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

Final Report
May 2019

National Concrete Pavement Technology Center




IOWA STATE UNIVERSITY
Institute for Transportation

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16. Abstract

The objective of this study was to determine the optimum joint spacing for thin concrete overlays based on different concrete overlay thicknesses, support systems, and concrete overlay types with and without structural macro-fibers.

In thin concrete overlays, 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 may lead to unnecessary maintenance efforts and costs. The optimum joint spacing design may need to be determined based on factors other than those that are currently considered.

This study included an analysis for recommended joint spacing using pavement design software as well as a field review of joint activation in existing concrete overlays using nondestructive testing. Test sections were also constructed to analyze a wider range of variables and to study early-age joint activation behavior.

The data showed that joint spacing was the most significant factor affecting joint activation. A design parameter, slab length over the radius of relative stiffness (L/ℓ), was identified to have a correlation with joint activation percentage and timing.

The data showed that use of macro-fibers did not affect the percentage or rate of joint activation compared to overlays without macro-fibers.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EXECUTIVE SUMMARY

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

Objective

The objective of this study was to determine the optimum joint spacing for thin concrete overlays (4-inch to 6-inch) 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 4-inch to 6-inch concrete overlays.

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/yd^3) within bonded concrete overlays on asphalt (BCOAs) and unbonded concrete overlays on concrete (UBCOCs).

Key Findings

The analytical investigation using the American Association of State Highway and Transportation Official's 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 (4-inch to 6-inch) 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 (6-foot) provides better performance than longer joint spacing designs (12-foot to 15-foot) 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 correlate 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 (4 to 5 inches) and had shorter joint spacing, often falling in the range of 60–80%.

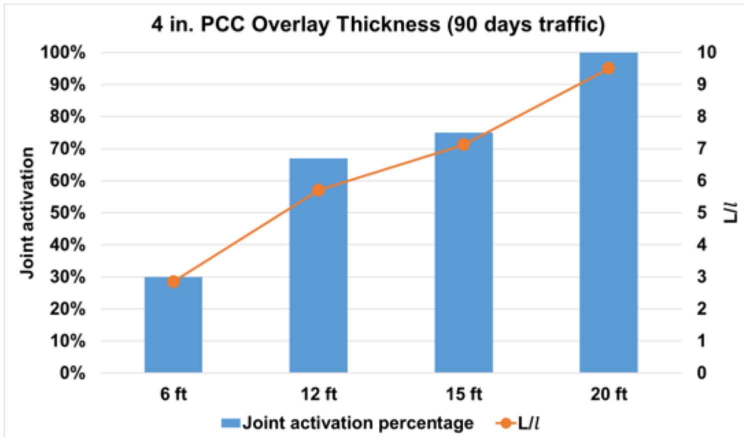
Testing of newly-constructed concrete overlay test sections indicated the following:

- 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 spacing (11 to 12 feet and greater) achieved near 100% joint activation. Un-activated joints were confined mainly to short slabs (5.5- to 6-foot sections).

- 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.

- 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.



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

- For short slab test sections in Mitchell County, thinner (4-inch) overlays demonstrated slightly slower joint activation rates than thicker (6-inch) 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/yd^3 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.

CHAPTER 1 – INTRODUCTION

The state of Iowa has more than 2,000 miles of concrete overlays on state, county, and city roadways (see Figure 1).

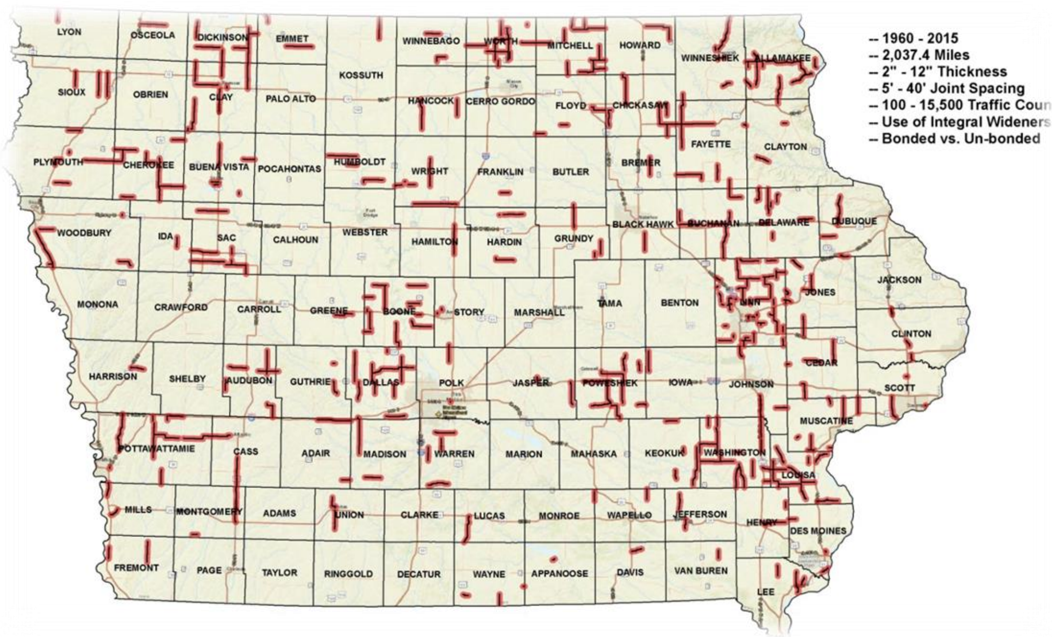


Figure 1. Iowa concrete overlays on state and county roadways

Many of these overlays were originally built with transverse joint spacing in the 15- to 20-foot range with only one centerline, longitudinal joint. They have performed well, particularly on lower traffic-volume roadways.

The current design approach to determining the spacing of longitudinal and transverse joints results in smaller panel sizes, normally in the range of 6 foot by 6 foot for 4-inch to 6-inch overlay thicknesses. In these thin concrete overlays, field observations have sometimes shown that not all contraction joints activate initially and, in some cases, do not activate until long after construction. For the purposes of this document, joint activation is defined as a crack deployed at the contraction joint saw cut.

Longer joint spacing is more desirable because it reduces the number of joints, which in turn reduces the cost of the joint installation and maintenance. However, longer joint spacing can also result in increased risk of mid-panel cracking or rougher pavements due to curling and warping.

Structural synthetic fibers have been gaining attention for use in overlays to increase the fatigue capacity and ductility (toughness) of the concrete overlay, reduce overlay thickness, help control differential slab movement caused by curling/warping, and to hold cracks together.

Objective

The objective of this study was to determine the optimum joint spacing for thin concrete overlays (4-inch to 6-inch) based on traffic loading, concrete overlay thickness, support system, presence of fibers, and concrete overlay type.

Research Plan

Phase 1 of this project was a performance study of concrete overlays in Iowa. (see Figure 2 for report cover).

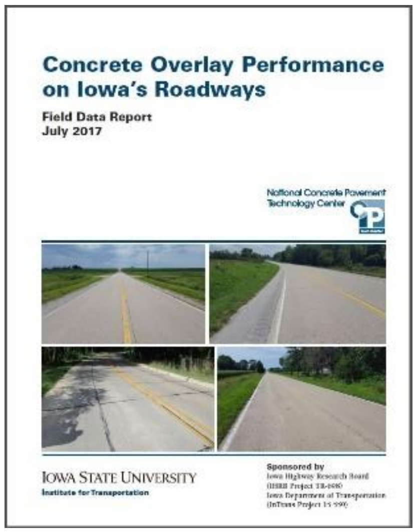


Figure 2. Concrete Overlay Performance report cover

A database including 384 concrete overlay projects was assembled. The database included pavement condition index (PCI), International roughness index (IRI), history (age, thickness, pavement section), traffic, and joint spacing.

Phase 2A utilized the project database and sorted the 4-inch to 6-inch thick overlays based on joint spacing, followed by overlay type, thickness, traffic, and support system, as well as on fabric separator layers, with and without fibers. An analytical investigation was performed using concrete overlay design software to understand optimum joint spacing behavior.

Field information gathered on existing overlays supplemented the software analysis. A non-destructive testing procedure was utilized to determine the amount of joint activation (see Figure 3).

Figure 3. MIRA device used to gather joint activation data

Phase 2B included the construction of new overlay projects, with test sections of various joint spacing and thicknesses, with and without fibers (see Figure 4).

Figure 4. Mitchell County test section paving

Test sections were constructed in Mitchell County of a bonded concrete overlay on asphalt (BCOA) and in Buchanan County of an unbonded concrete overlay on concrete (UBCOC).

The data from Phases 2A and 2B were analyzed to gain an understanding of the joint activation behaviors with the intent of identifying design parameters to optimize joint spacing.

CHAPTER 2 – ANALYTICAL INVESTIGATION

AASHTOWare Pavement ME Design (Version 2.3.1) and BCOA-ME are computer models used to assist with concrete pavement and overlay design. They can be used to simulate alternative joint spacing design options for various conditions such as traffic loading, thickness of the overlay, support systems, and overlay types with and without fibers. They can also be used to identify effects of joint spacing and thickness on predicted concrete overlay service life.

This latter ability was utilized to help understand the effects of these parameters on overlay joint activation.

AASHTOWare Pavement ME Analysis

AASHTOWare Pavement ME Design (version 2.3.1) supports a minimum longitudinal joint spacing of 12-foot (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 overlays selected in the analytical investigation included BCOA and UBCOC. Overlay thicknesses of 6-inch and less were placed in the bonded category, which is consistent with the Iowa Department of Transportation (DOT) definition. It was noted that a majority of overlays in the Iowa secondary road system were designed with a 6-inch 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	
Traffic (AADTT)	75	
Climate station	Des Moines	
Joint spacing (ft)	12 × 12 12 × 15 12 × 20	12 × 12 12 × 15 12 × 20
Thickness (in.)	4 to 6	5 to 6
Existing AC or concrete 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 as follows:

$$IRI = IRIini + C1 \times CRK + C2 \times SPALL + C3 \times TFAULT \times 5{,}280 \div JSP + C4 \times SF \quad \textbf{(1)}$$

where,
IRI = Predicted IRI, in./mi
IRIini = Initial smoothness measured as IRI, in./mi
C 1, 2, 3, 4 = Calibration coefficients
CRK = Percent slabs with transverse cracks (all severities)
SPALL = Percentage of joints with spalling (medium and high severities)
TFAULT = Total joint faulting cumulated, in.
JSP = Joint spacing, ft
SF = Site factor

The plots generated by the models are shown in Figures 5 through 10.

For the 12-foot joint spacing of 4- to 6-inch thick BCOA (Figure 5):

- Concrete overlays perform better when placed on thicker asphalt concrete (AC) pavements.
- The thicker the concrete overlay, the better the performance.
- The large increase in IRI in approximately year 20 and year 22 for the 4-inch thick BCOA on 4-inch thick asphalt and 6-inch thick asphalt coincides with the fact that the Pavement ME software does not recommend a thin concrete overlay (4-inch thick) for joint spacing 12-foot or larger.

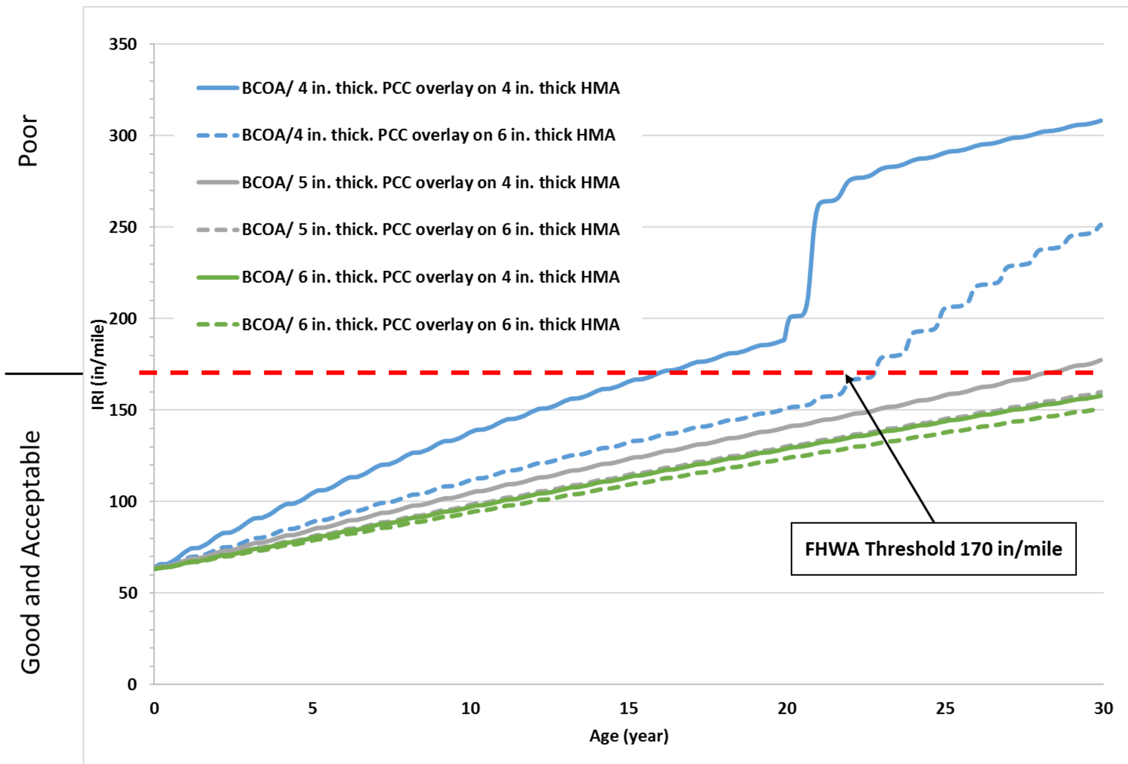


Figure 5. 12-foot joint spacing concrete overlays Pavement ME Design predicted IRI values versus age: BCOA

The key finding in Figure 6 for the 12-foot joint spacing of 5-inch to 6-inch thick UBCOCs on existing 6-inch thick concrete is that they perform well with a service life of approximately 30 years before an IRI threshold of 170 in./mi is reached.

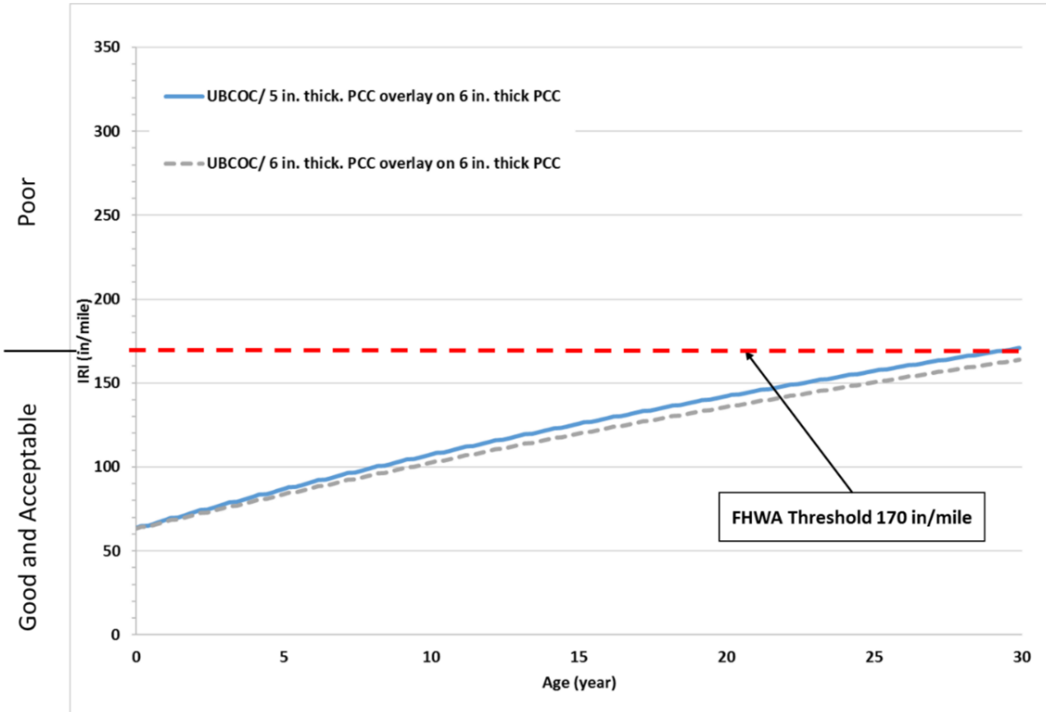


Figure 6. 12-foot joint spacing concrete overlays Pavement ME Design predicted IRI values versus age: UBCOC

For the 15-foot joint spacing of 4-inch to 6-inch thick BCOAs (Figure 7):

- Concrete overlays perform better when placed on thicker AC pavements.
- The thicker the concrete overlays, the better the performance.
- The large increase in IRI in approximately year 21 for the 4-inch thick BCOA on 4-inch thick asphalt and year 22 on the 6-inch thick asphalt coincides with the fact that the Pavement ME software does not recommend a thin concrete overlay for joint spacing 12-foot or larger.

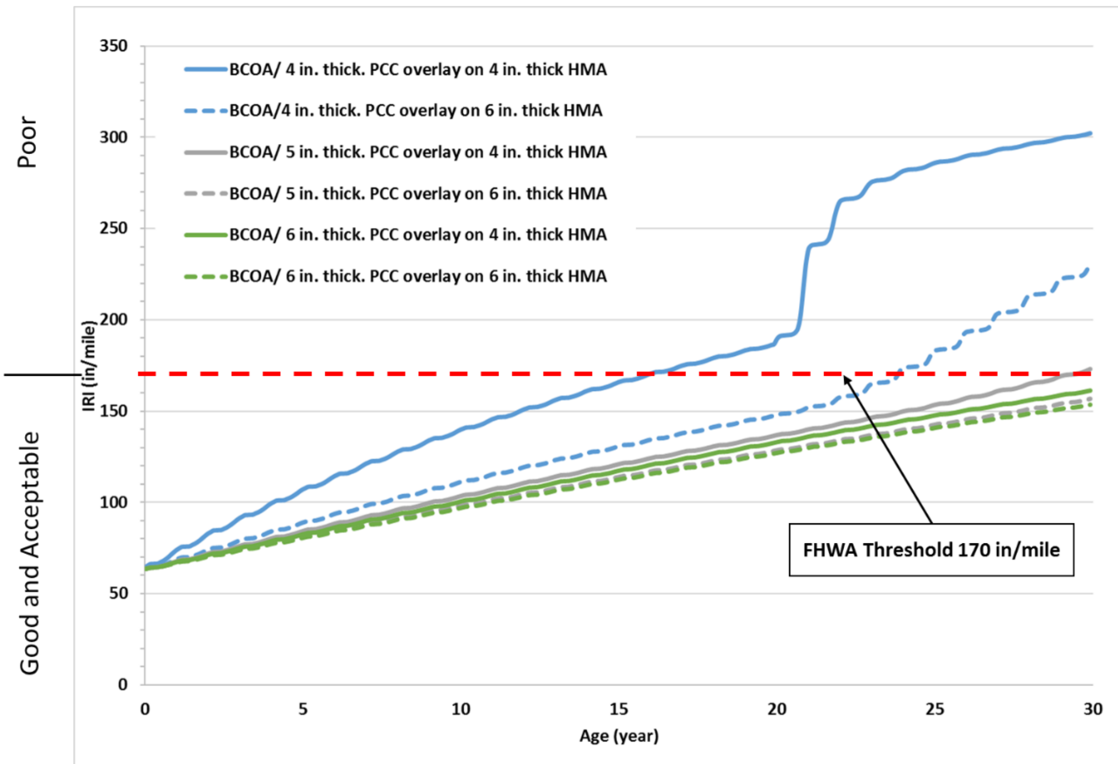


Figure 7. 15-foot joint spacing concrete overlays Pavement ME Design predicted IRI values versus age: BCOA

The key finding observed in Figure 8 for the 15-foot joint spacing of 5-inch to 6-inch thick UBCOCs on existing 6-inch thick concrete is that the overlays perform well with a service life of approximately 30 years before an IRI threshold of 170 in./mi is reached.

