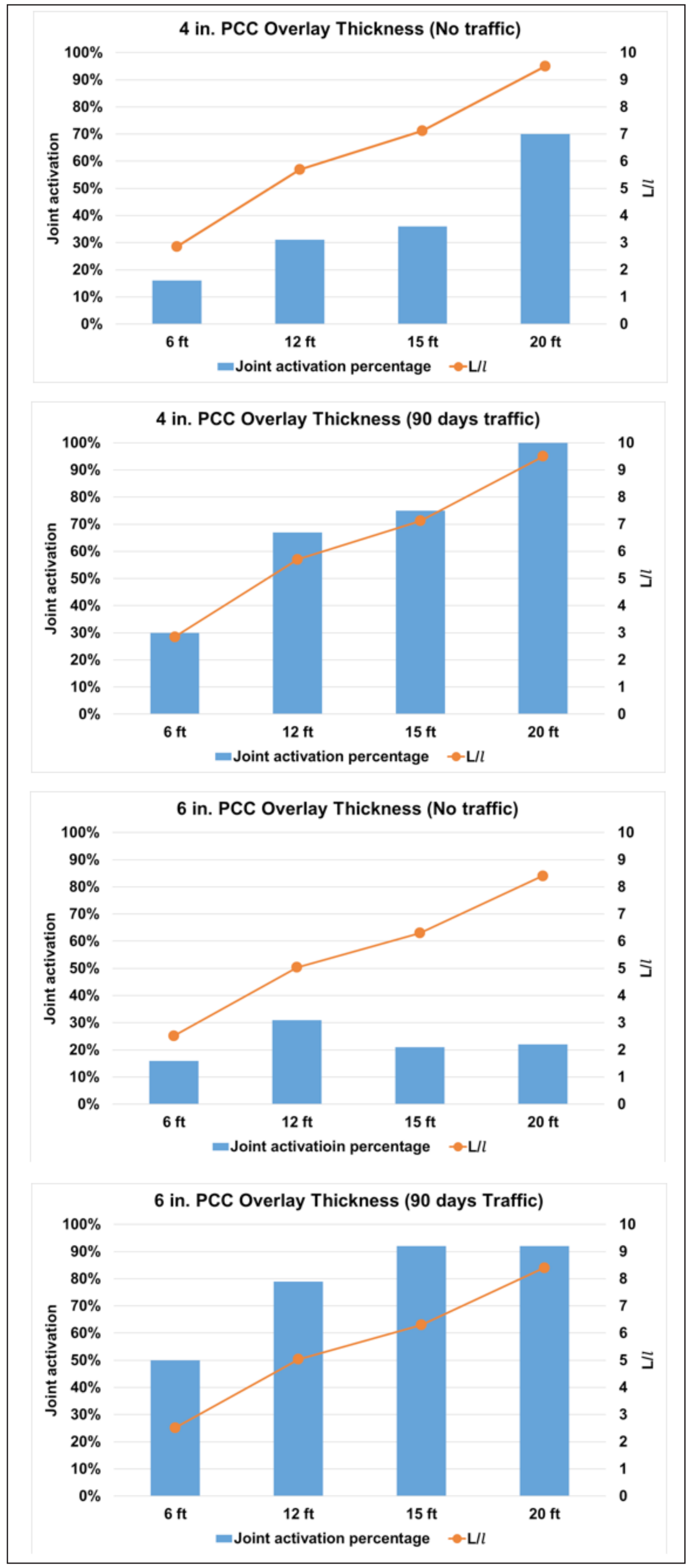

Figure 16. Joint activation vs. L/ℓ and joint spacing for Mitchell County concrete overlay test sections

Discussion

- For thin (4 in. to 6 in. thick) concrete overlays, consideration should be given designing joint spacing to achieve L/ℓ between 4 and 7 to help provide the desired balance between maximum, timely joint activation and good overlay performance.
- As a quick reference for joint spacings on low volume roads, consideration should be given to increasing the multiplier of max. joint spacing, in feet times overlay thickness in inches, from 1.5 to 2.0 for thin (6 in.) overlays with low traffic counts (750 ADT; 75 AADTT) to allow improved joint activation. See table 5 for more information. A 4 in. thick overlay could use the same multiplier but consideration should be given to a 6 ft longitudinal joint spacing to avoid placing a joint in the wheel path.
- For heavier traffic than 75 AADTT, the multipliers outlined above may not fit the traffic conditions for joint activation, and lower multipliers may be more appropriate, similar to the current standards described in the 2014 Guide to Concrete Overlays and outlined in table 5 of this document.

Future Research

This study offered insight into joint activation in concrete overlays and provided guidance on optimizing joint spacing design to promote favorable joint activation behavior. However, there are other factors important to long-term performance of concrete overlays that are influenced by joint spacing as well, including curling, warping, joint opening, and aggregate interlock. Future research is warranted to study these behaviors, measure their impacts on ride quality and load transfer efficiency, and analyze how they are affected by parameters such as overlay type, bond condition, and fiber-reinforcement. A better understanding of these factors can build on the findings of joint activation behavior for further optimization of concrete overlay design.

Full Report

The full report, Optimized Joint Spacing for Concrete Overlays with and without Structural Fiber Reinforcement by Jerod Gross, Dan King, Halil Ceylan, Yu-An Chen, and Peter Taylor, sponsored by the Iowa Highway Research Board, Iowa Department of Transportation, can be accessed here: https://intrans.iastate.edu/app/uploads/2019/06/optimized_joint_spacing_for_overlays_w_cvr.pdf

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