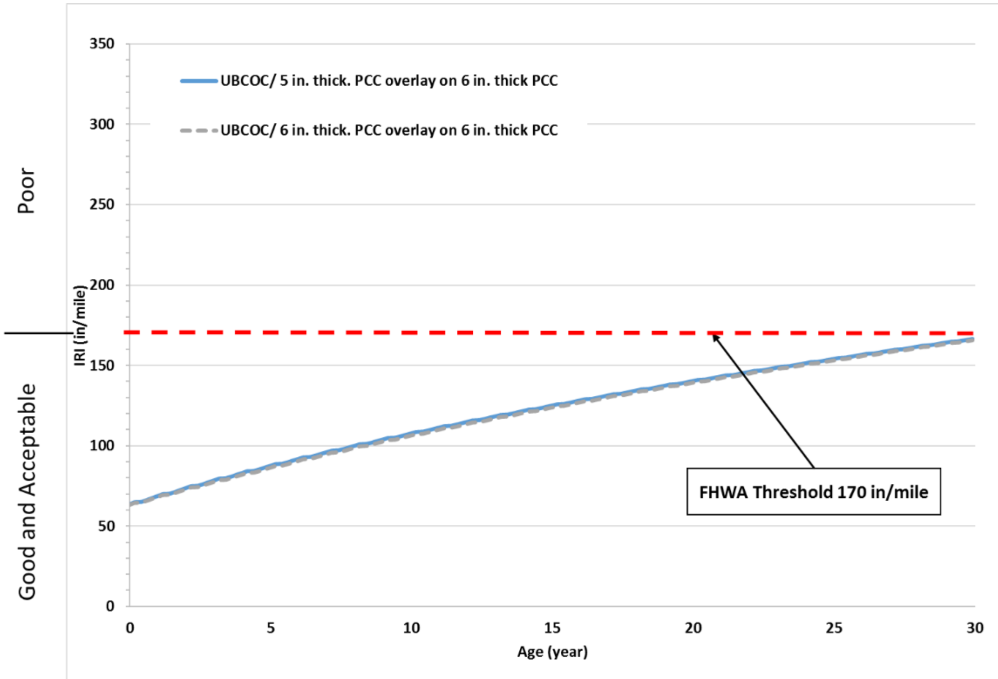


Figure 8. 15-foot joint spacing concrete overlays Pavement ME Design predicted IRI values versus age: UBCOC

For the 20-foot joint spacing of 4-inch to 6-inch thick BCOAs (Figure 9):

- Concrete overlays perform better when placed on thicker AC pavements.
- The thicker the concrete overlay, the better the performance.
- The large increase in IRI in approximately year 20 for the 4-inch thick BCOA on 4-inch thick asphalt coincides with the fact that the Pavement ME software does not recommend a thin concrete overlay (4-inch thick) for joint spacing 12-foot or larger.

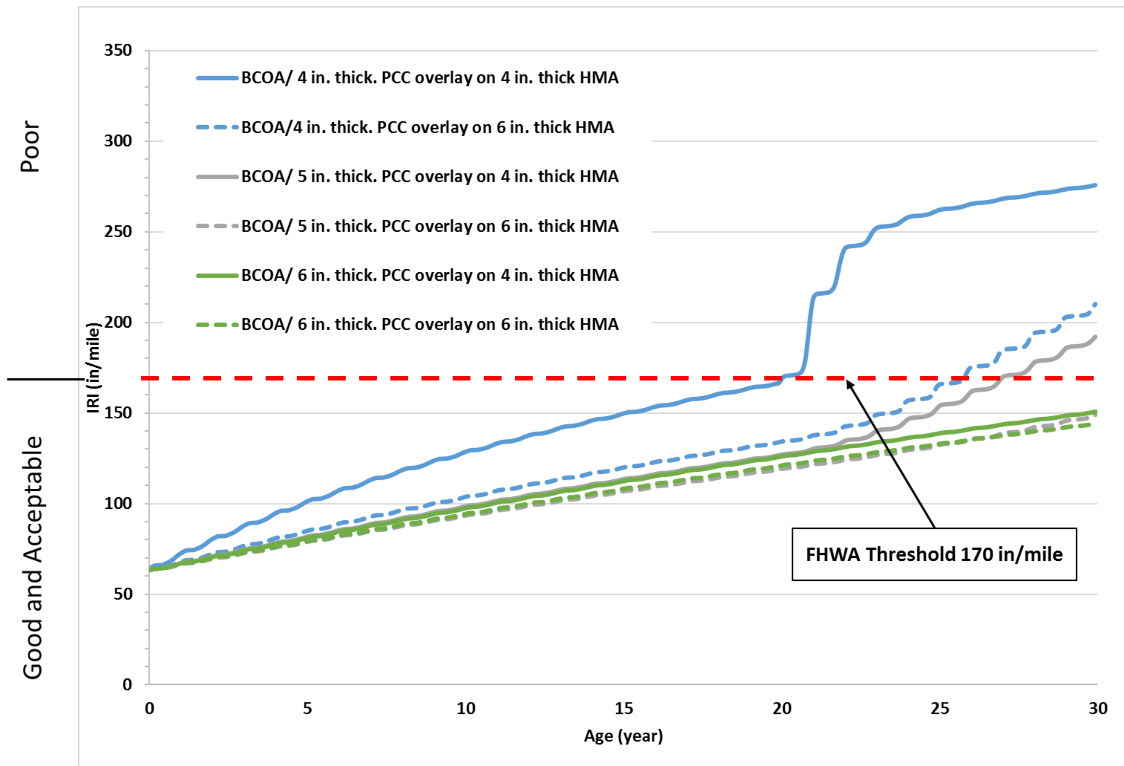


Figure 9. 20-foot joint spacing concrete overlays Pavement ME Design predicted IRI values versus age: BCOA

The key finding observed in Figure 10 for the 20-foot joint spacing of 5-inch to 6-inch thick UBCOCs is that both the 5-inch and 6-inch thick concrete overlays perform well with a service life of more than 30 years before an IRI threshold of 170 in./mi is reached.

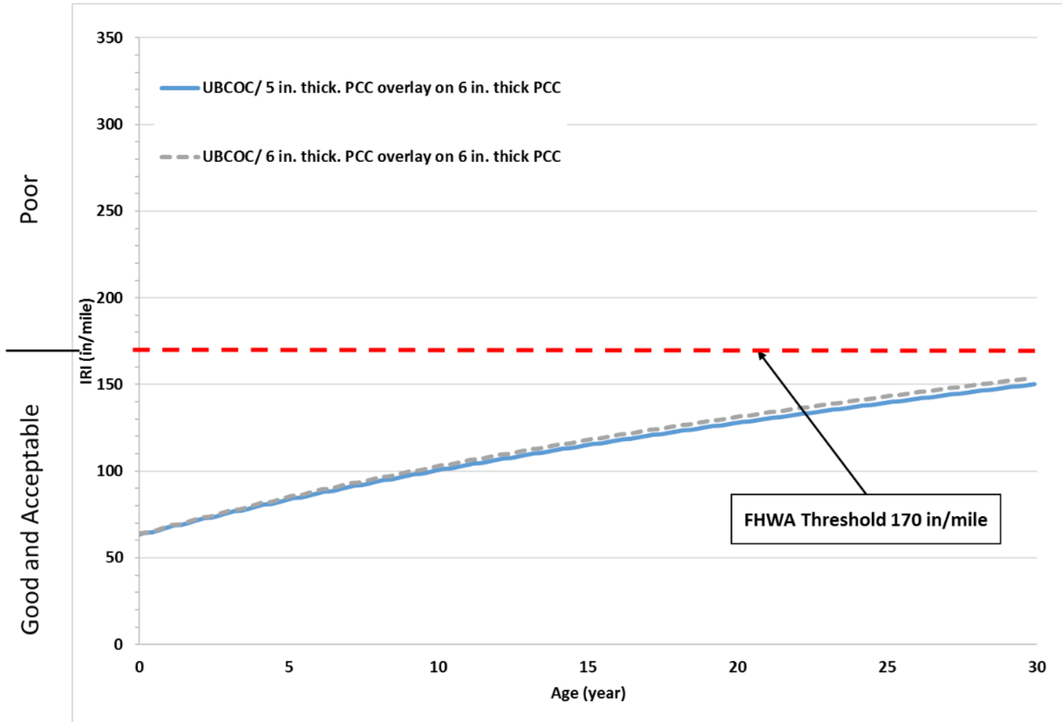


Figure 10. 20-foot joint spacing concrete overlays Pavement ME Design predicted IRI values versus age: UBCOC

BCOA-ME Analysis

The Bonded Concrete Overlay of Asphalt Mechanistic-Empirical (BCOA-ME) design procedure was developed at the University of Pittsburgh in 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 the 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 12 × 12 12 × 15

Using BCOA-ME software, Figures 11 through Figure 13 were developed to show the relationship between the software recommended concrete overlay thickness and maximum allowable percentage of cracked slabs for different joint spacing. In each of the figures, existing AC thicknesses of 4-inch and 6-inch were analyzed.

As shown in Figure 11, for concrete overlays with 6-foot joint spacing:

- Recommended concrete overlay thicknesses decreased with increasing thicknesses of underlying AC.
- Recommended concrete overlay thicknesses decreased with the use of fibers.

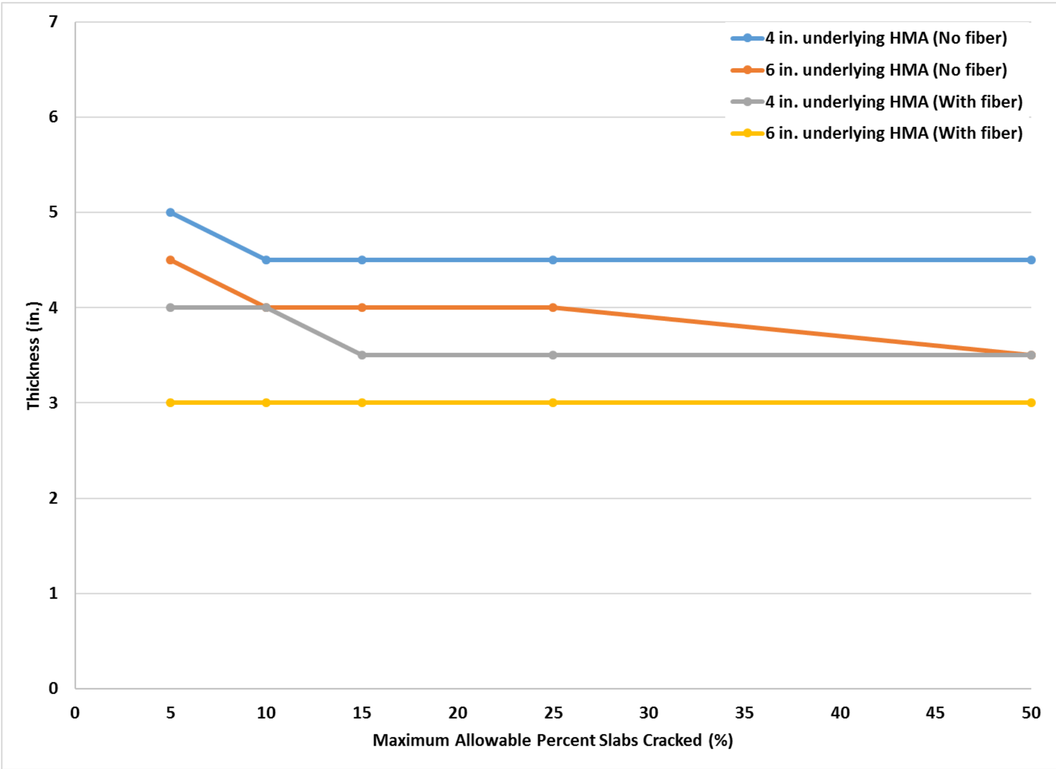


Figure 11. 6-foot joint spacing concrete overlays using BCOA-ME design predicted thickness versus maximum allowable percent of cracked slabs

As shown in Figure 12, for concrete overlays with 12-foot joint spacing, recommended concrete overlay thicknesses were slightly higher when compared to 6-foot joint spacing.

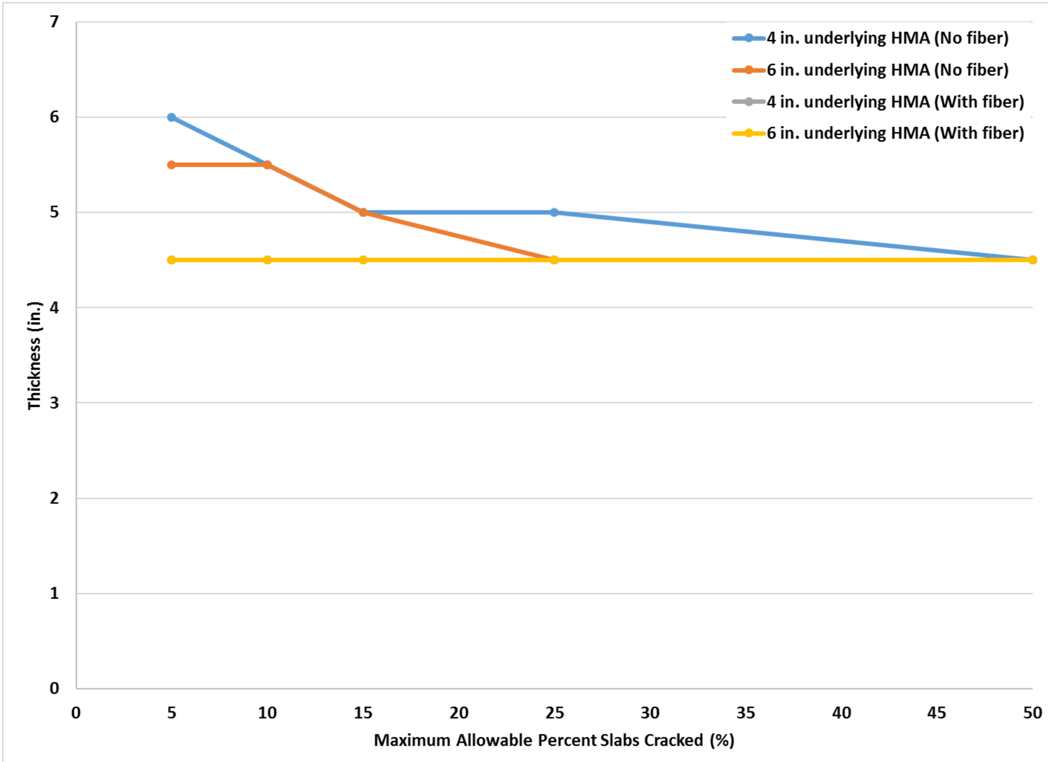


Figure 12. 12-foot joint spacing concrete overlays using BCOA-ME design predicted thickness versus maximum allowable percentage of cracked slabs

As shown in Figure 13, for concrete overlays with 15-foot joint spacing, recommended concrete overlay thicknesses were slightly higher when compared to 12-foot joint spacings.

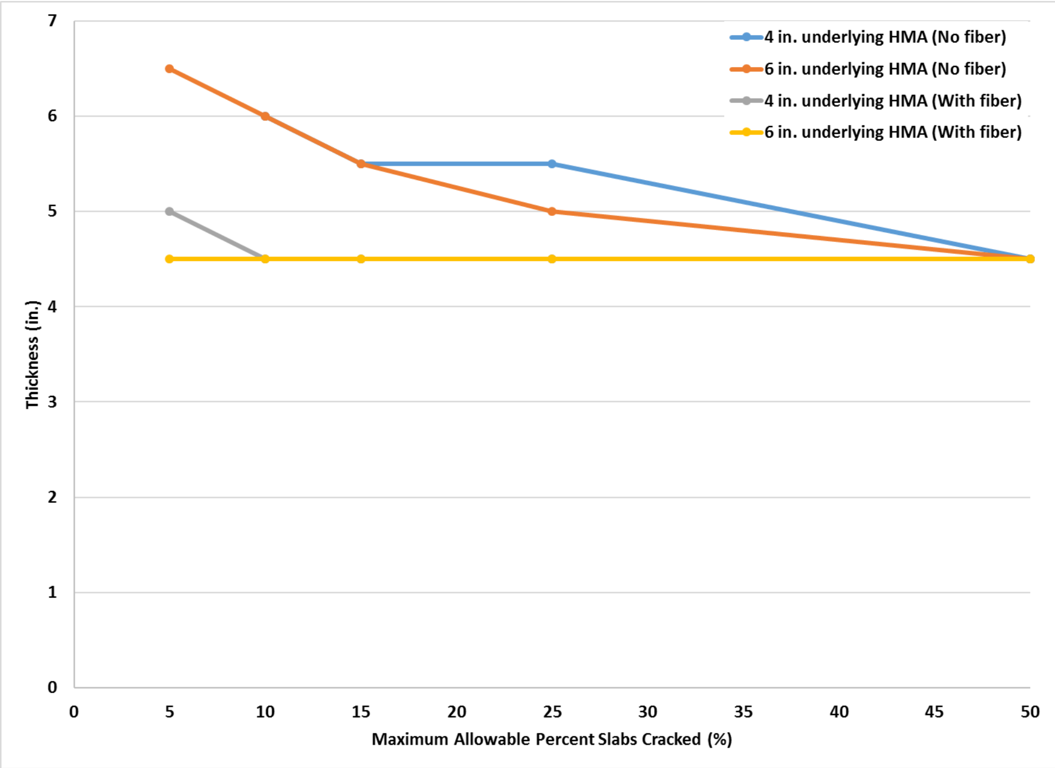


Figure 13. 15-foot joint spacing concrete overlays using BCOA-ME design predicted thickness versus maximum allowable percentage of cracked slabs

Summary of Key Findings

AASHTOWare Pavement ME Design (Version 2.3.1) and BCOA-ME were used to identify effects of joint spacing and thickness on predicted concrete overlay service life. The major findings from the analytical investigation are summarized as follows:

- Thicker existing AC pavement layers and thicker concrete overlays extend the service life. Because the existing pavement behaves as a base with load-carrying capability, its thickness and condition are critical in affecting concrete overlay service life.

- 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.

- For a 20-foot joint spacing, increasing thickness did not appear to affect performance. This may be because 20-foot joint spacing is too large.

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

CHAPTER 3 – JOINT ACTIVATION OF EXISTING OVERLAYS

The original plan for testing joint activation of existing concrete overlays included coring of longitudinal and transverse joints. However, in order to study more pavements, it was decided to utilize a remote sensing device. The method of analysis followed that of Tran and Roesler (2019).

The field testing included 52 test sites, each of which included 10 transverse joints and two-to-five longitudinal joints for a total of more than 600 tests.

Test Method

Joint activation data were collected using a MIRA device with an antenna composed of a 4 × 12 array of point transducers. Interpretation of the data collected by the device to assess joint activation was developed at the University of Illinois (Tran and Roesler 2019). The system uses an ultrasonic pitch-catch method to evaluate internal defects in a concrete element. In the pitch-catch method, one transducer sends a stress-wave pulse at 35 kHz, and a second transducer receives the reflected pulse.

Data from the MIRA device can be used to determine whether a sawn joint in the concrete is activated based on whether or not the crack is deployed given the fact that an air gap in a crack will reflect the pulse, while an uncracked section will permit the pulse to pass through relatively unchanged. The device is placed over the sawcut so that half the transducers are on each side of the cut.

The energy transmitted from antenna No. 2 and received at sensor 7 (E7) is divided by the energy received at sensor 6 (E6) (Tran et al. 2018):

$$\text{Normalized energy} = E7 \div E6 \quad \textbf{(2)}$$

As shown in Figure 14, if the energy at receiver 7 is higher than 0.35, it indicates there was no crack deployment at the joint because energy was transferred to the sensor on the other side of the sawcut.

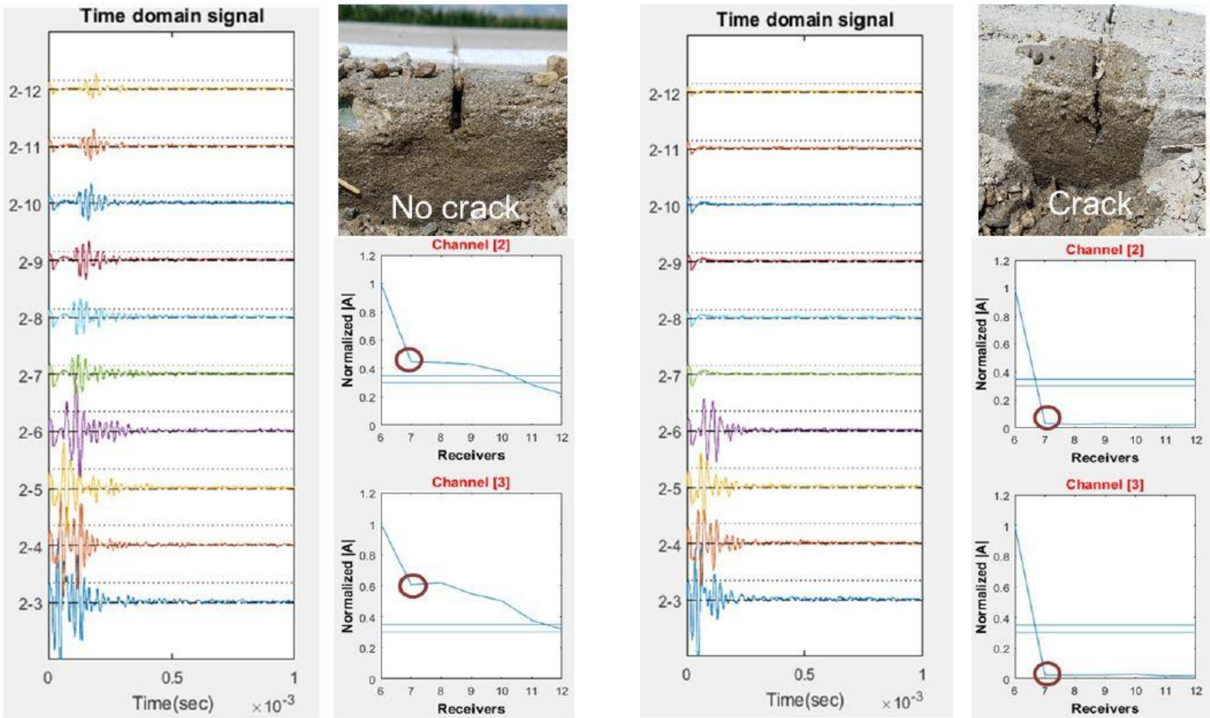


Figure 14. MIRA analysis results for joint activation

Conversely, normalized energy lower than 0.3 at receiver 7 suggests there was crack deployment at the joint. A normalized energy reading between 0.35 and 0.3 indicates either a very tight crack beneath the sawcut or no crack beneath the sawcut, and the data in such cases are reported as inconclusive. Tran and Roesler (2019) reported the method has an accuracy of 96% based on a visual check.

Pavements Investigated

The MIRA test method was used to analyze 52 existing in-service Iowa concrete overlays (Table 3).

Table 3. Breakdown of test sections evaluated

		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

A full listing of these projects (and complete test results) are contained in the Appendix. These projects included BCOAs and UBCOCs. Project thicknesses ranged from 4 to 7 inches, and transverse joint spacing ranged from 5.5 to 40 feet. Table 3 breaks down the total number of joints from which data were collected by overlay type, thickness, joint spacing, age, and traffic.

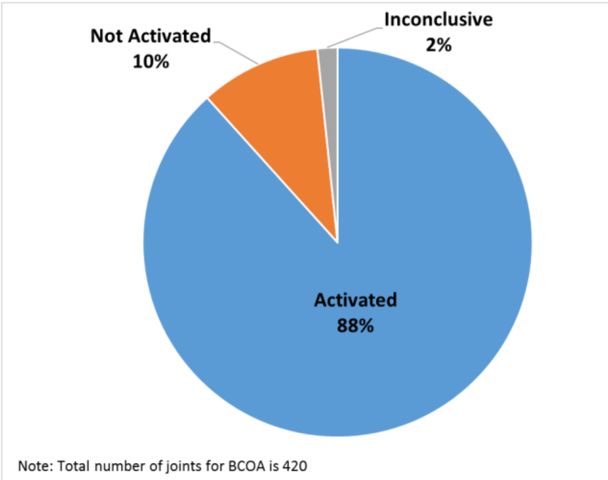
Testing at each project site included 10 transverse joints and two-to-five longitudinal joints. The test was repeated 10 times at each joint. On 23 of the overlays, the MIRA results were verified by digging at the shoulder of the pavement to visually inspect the side of the slab. Based on these visual checks, the MIRA testing appeared to exhibit 86% accuracy in positively predicting joint activation.

Results

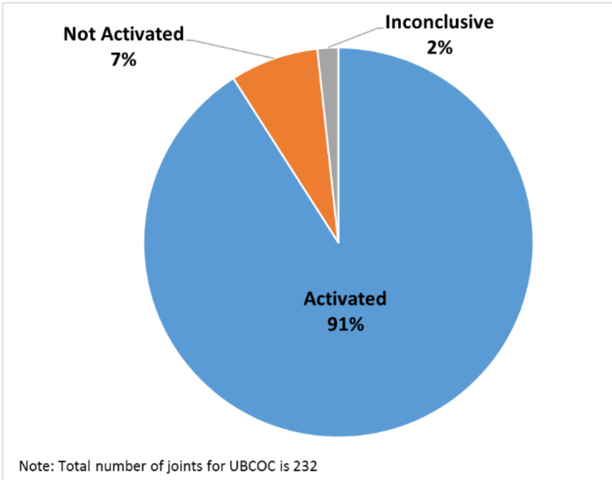
The MIRA test results are summarized in Figures 15 through 26, while complete test results for all 52 projects are included in the Appendix.

Overlay Type

As shown in Figure 15, joint activation did not vary with overlay type (BCOA vs. UBCOC).



BCOA

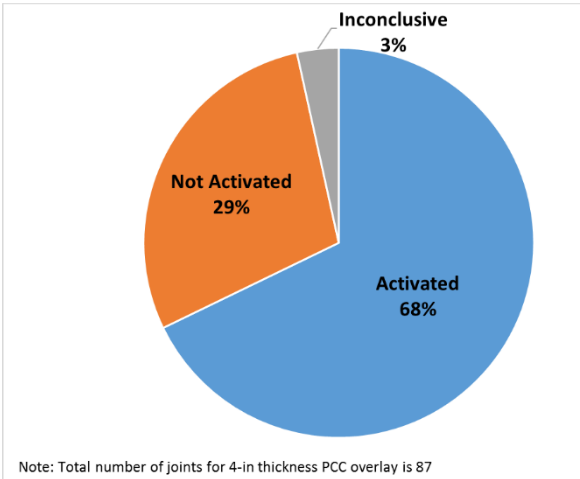


UBCOC

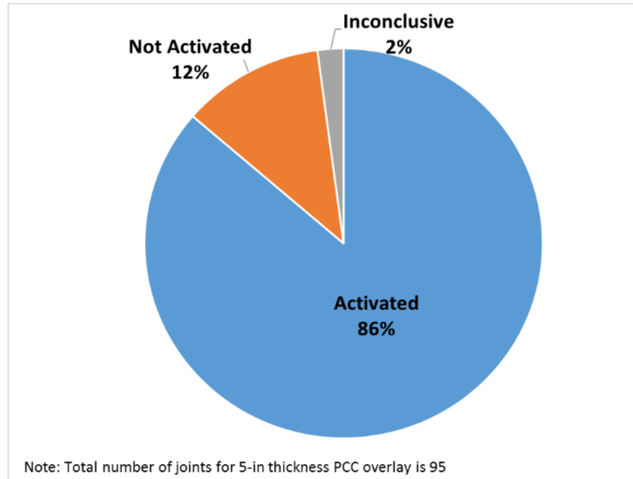
Figure 15. Percentage of joints activated for different concrete overlay types

Overlay Thickness

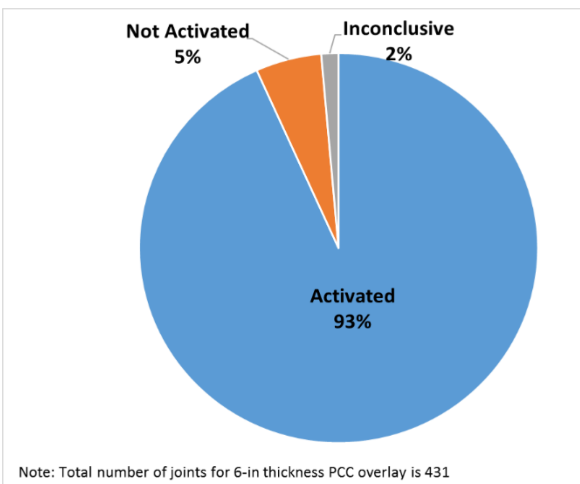
As shown in Figure 16, higher overlay thickness led to increased joint activation.



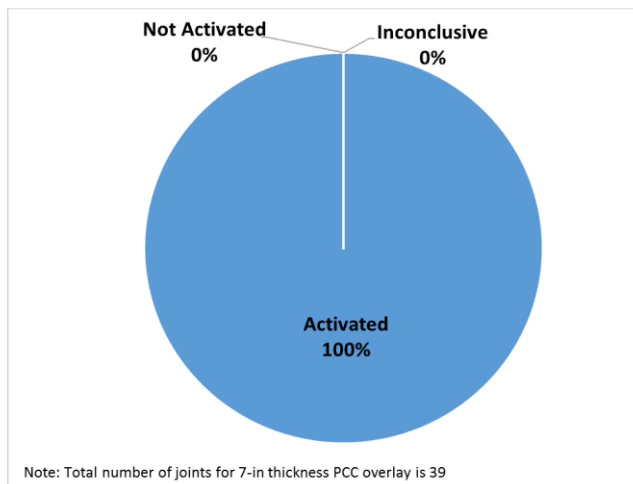
4-inch thickness



5-inch thickness



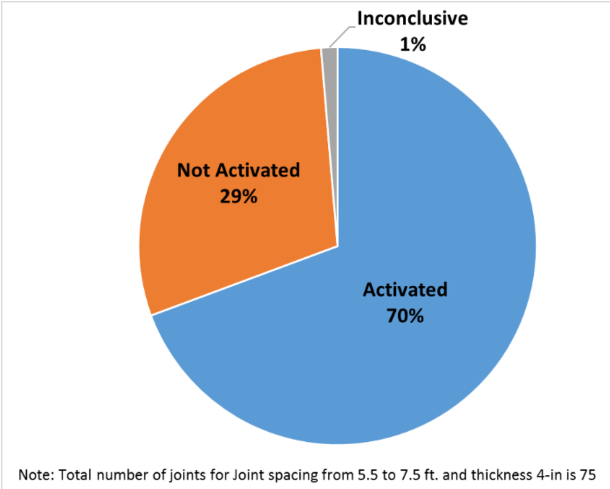
6-inch thickness



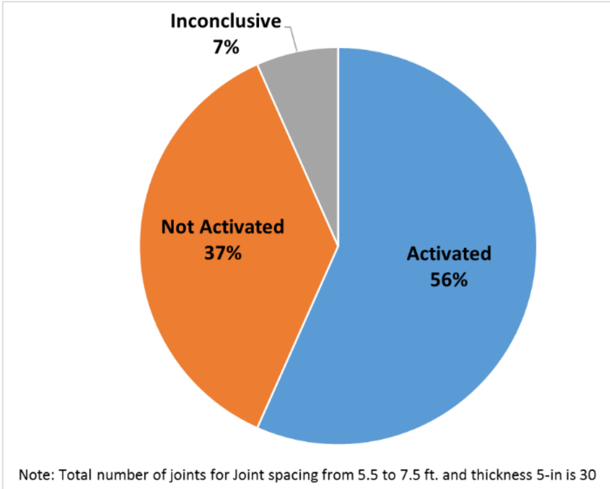
7-inch thickness

Figure 16. Percentage of joints activated for different concrete overlay thickness

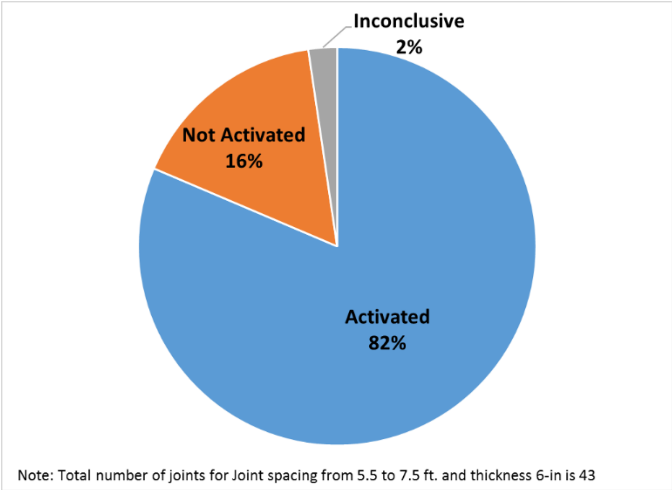
As shown in Figure 17, there were no clear trends for different thicknesses with 5.5- to 7.5-foot joint spacing.



4-inch thickness



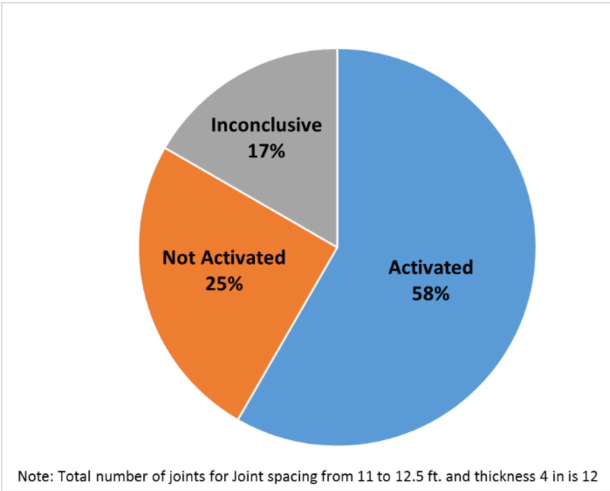
5-inch thickness



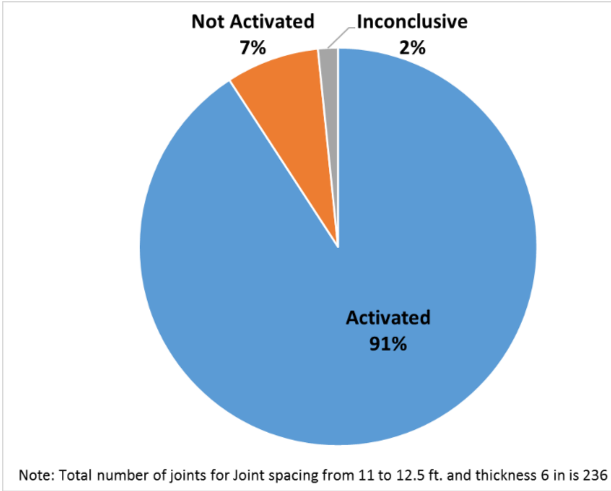
6-inch thickness

Figure 17. Percentage of joints activated for different thickness of 5.5- to 7.5-foot joint spacing overlays

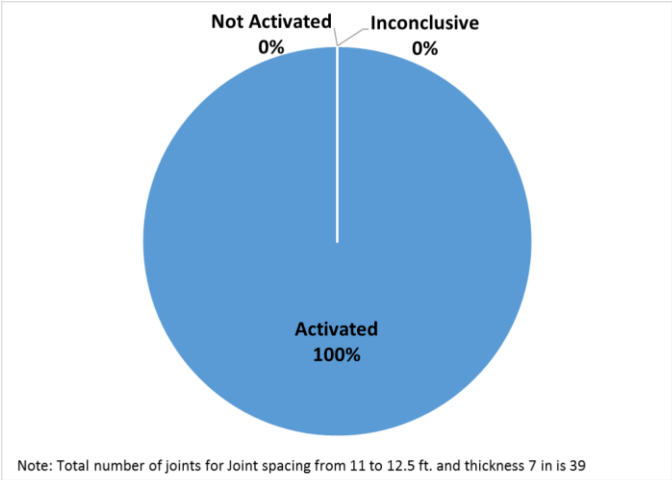
As shown in Figure 18, for 11- to 12.5-foot joint spacing, increased thickness led to increased joint activation.



4-inch thickness



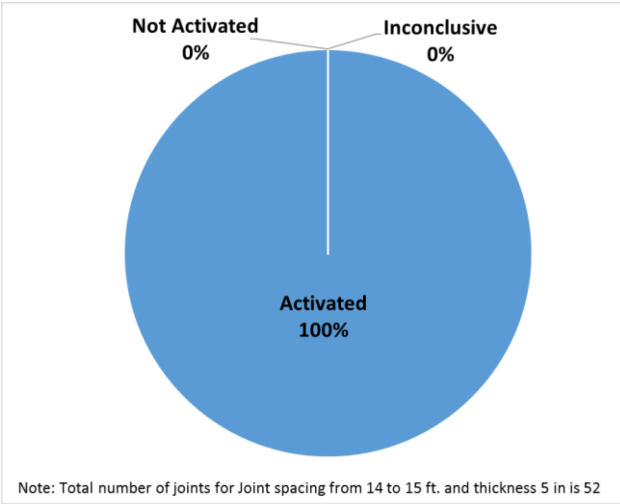
6-inch thickness



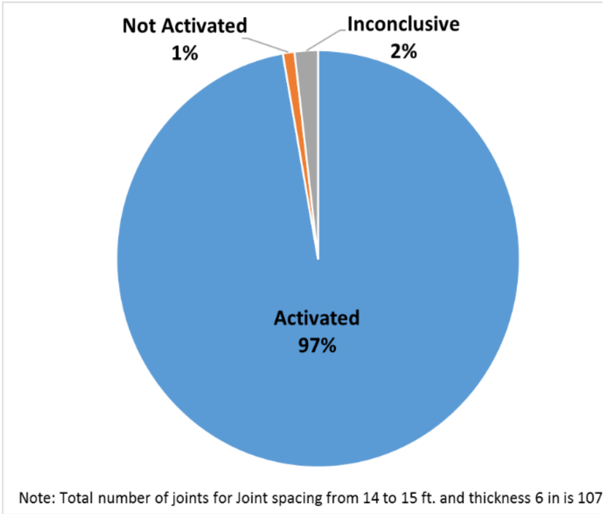
7-inch thickness

Figure 18. Percentage of joints activated for different thickness of 11- to 12.5-foot joint spacing overlays

As shown in Figure 19, for 14- to 15-foot joint spacing, most of the joints were activated.



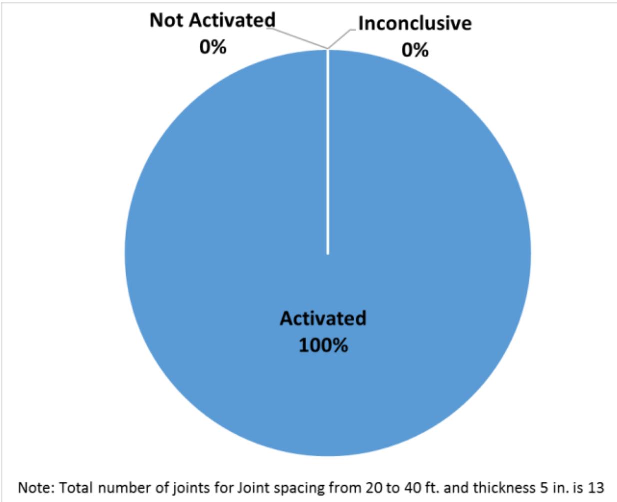
5-inch thickness



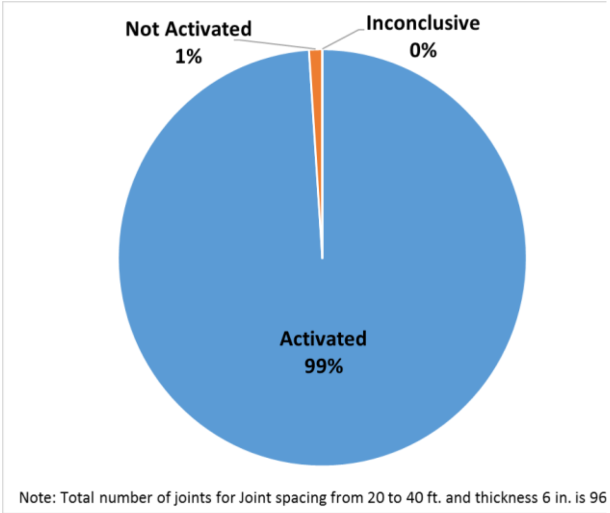
6-inch thickness

Figure 19. Percentage of joints activated for different thickness of 14- to 15-foot joint spacing overlays

As shown in Figure 20, for 20- to 40-foot joint spacing, most of the joints were activated.



5-inch thickness

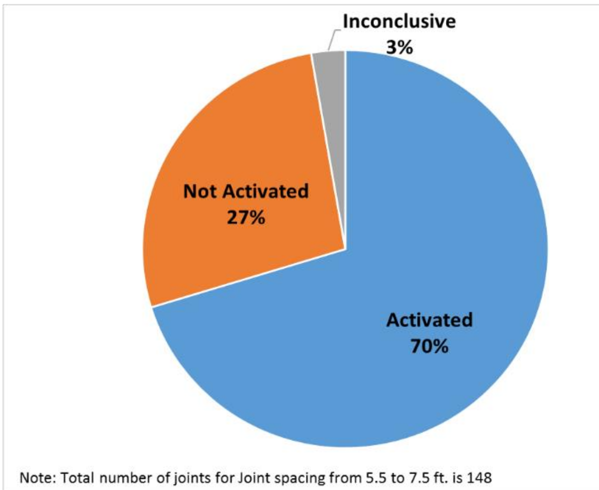


6-inch thickness

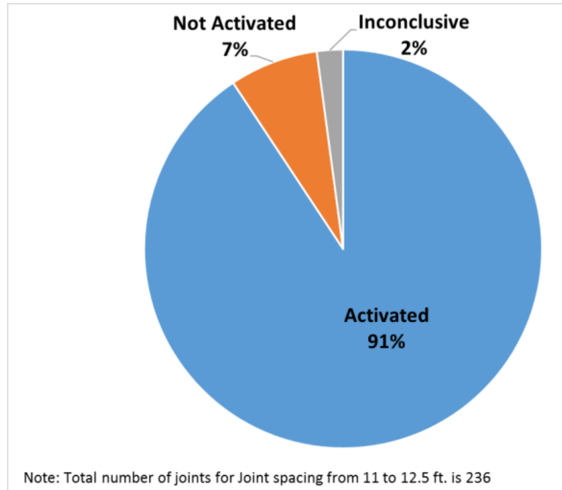
Figure 20. Percentage of joints activated for different thickness of 20- to 40-foot joint spacing overlays

Joint Spacing

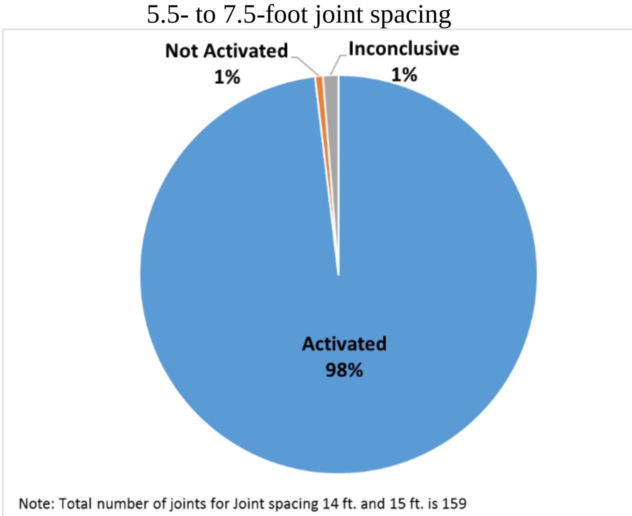
As shown in Figure 21, longer overlay joint spacing led to increased joint activation.



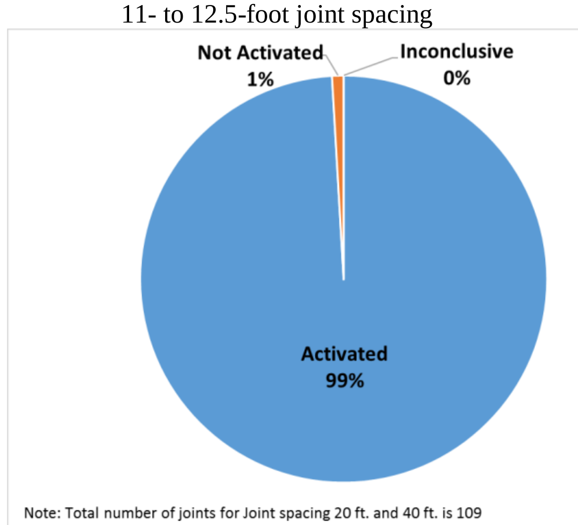
5.5- to 7.5-foot joint spacing



11- to 12.5-foot joint spacing



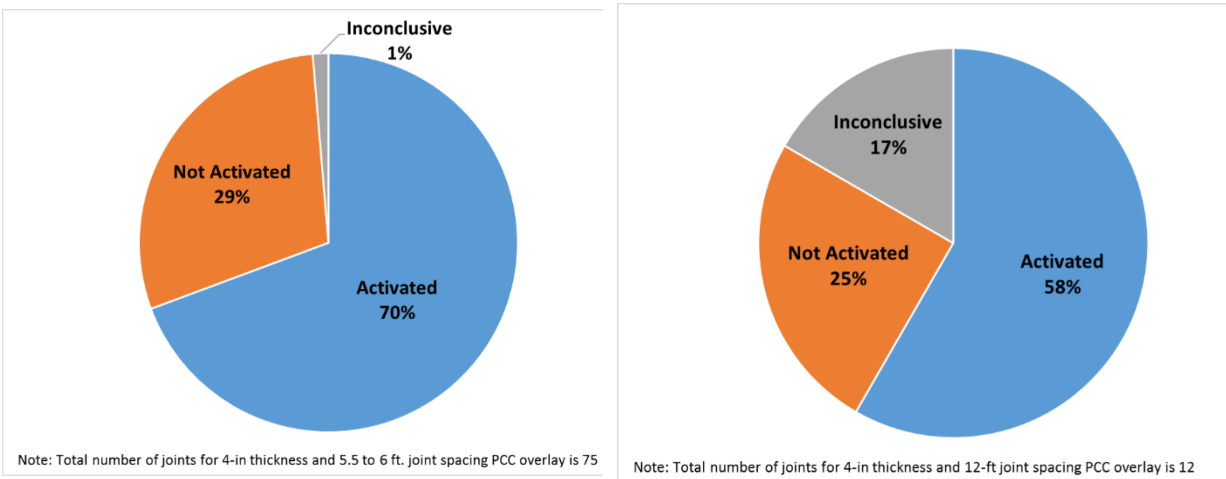
14- and 15-foot joint spacing



20- and 40-foot joint spacing

Figure 21. Percentage of joints activated for different joint spacing

As shown in Figure 22, longer joint spacing did not lead to increased joint activation. This may have been due to a limited sample size.



5.5- to 6-foot joint spacing 12-foot joint spacing

Figure 22. Percentage of joints activated for different joint spacing of 4-inch thick concrete overlays

As shown in Figure 23, longer joint spacing led to increased joint activation.

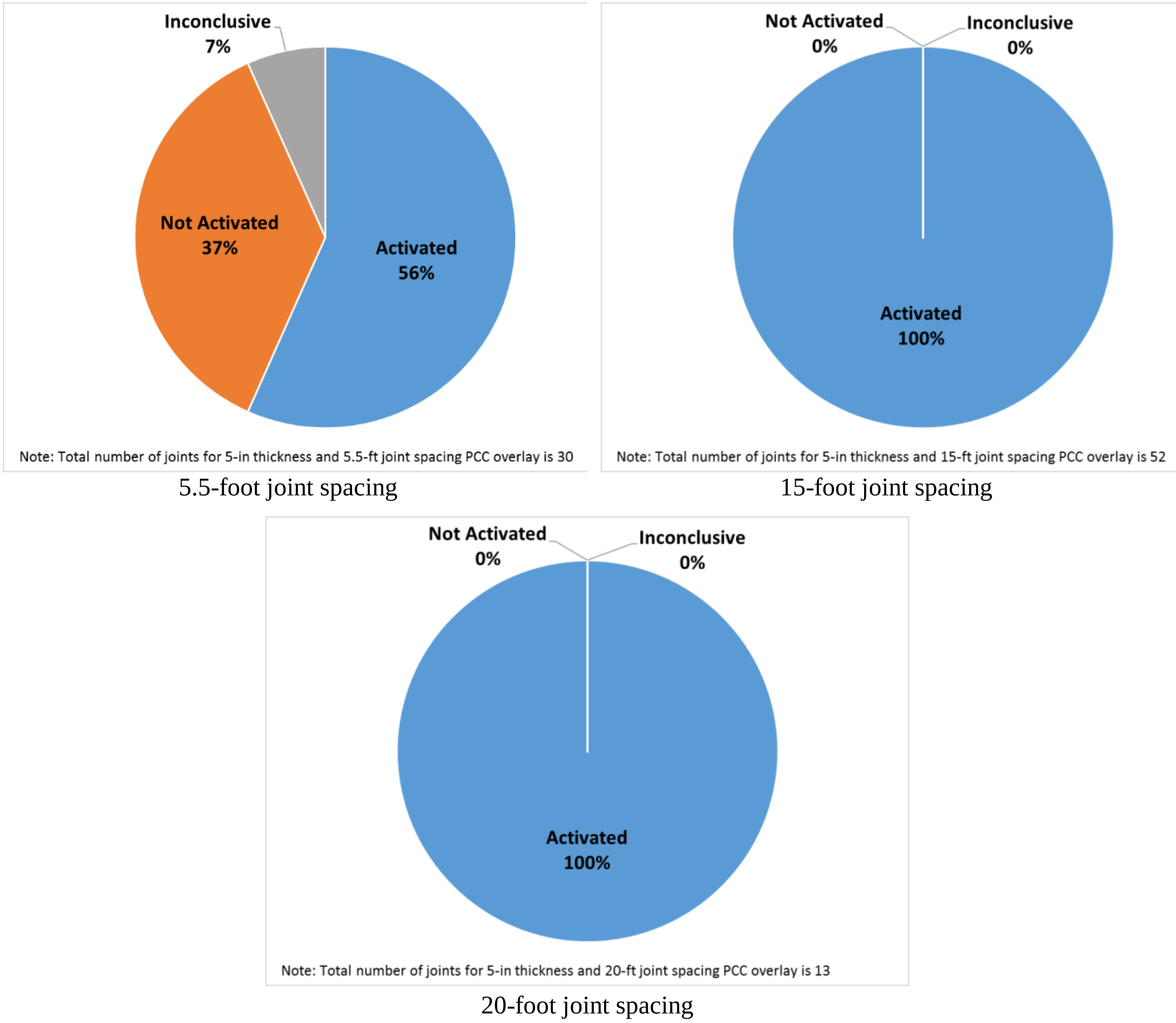
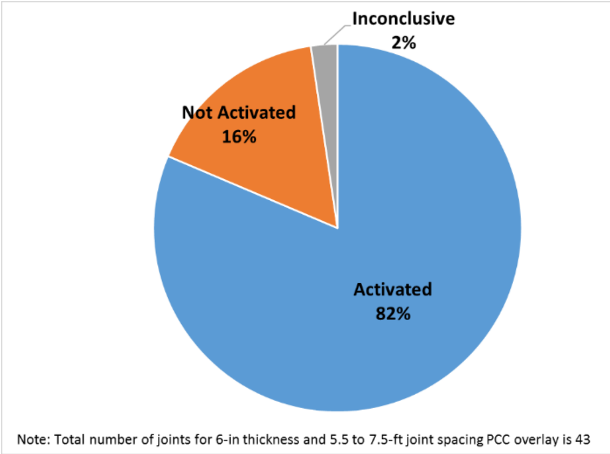
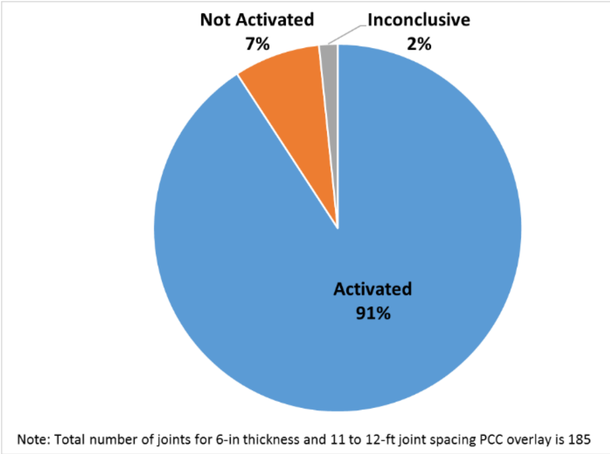


Figure 23. Percentage of joints activated for different joint spacing of 5-inch thick concrete overlays

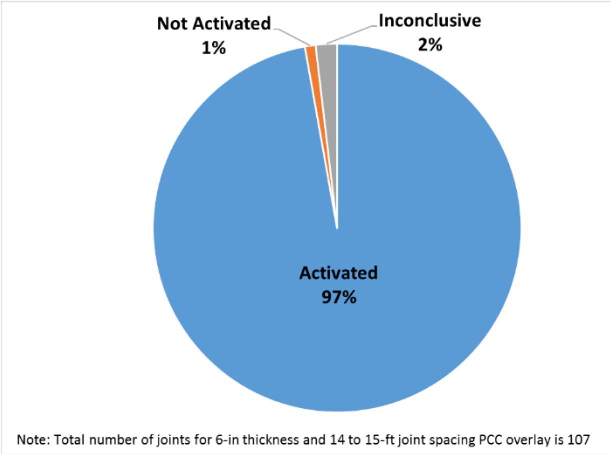
As shown in Figure 24, activation increased with increased joint spacing, except for the 40-foot set. This anomaly may have been due to a limited sample size.



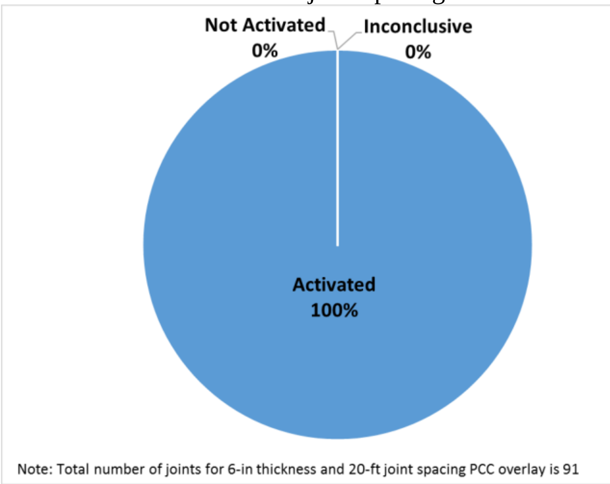
5.5- to 7.5-foot joint spacing



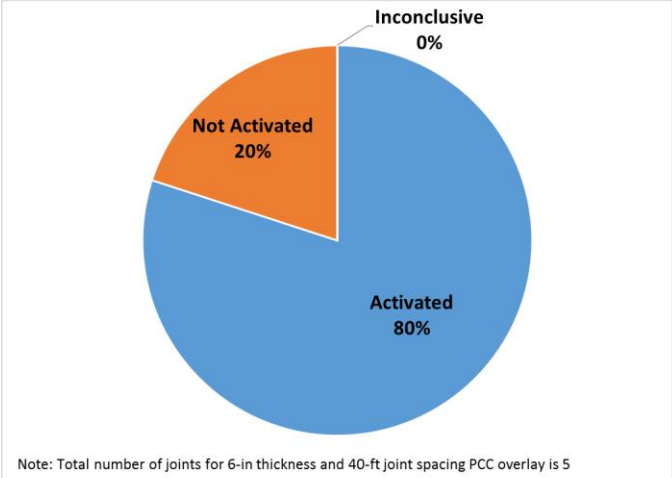
11- to 12-foot joint spacing



14- to 15-foot joint spacing



20-foot joint spacing



40-foot joint spacing

Figure 24. Percentage of joints activated for different joint spacing of 6-inch thick concrete overlays

Age

As shown in Figure 25, most of the joints were activated in overlays more than 10 years old.

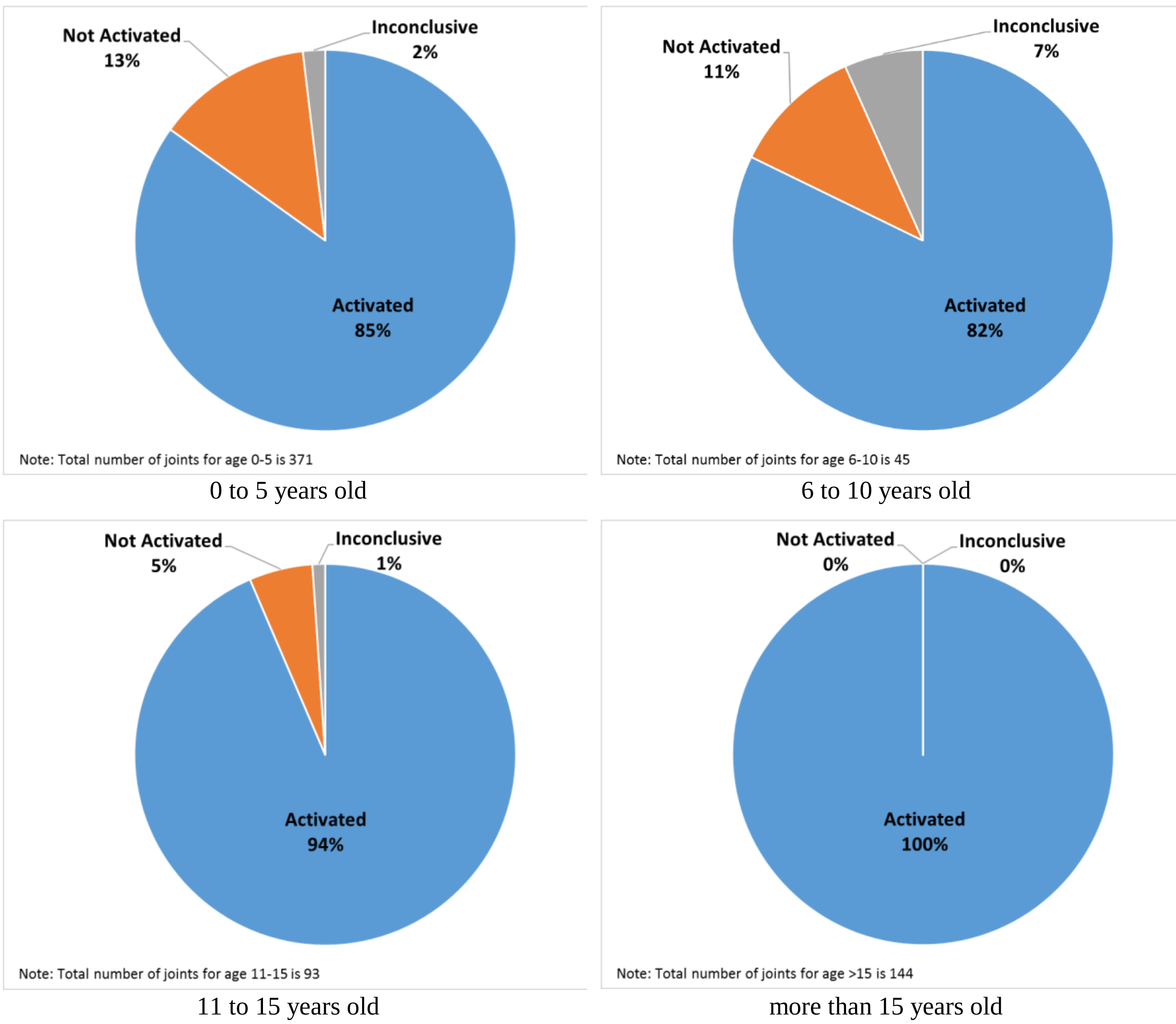
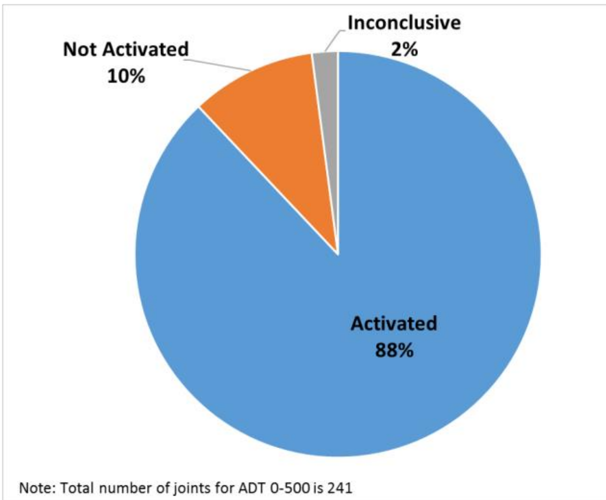


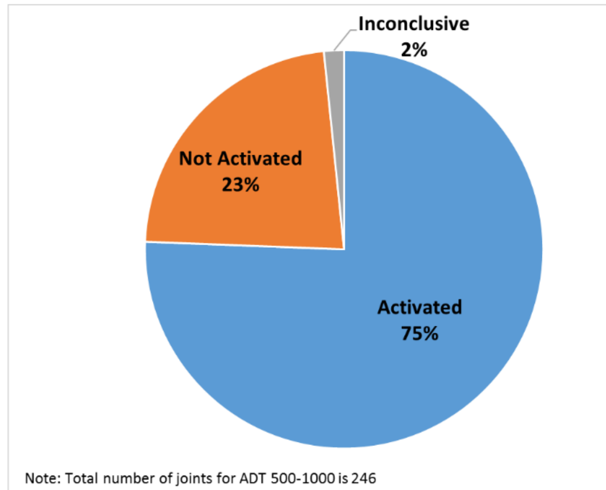
Figure 25. Percentage of joints activated for different overlay ages

Traffic Volume

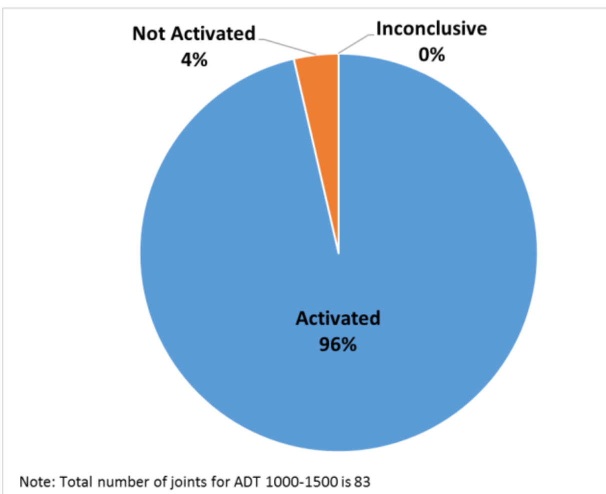
As shown in Figure 26, joint activation was not affected by traffic volume.



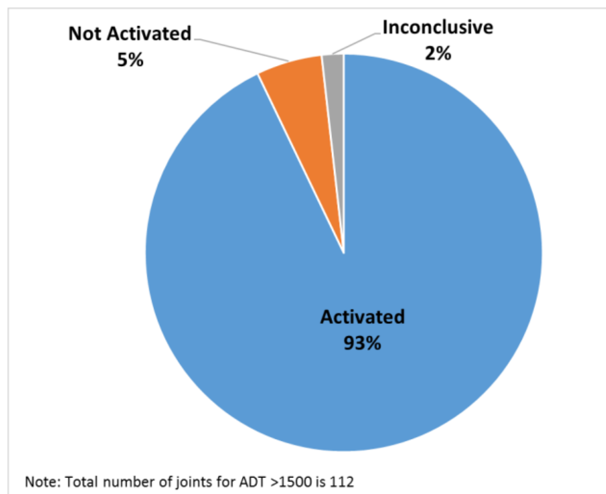
ADT 0 to 500



ADT 501 to 1,000



ADT 1,001 to 1,500



ADT more than 1,500

Figure 26. Percentage of joints activated for different traffic volumes

Key Findings

MIRA ultrasonic shear-wave tomography testing was used to measure joint activation on concrete overlays to develop recommendations for optimized joint spacing. The major findings are summarized as follows:

- Joint activation did not depend or vary based on overlay type (BCOA vs. UBCOC).
- In general, concrete overlays with longer joint spacing exhibited increased joint activation.
- In general, concrete overlays with greater thickness achieved increased percentages of joint activation.
- Joint activation rates did not vary with traffic volume.
- 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.
- After 10 years of service, most of the joints were activated. However, joints that did not activate were mostly confined to short slab sections that were 10 years old or younger.
- In concrete overlays with greater than 6-inch thickness and 12-foot or greater joint spacing, activation rates were high, often approaching 100%. Rates were lower in overlays that were thinner (4–5 inch) and with shorter joint spacing, often falling in the range of 60–80%.

CHAPTER 4 – NEW TEST SECTIONS

Introduction

The analytical investigation covered in Chapter 2 provided insights into the expected performance of concrete overlays with different joint spacing, and the field investigation covered in Chapter 3 analyzed data on joint activation behavior of existing concrete overlays. Alongside these studies, test sections were constructed in 2017 and 2018 to gain further insight into optimized joint spacing.

The construction of new concrete overlay test sections offered the ability 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.

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 unbonded concrete overlay of concrete built in Buchanan County, east of Dunkerton, in August 2018. Table 4 lists the design parameters for these two projects.

Table 4. Design of typical sections, Mitchell and Buchanan County overlay projects

Design Parameters	**Mitchell County IA 105**	**Buchanan County Road V-62**
Overlay Type	**BCOA (composite)**	**UBCOC**
Construction Date	August 2017	August 2018
Thickness (in.)	6	6
Transverse Joint Spacing (ft)	12	11
Longitudinal Joint Spacing (ft)	12	11
Traffic (AADT)	800	1,180
Interlayer Type	n/a	Geotextile
Fiber-Reinforcement	No	No

The exact locations of these projects can be found in the Appendix. Design parameters important to joint behavior were identified and a test matrix was developed to vary the test section designs based on typical design parameters.

Initially, it was thought that the conclusions and recommendations of the analytical investigation (Chapter 2) and field investigation (Chapter 3) would allow for refining the scope of the test sections to consider fewer variables. However, due to construction schedules, the test section designs needed to be finalized before results of those analyses were complete. Therefore, the test sections were designed with a wide range of variables without final input from the early phases of this study. Ultimately, the broad scope of the test sections was beneficial to the analysis, allowing for a greater understanding of joint spacing behavior.

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. Fiber-reinforcement was additionally 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 5 lists the full test matrix of test sections considered across the two projects.

Table 5. Design parameters for experimental test sections.

Project/ Overlay Type	Thickness (in.)	Joint Spacing (ft) (Transverse × Longitudinal)	Fiber-Reinforcement (lb/yd^3)
Mitchell County	4	6 × 6	0
			4
		12 × 12	0
			4
		15 × 12	0
			4
		20 × 12	0
			4
	6	6 × 6	0
			4
		12 × 12	0
			4
		15 × 12	0
			4
		20 × 12	0
			4
Buchanan County	6	5.5 × 5.5	0
			4
		11 × 11	0
			4
		15 × 11	0
			4
		20 × 11	0
			4
		30 × 11	0
			4
		40 × 11	0
			4

In keeping with the projects selected for the test sections, the two overlay types considered in this study were BCOA and UBCOC. Bonded concrete overlays on concrete (BCOCs) were not considered for study because joint spacing is controlled by the existing pavement. Thicker (over 6-inch) unbonded concrete overlays on asphalt (UBCOAs) were not considered for study because conventional concrete pavement joint spacings are used successfully on those types of projects. Additionally, some designers or practitioners might consider a 6-inch concrete overlay of asphalt to be a UBCOA project rather than a BCOA. Therefore, insights gained from the 6-inch test sections in Mitchell County are likely applicable to relatively thin UBCOA projects as well.

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

Diagrams of the test sections in Mitchell and Buchanan Counties are found in Figures 27 and 28, respectively.

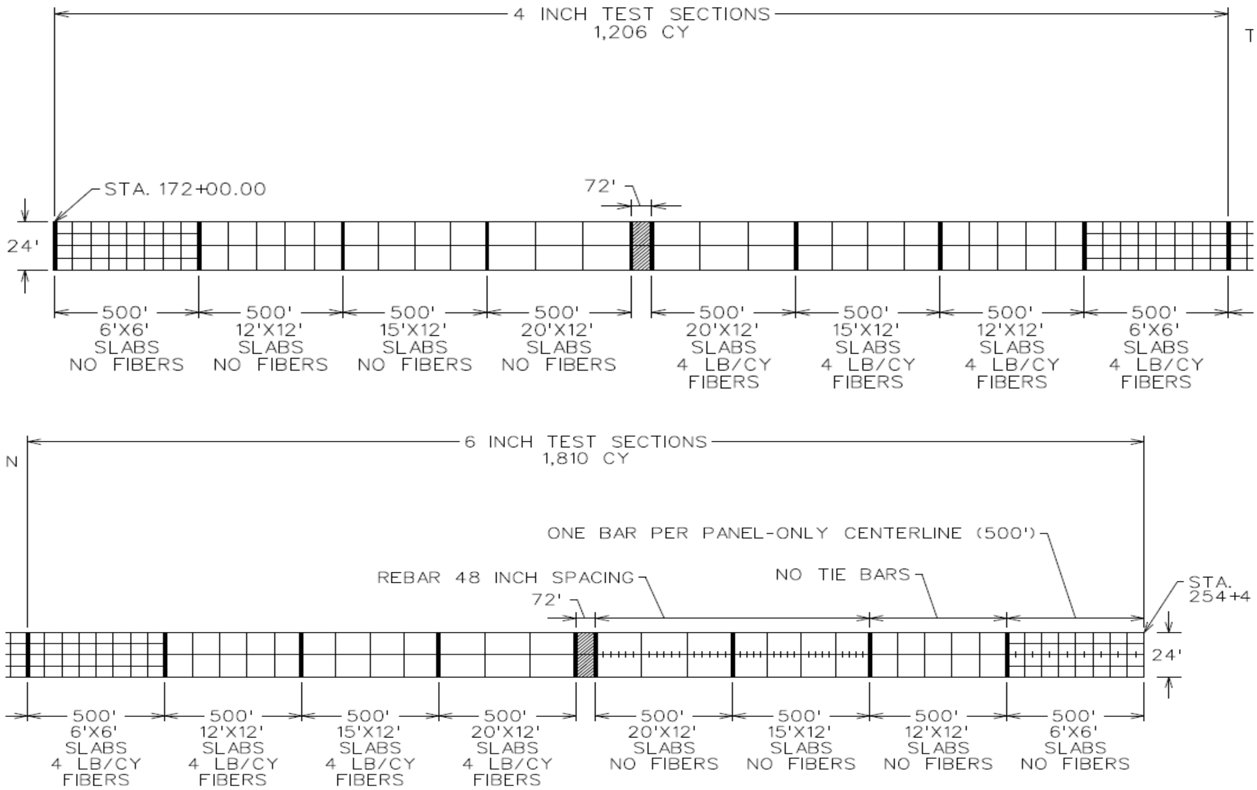


Figure 27. Mitchell County test section plan

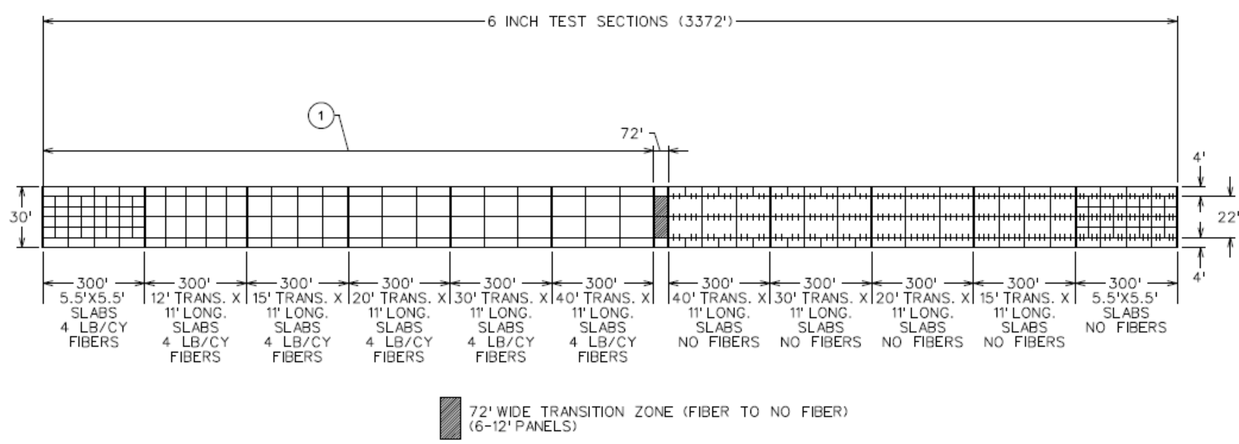


Figure 28. Buchanan County test section plan

The length of the test sections was chosen based on the ability to construct them contiguously in areas with consistent geometric design and between major intersections. The Mitchell County test sections were 500 feet long, while the Buchanan County test sections were 300 feet long. Transition areas were provided between sections with thickness changes and/or where fibers needed to be added to or removed from the mix.

An additional variable considered in the test sections was method of longitudinal joint reinforcement. In the fiber-reinforced test sections in both projects, fibers completely replaced tie steel at the centerline. In Buchanan County, which had integrally paved shoulders, fibers also replaced tie bars at the longitudinal joint with the shoulder. As seen in Figure 27, the Mitchell County project also featured reduced tie steel in the 6-inch, 6-foot slab test section without fibers and no tie steel in the 6-inch, 12-foot slab test section without fibers. While these factors will be of interest for future study, they did not have any observed early impacts on joint activation or other aspects of performance, so they are not discussed further in this report.

Figure 29 includes images from the August 2017 construction of the Mitchell County test sections.

Figure 29. Mitchell County construction showing addition of fibers at the batch plant (top left), paving (top right), finishing with burlap drag (bottom left), and curing and tining (bottom right)

Field Monitoring and Data Collection

Activation of transverse and longitudinal joints was measured and monitored using the same MIRA test method outlined in Chapter 3, except visual inspection was used in lieu of the MIRA device in the sections assessed before shouldering had been completed. The number of joints that were assessed in each test section is listed in Table 6.

Table 6. Joints assessed using the MIRA at test sections

Overlay location and type	Thickness (in.)	Joint spacing (ft)	Number of joints assessed using visual observation*	Number of joints assessed using MIRA*
Mitchell County (BCOA)	4	6	16	15
		12	8	12
		15	7	12
		20	5	12
	6	6	16	15
		12	8	12
		15	7	12
		20	5	12
Buchanan County (UBCOC)	6	5.5	18	15
		12	8	12
		15	7	12
		20	5	12
		30	3	7
		40	3	7

*Number of joints assessed for each section, both with and without fiber-reinforcement

After construction, multiple visits were made to each project to monitor the evolution of joint activation over time. Save for the initial visual inspection, all MIRA testing was performed over the same joints each time. These visits were intended to be made in approximately 90-day increments, but there was some variation in the actual dates of testing. Testing dates along with daily temperatures are listed in Table 7.

Table 7. Mitchell and Buchanan County testing dates and temperatures

Project	Test Date	Daily High (°F)	Daily Low (°F)	Day Average (°F)
Mitchell County	8/25/2017 (Visual Inspection)	69	55	62
	10/3/2017	73	50	62
	1/30/2018	29	-1	14
	5/9/2018	62	51	57
	11/30/2018	31	27	29
	4/4/2019	43	34	39
Buchanan County	8/14/2018 (Visual Inspection)	84	62	73
	4/3/2019	57	24	41

Results

Figures 30 through 43 present joint activation percentages measured for the various test sections over time, organized by thickness and joint spacing. Complete results for each transverse and longitudinal joint tested in every section are found in the Appendix.

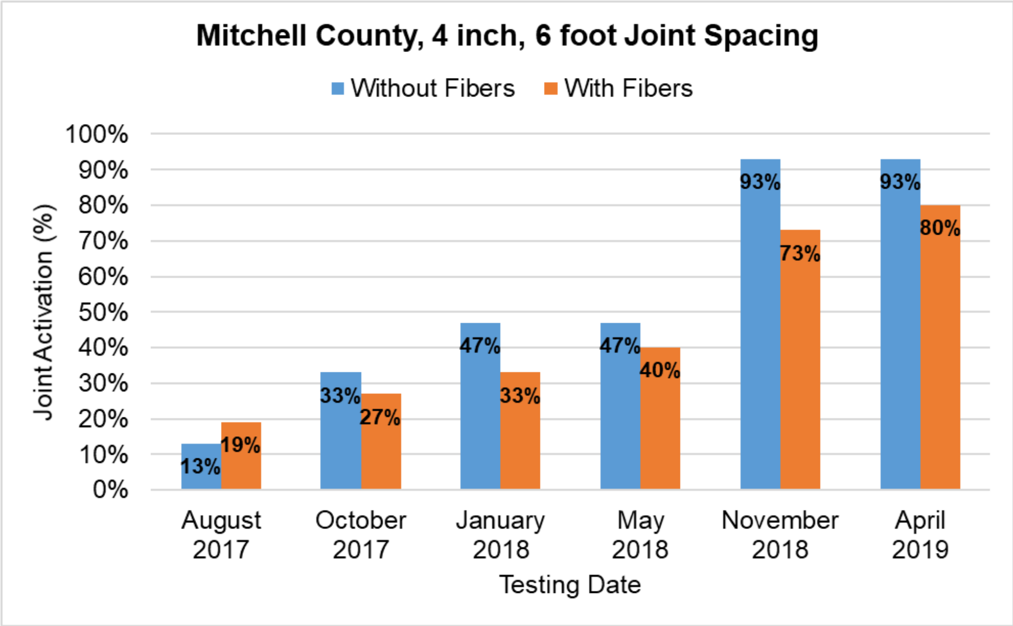


Figure 30. Joint activation results for Mitchell County, 4-inch, 6-foot joint spacing

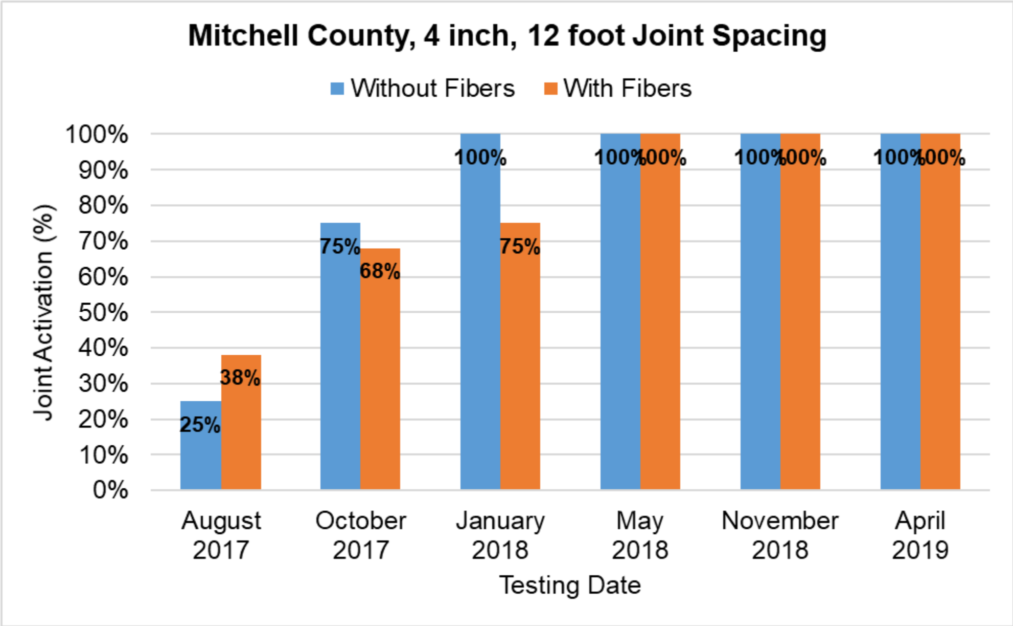


Figure 31. Joint activation results for Mitchell County, 4-inch, 12-foot joint spacing

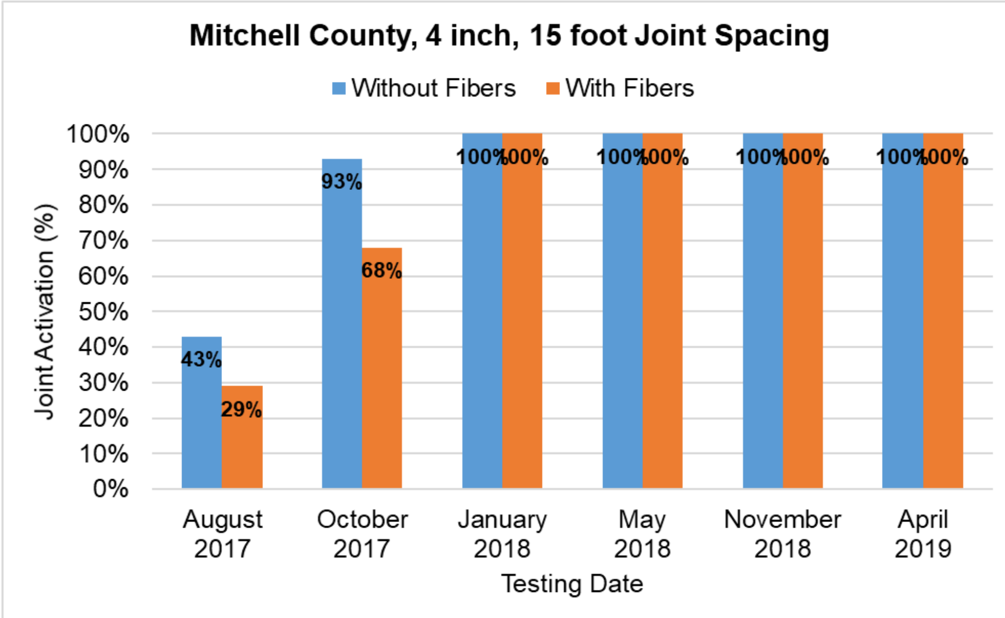


Figure 32. Joint activation results for Mitchell County, 4-inch, 15-foot joint spacing

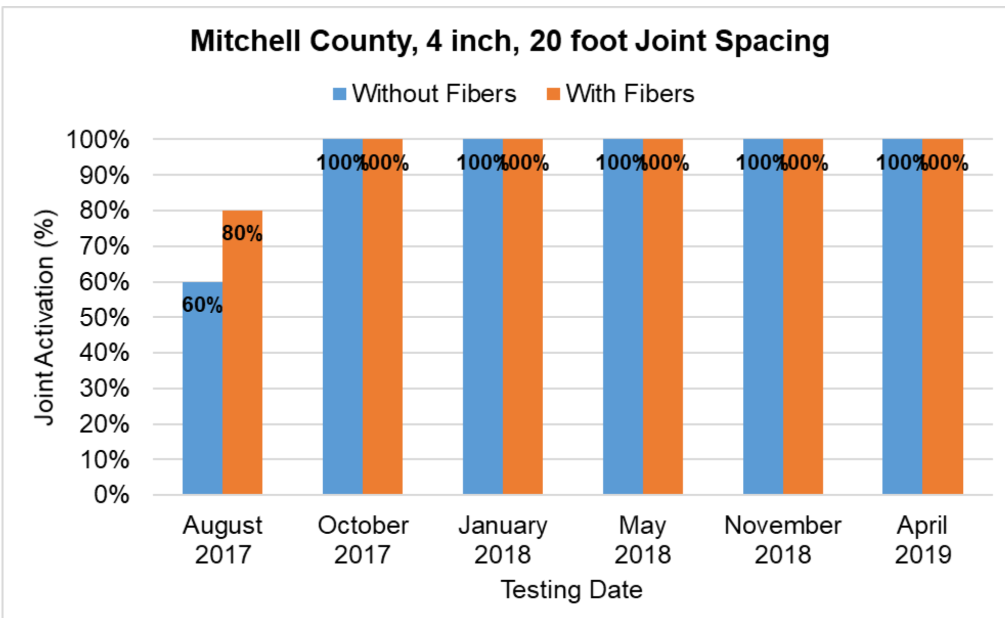


Figure 33. Joint activation results for Mitchell County, 4-inch, 20-foot joints

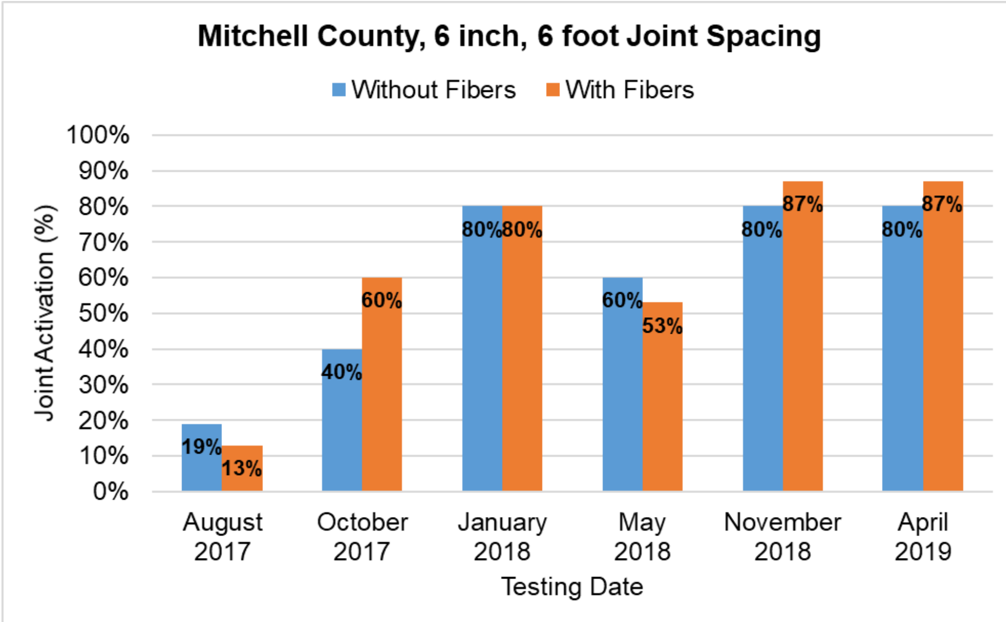


Figure 34. Joint activation results for Mitchell County, 6-inch, 6-foot joint spacing

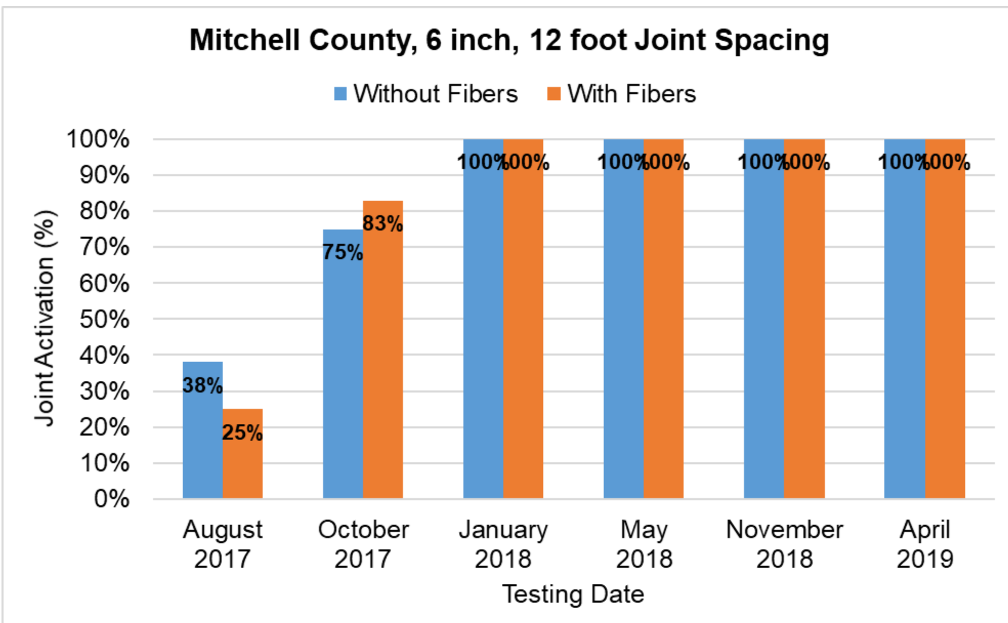


Figure 35. Joint activation results for Mitchell County, 6-inch, 12-foot joint spacing

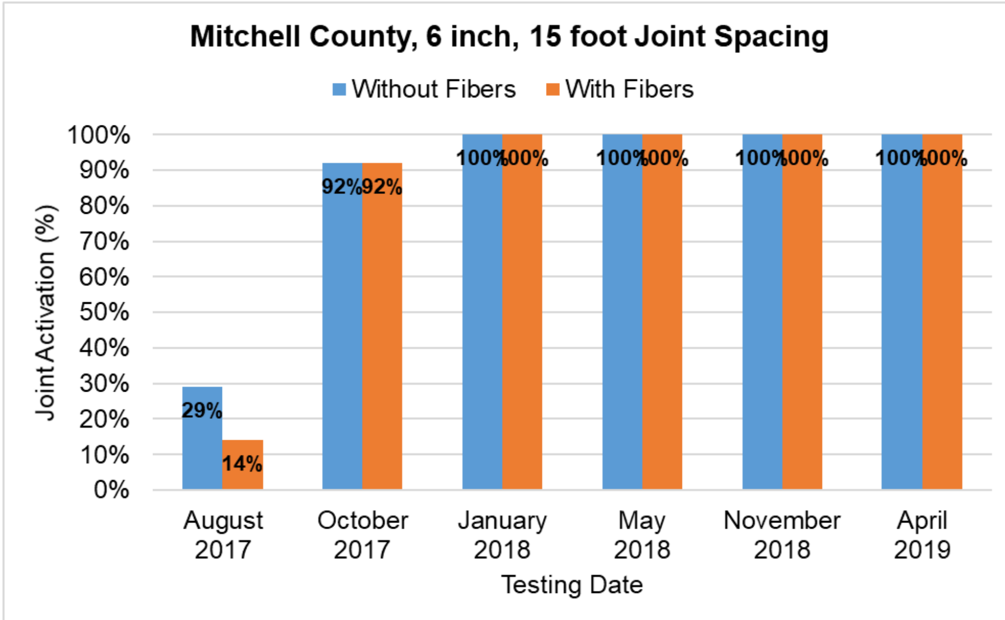


Figure 36. Joint activation results for Mitchell County, 6-inch, 15-foot joint spacing

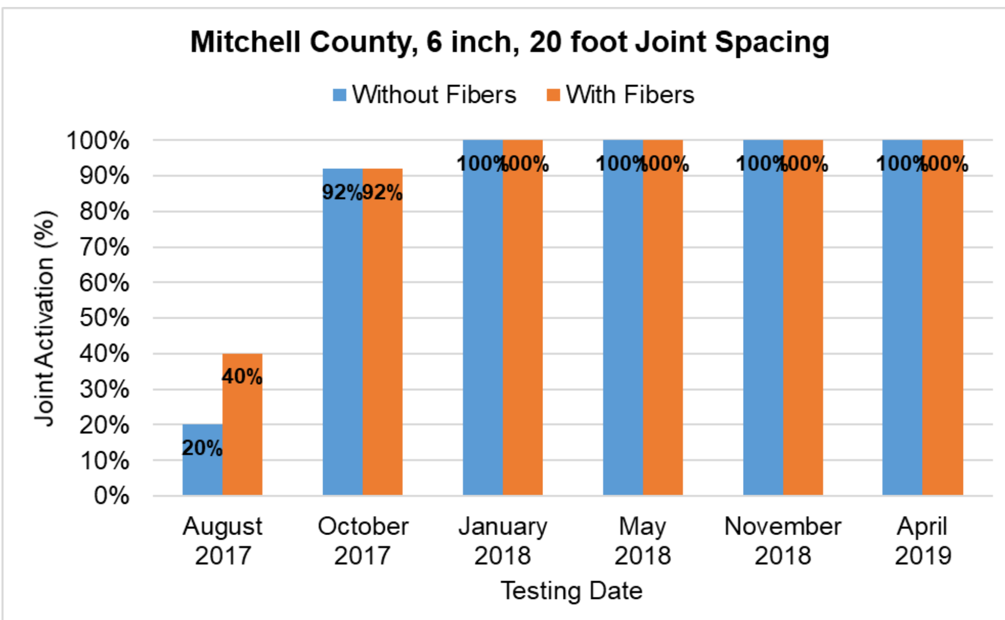


Figure 37. Joint activation results for Mitchell County, 6-inch, 20-foot joint spacing

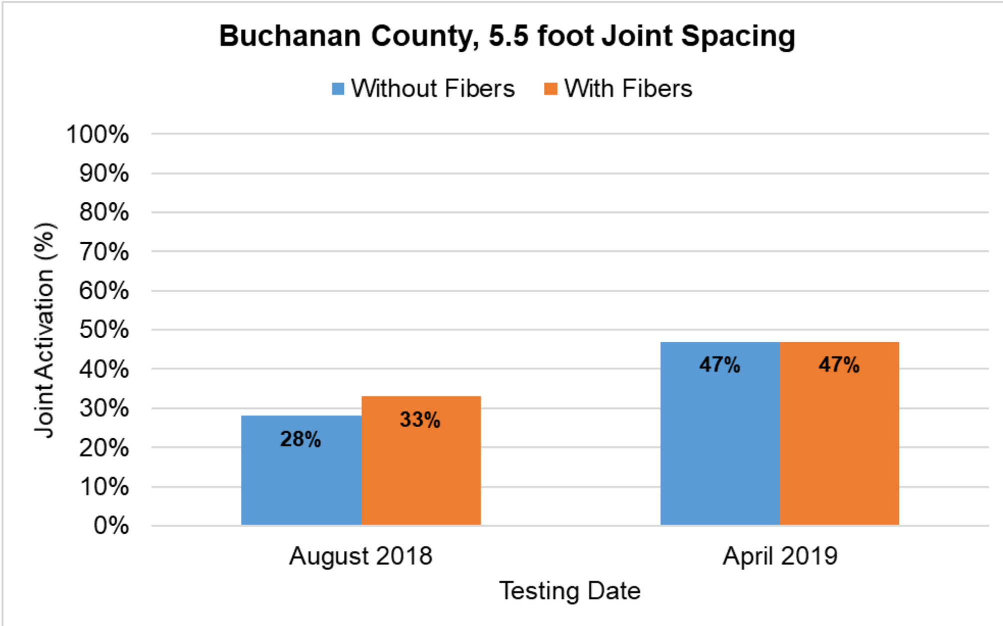


Figure 38. Joint activation results for Buchanan County, 5.5-foot joint spacing

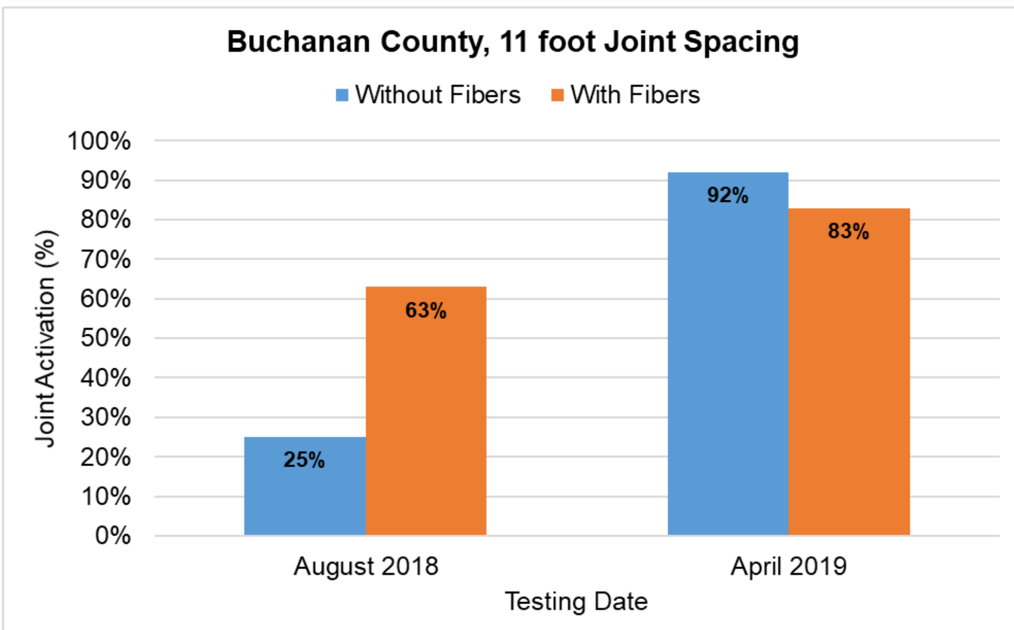


Figure 39. Joint activation results for Buchanan County, 11-foot joint spacing

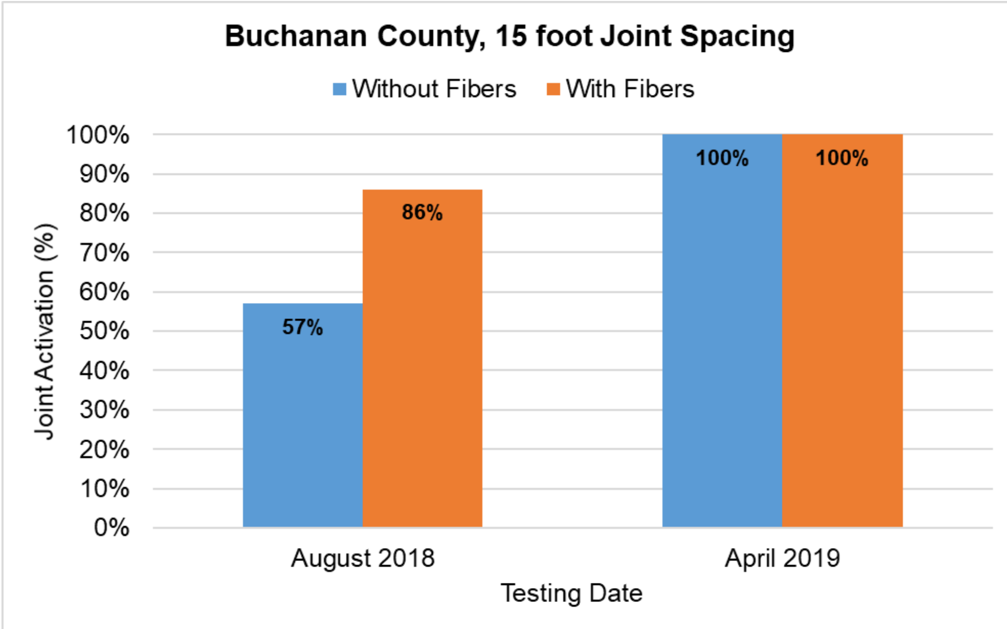


Figure 40. Joint activation results for Buchanan County, 15-foot joint spacing

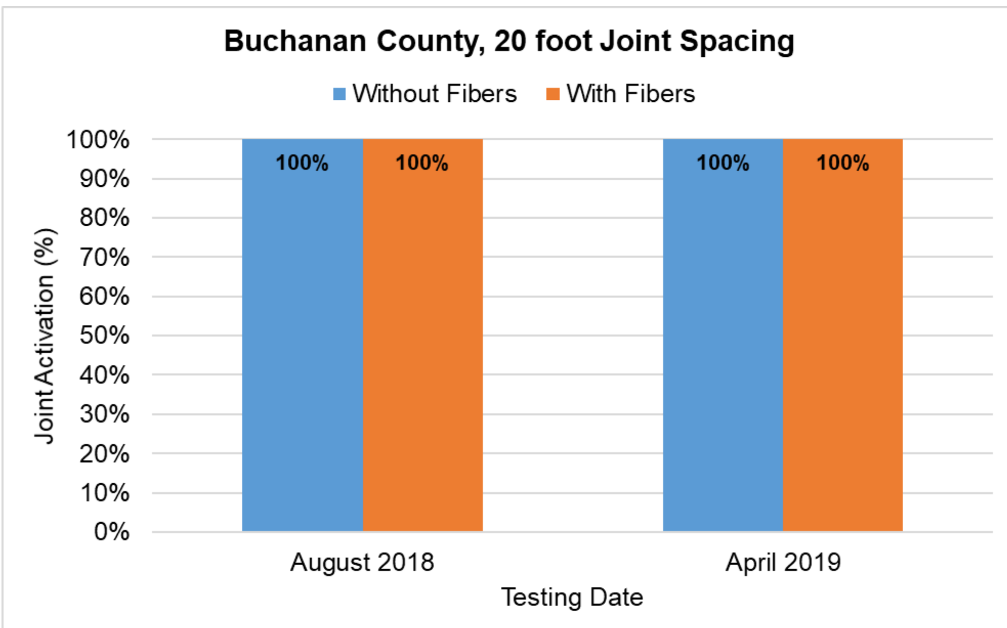


Figure 41. Joint activation results for Buchanan County, 20-foot joint spacing

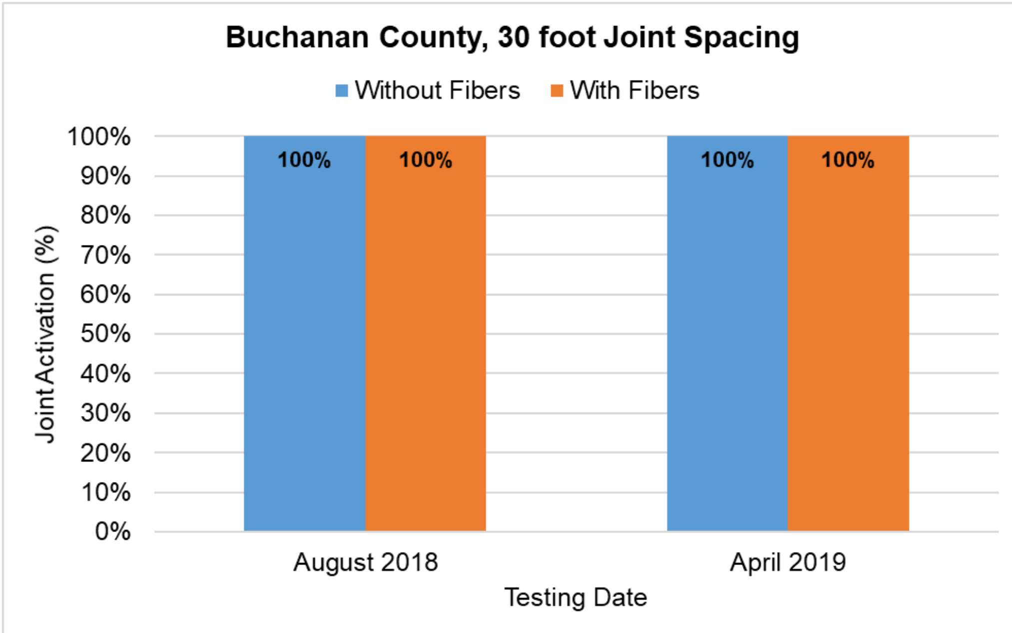


Figure 42. Joint activation results for Buchanan County, 30-foot joint spacing

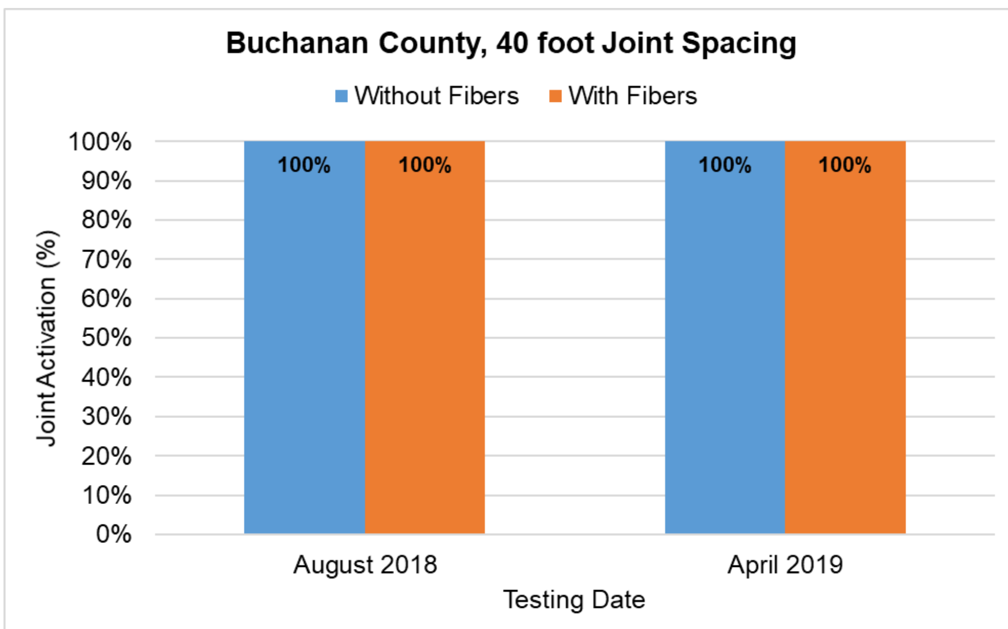


Figure 43. Joint activation results for Buchanan County, 40-foot joint spacing

Analysis and Discussion

General 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 by the time of the initial visual inspection just after construction. The rest of the sections began with varying rates of un-activated joints.

The progression of joint activation and ultimate 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-inch sections than in the 4-inch sections. Fiber-reinforcement was not observed to have a significant impact on the rate of joint activation or ultimate activation rates. These findings are discussed in more detail below.

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 30, 34 and 38. 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, after about a year post-construction, virtually all joints in sections with 12-foot joint spacing or greater went on to crack. The Buchanan County 11-foot 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-foot sections.

The higher degree of activation observed in sections with longer joint spacing is consistent with the findings in existing concrete overlays in Chapter 3. These relationships make sense given that, fundamentally, shrinkage-related stresses increase as joint spacing increases (Roesler and Wang 2009). Curling-related stresses also increase with increased joint spacing (Harrington and Fick 2014), which is also an important factor in joint activation (Roesler and Wang 2009).

Given the observations in this study, a more detailed analysis of slab geometry was carried out to better understand joint activation behavior and help optimize joint spacing design for concrete overlays. This analysis is detailed in the next subsection.

Detailed Analysis of Slab Size Effects

Bradbury (1938) provided insight into the parameters influencing pavement stresses. The curling stress of concrete can be estimated as:

Curling interior stress, $\sigma_t = \frac{E\alpha\Delta T}{2}\left[\frac{C_x+\mu C_y}{1-\mu^2}\right]$ **(3)**

Curling edge stress, $\sigma_t = \frac{CE\alpha\Delta T}{2}$ **(4)**

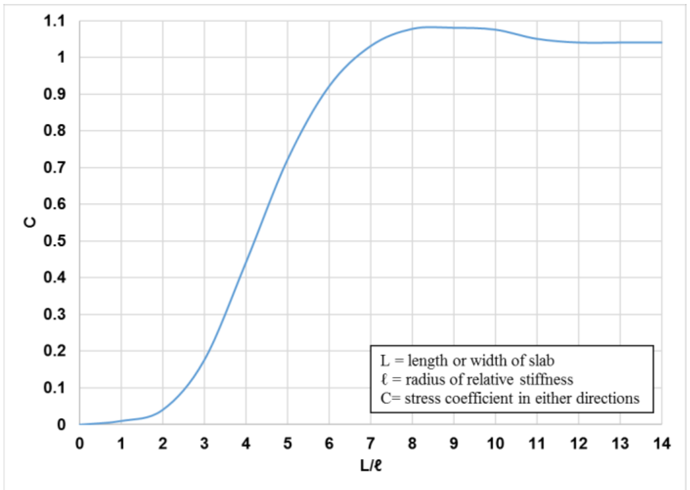
where, σ_t is the slab curling stress, $C_{x,y}$ are the stress coefficients for a finite slab, E is the modulus of elasticity, α is the coefficient of thermal expansion, and ΔT is the temperature differential between the top and bottom of the slab.

The stress coefficients depend on the radius of relative stiffness, ℓ, between the slab and foundation, defined by Westergaard (1927) as:

$\ell = \sqrt[4]{\frac{Eh^3}{12k(1-\mu^2)}}$ **(5)**

where, E is the modulus of elasticity, h is the slab thickness, μ is Poisson's ratio, and k is the modulus of subgrade reaction.

As seen in Figure 44, a higher ratio of slab length to radius of relative stiffness, L/ℓ, in the range from 1 to 8, leads to an increase in the stress coefficient for a finite slab.



Adapted from Bradbury 1938

Figure 44. Differential curling stress coefficient (C) for different values of the ratio of slab length and radius of relative stiffness (L/ℓ)

Outside of the range of L/ℓ from 1 to 8, slab proportions have little effect on stress coefficient. In those ranges, the temperature differential between the top and bottom of the slab becomes the most important parameter with respect to curling stress.

Figure 45 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 seen in the figure, 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-inch thick test sections, L/ℓ ranges from 2.9 and 9.5, while for the 6-inch sections, L/ℓ ranges from 2.5 to 8.4.

As seen in Figure 45, as L/ℓ increases, the rate of joint activation increases, especially with increasing time after construction.

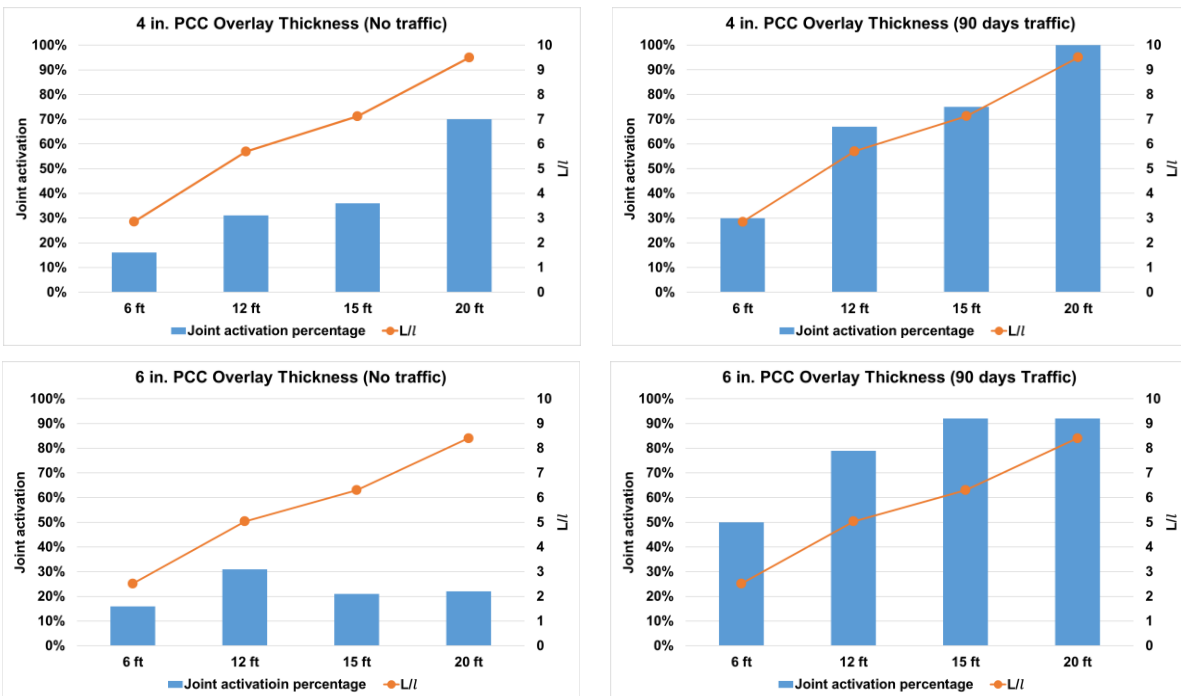


Figure 45. Joint activation vs. L/ℓ and joint spacing for Mitchell County concrete overlay test sections

Figure 46 presents the relationship between joint activation and L/ℓ in the Buchanan County test sections immediately after construction.

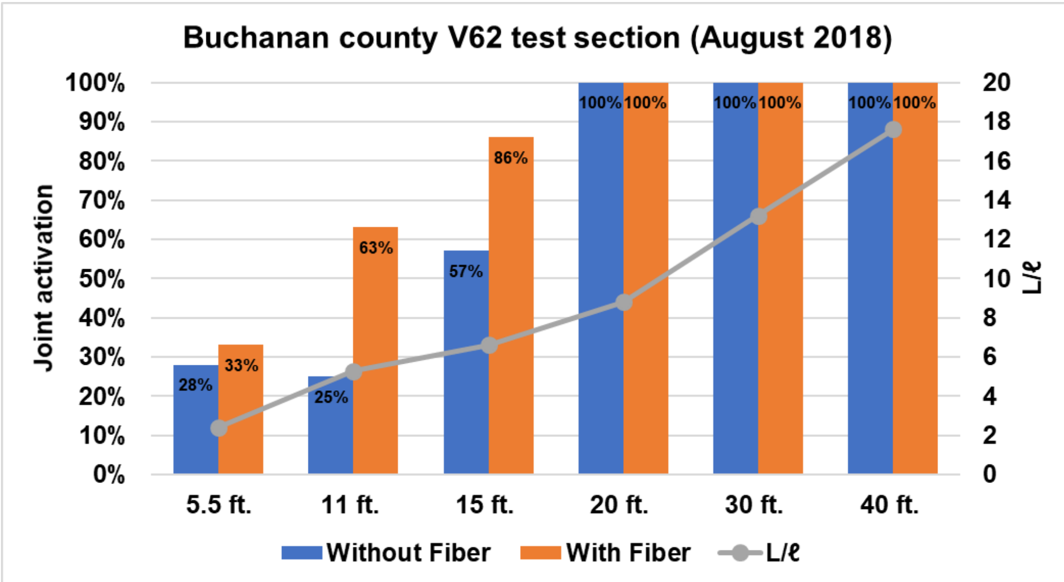


Figure 46. Joint activation vs. L/ℓ and joint spacing for Buchanan County concrete overlay test sections

Again, there is a strong correlation suggesting increased joint activation with higher L/ℓ.

The similarities between the trends in Figures 45 and 46 indicate that L/ℓ is a good indicator for helping quantify the correlation between longer joint spacing and a higher, faster rate of joint activation. Analyzing L/ℓ and its fundamental relationship with the stresses responsible for joint activation indicate that it is a factor that should be considered to help determine optimum joint spacing for a concrete overlay.

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, 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.

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. Designers may wish to seek joint spacing that leads to L/ℓ values that are sufficient to ensure timely activation of joints without risking negative performance impacts. Based on the relationships shown in Figures 45 and 46, designing to achieve L/ℓ values between 4 and 7 may be optimal.

Effect of Thickness on Joint Activation

In Mitchell County, where test sections were built at both 4 and 6 inches, thickness did not appear to have a large impact on joint activation, particularly when looking at sections with 12-foot joint spacing and greater. However, some differences were observed when comparing the 6-foot slab sections.

Figures 30 and 34 show joint activation rates in Mitchell County in the 4- and 6-inch thick short-slab test sections, respectively. In these figures, it can be seen that, during the first winter of service (January 2018), just 33–47% of joints had activated in the 4 inch thick sections, while 80% of joints had activated in the 6-inch sections. These findings reflect similar differences observed in the analysis of exiting overlays in Chapter 4, where all 4-inch overlays had a slightly lower joint activation rate (68%) compared to 5-inch (86%) and 6-inch (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- and 6-inch test sections by 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. Dominant joints sometimes lead to poor joint performance due to loss of load transfer (Gross et al. 2017, King and Roesler 2014).

Relative to thickness, joint spacing had a far more significant impact on joint activation in these test sections. The magnitude of impact of thickness on joint activation at short joint spacing is small compared to that of joint spacing. This is evident based on comparing a short-slab (5.5- to 6-foot) with approximately 50% joint activation, to a conventional (>12 foot) slab with nearly 100% joint activation within the first year of service. This can be observed by comparing the results of Figure 30 with Figures 31 through 33, and Figure 34 with Figures 35 through Figure 37. Thickness did not appear to have any effect on joint activation behavior when joint spacing was 12-foot or longer.

That said, based on observations in Mitchell County and in the existing Iowa overlays analyzed in Chapter 4, thickness may have a small impact on rate of joint activation in concrete overlays with 5.5- to 6-foot spacing. Future study specific to overlays with short slabs may be helpful to further analyze these differences.

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).

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. They will, however, as observed, help to limit the width of the cracks over time.

Despite no observed effect on joint activation, because of their ability to keep cracks and joints tight, fiber-reinforcement may still provide benefits to joint performance and crack control. In fact, these benefits were observed immediately in the Mitchell County project.

After the first winter of service, reflective cracking was observed in both the typical section and the test sections with fiber reinforcement. However, cracking was significantly reduced in the fiber-reinforced test sections, and when it did appear, the cracks were noticeably thinner than in the sections without fiber reinforcement. Side-by-side examples are shown in Figure 47.

Figure 47. Comparison of reflective cracks developed in test sections without fibers (left) to those with fiber reinforcement (right)

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 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.

Apparent Effect of Temperature on MIRA Measurements

In two Mitchell County test sections, the joint activation percentage appeared to decrease over time. These two examples can be seen in Figure 34, where joint activation drops in the 6-inch, 6-foot joint spacing test sections, both with and without fibers, between January and May 2018. The full results in the Appendix show that several transverse joints in these sections switch from a "crack" to a "no crack" result between the two tests.

Given that joints should not be able to "de-activate," it is likely that these observations reflect a temperature effect on the accuracy of the MIRA measurements. When temperatures drop, slabs contract and joints and cracks open. Conversely, when temperatures rise, slabs expand and joints and cracks close. As shown previously in Table 5, the average temperature on the day of the January testing was just 14°F, while the average temperature during testing in May was 57°F.

Based on these results, it appears that the MIRA test method can detect certain thin cracks in cold weather, but it is not sensitive enough to detect those same cracks in warmer temperatures. Notably, when the next set of test results were obtained in cooler temperatures (29°F) in November 2018, the results appeared to correct themselves and resumed the normal trend of increasing activation over time.

Despite this flaw in the test method, it is intuitive to understand and can be accounted for in analysis. It should be noted that this effect was only observed for shorter (5.5- to 6-foot) slab sizes. At more conventional joint spacing, the MIRA test appears to be sufficiently sensitive to avoid temperature effects.

Conclusions

Concrete overlay test sections were constructed in Mitchell and Buchanan Counties in August 2017 and August 2018, respectively, to further investigate joint activation behavior. These new test sections allowed for more controlled comparison of factors including thickness, joint spacing, fiber-reinforcement, and overlay type, and allowed for monitoring of the evolution of joint activation at regular intervals post-construction. Major findings and recommendations are summarized as follows:

- 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, sections with conventional joint spacing achieved nearly 100% joint activation. Un-activated joints were confined mainly to short slab sections.

- 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.

- 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 (4-inch) overlays demonstrated slightly slower joint activation rates than thicker (6-inch) 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.

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

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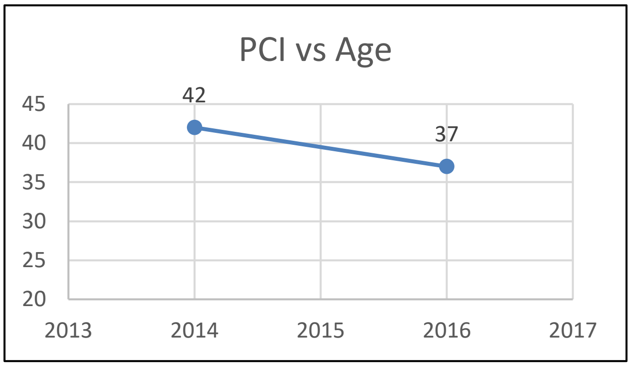
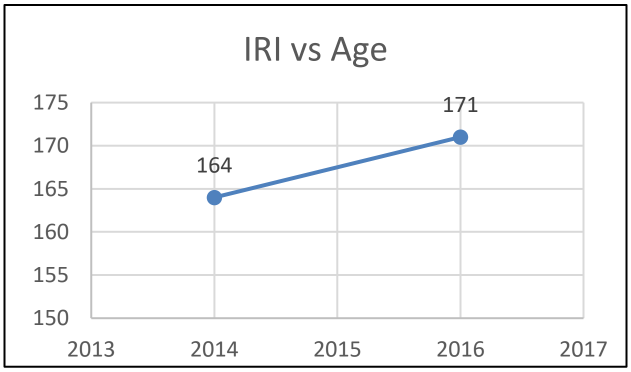
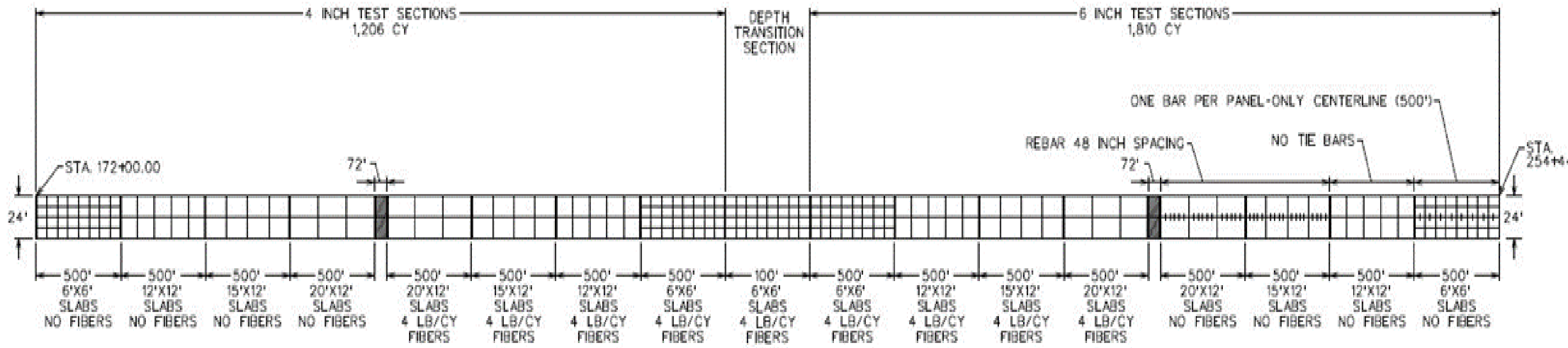
APPENDIX

Mitchell County Test Sections

Location	Mitchell Co.
Road	IA 105
Thickness	4.0" and 6.0"
Overlay Type	UBCOA
Traffic (AADT)	800
Date	4/3/2019
Time	9:20 AM (600 days test)
Temp	42°






4 INCH TEST SECTIONS
1,206 CY
DEPTH TRANSITION SECTION
6 INCH TEST SECTIONS
1,810 CY
ONE BAR PER PANEL-ONLY CENTERLINE (500')
REBAR 48 INCH SPACING
NO TIE BARS
STA. 172+00.00
STA. 254+44
72'
72'
24'
24'
500' 6'X6' SLABS NO FIBERS
500' 12'X12' SLABS NO FIBERS
500' 15'X12' SLABS NO FIBERS
500' 20'X12' SLABS NO FIBERS
500' 20'X12' SLABS 4 LB/CY FIBERS
500' 15'X12' SLABS 4 LB/CY FIBERS
500' 12'X12' SLABS 4 LB/CY FIBERS
500' 6'X6' SLABS 4 LB/CY FIBERS
100' 6'X6' SLABS 4 LB/CY FIBERS
500' 6'X6' SLABS 4 LB/CY FIBERS
500' 12'X12' SLABS 4 LB/CY FIBERS
500' 15'X12' SLABS 4 LB/CY FIBERS
500' 20'X12' SLABS 4 LB/CY FIBERS
500' 20'X12' SLABS NO FIBERS
500' 15'X12' SLABS NO FIBERS
500' 12'X12' SLABS NO FIBERS
500' 6'X6' SLABS NO FIBERS

Visual Inspection on 6-Inch Test Sections without Fiber

6-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	Crack
T3	No crack
T4	No crack
T5	No crack
T6	No crack
T7	No crack
T8	Crack
T9	No crack
T10	No crack
T11	No crack
T12	No crack
T13	Crack
T14	No crack
T15	No crack
T16	No crack

12-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	No crack
T3	No crack
T4	Crack
T5	No crack
T6	No crack
T7	Crack
T8	No crack

15-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	Crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack

20-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	No crack
T3	Crack
T4	No crack
T5	No crack

MIRA Testing on 6-Inch Test Sections without Fiber

90-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	No crack
T7	No crack
T8	Crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	No crack
L2	No crack
L3	No crack
L4	No crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	No crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	Crack
L2	No crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	No crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	No crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

180-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack
T6	Crack
T7	No crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

270-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack
T6	No crack
T7	No crack
T8	Crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

480-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack
T6	Crack
T7	No crack
T8	Crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack

600-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack
T6	Crack
T7	No crack
T8	Crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack

Visual Inspection on 6-Inch Test Sections with Fiber

6 ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	No crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack
T8	No crack
T9	No crack
T10	No crack
T11	No crack
T12	No crack
T13	No crack
T14	No crack
T15	No crack
T16	Crack

12 ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	Crack
T3	No crack
T4	No crack
T5	No crack
T6	No crack
T7	Crack
T8	No crack

15 ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	No crack
T3	No crack
T4	No crack
T5	Crack
T6	No crack
T7	No crack

20 ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	Crack
T3	No crack
T4	Crack
T5	No crack

MIRA Testing on 6-Inch Test Sections without Fiber

90-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	No crack
T7	Crack
T8	Crack
T9	No crack
T10	No crack

Test No	MIRA Result
L1	No crack
L2	Crack
L3	Crack
L4	No crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	No crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	No crack
L3	-
L4	-
L5	-

180-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	No crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	No crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

270-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	No crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	No crack
T8	No crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	No crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

480-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	No crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

600-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	No crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

Visual Inspection on 4-Inch Test Sections without Fiber

6-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	No crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack
T8	No crack
T9	No crack
T10	No crack
T11	No crack
T12	No crack
T13	No crack
T14	Crack
T15	No crack
T16	No crack

12-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	Crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack
T8	No crack

15-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	Crack
T3	No crack
T4	Crack
T5	No crack
T6	Crack
T7	No crack

20-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	No crack

MIRA Testing on 4-Inch Test Sections without Fiber

90-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	No crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	No crack
L2	No crack
L3	No crack
L4	Crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	Crack
T3	Crack
T4	Crack
T5	No crack
T6	Crack
T7	No crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	No crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

180-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	No crack
T3	No crack
T4	Crack
T5	No crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	No crack

Test No	MIRA Result
L1	No crack
L2	No crack
L3	Crack
L4	Crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

270-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	No crack
T3	No crack
T4	Crack
T5	Crack
T6	Crack
T7	No crack
T8	No crack
T9	Crack
T10	Unknown

Test No	MIRA Result
L1	No crack
L2	No crack
L3	Crack
L4	Crack
L5	No crack

480-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

600-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	No crack

Visual Inspection on 4-Inch Test Sections with Fiber

6-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	No crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack
T8	No crack
T9	No crack
T10	Crack
T11	No crack
T12	No crack
T13	No crack
T14	No crack
T15	No crack
T16	Crack

12-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	No crack
T3	No crack
T4	Crack
T5	No crack
T6	No crack
T7	Crack
T8	No crack

15-ft Joint Spacing

Joint number	Joint activation
T1	No crack
T2	No crack
T3	Crack
T4	No crack
T5	No crack
T6	No crack
T7	Crack

20-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack

MIRA Testing on 4-Inch Test Sections with Fiber

90-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	Crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack
T8	Crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	No crack
L2	No crack
L3	No crack
L4	No crack
L5	No crack

12-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	No crack
T5	Crack
T6	No crack
T7	Crack
T8	Crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	No crack
L2	No crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	No crack
T4	Crack
T5	Crack
T6	Crack
T7	No crack
T8	Crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	No crack
L2	No crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

180-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	No crack
T3	No crack
T4	No crack
T5	No crack
T6	Crack
T7	No crack
T8	No crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	No crack
L3	No crack
L4	Crack
L5	Crack

12-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	No crack
T7	Crack
T8	Crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	No crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

20-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

270-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	No crack
T3	Crack
T4	No crack
T5	No crack
T6	Unknown
T7	Crack
T8	No crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	No crack
L3	No crack
L4	Crack
L5	Crack

480-Day Test

6-ft Joint Spacing

Test No	MIRA Result
T1	No crack
T2	Crack
T3	Crack
T4	Crack
T5	No crack
T6	Crack
T7	Crack
T8	Crack
T9	No crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	No crack
L4	Crack
L5	Crack

600-Day Test

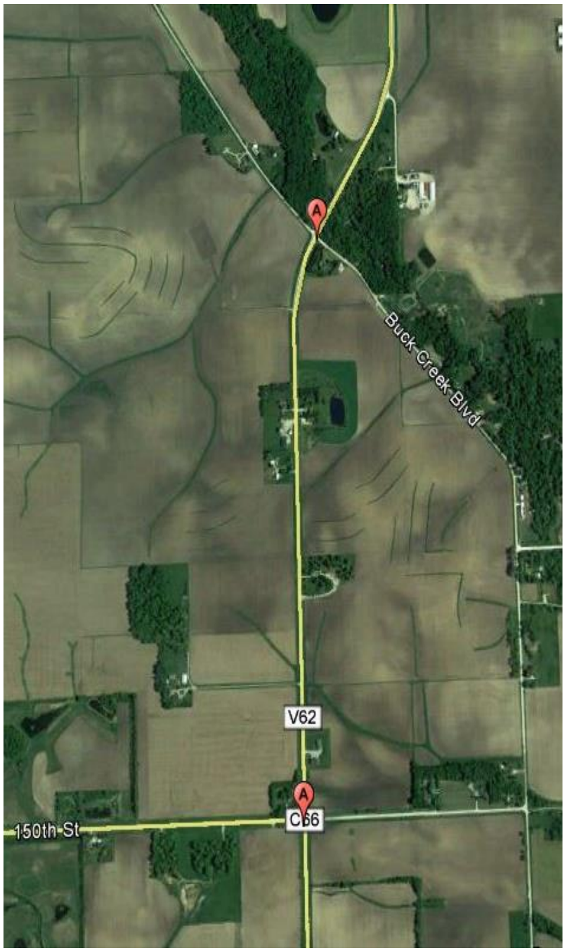
6-ft Joint Spacing

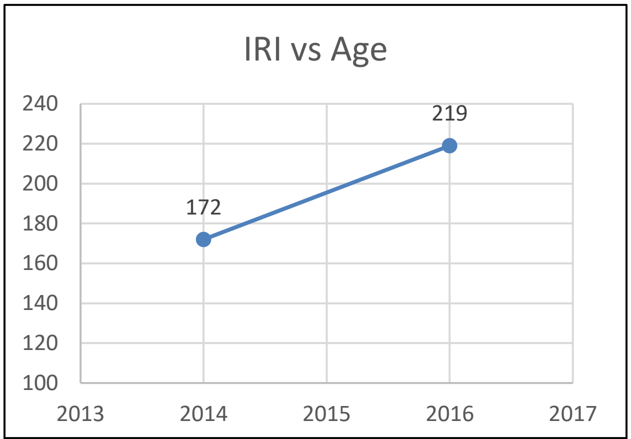
Test No	MIRA Result
T1	No crack
T2	Crack
T3	Crack
T4	Crack
T5	No crack
T6	Crack
T7	Crack
T8	Crack
T9	No crack
T10	Crack

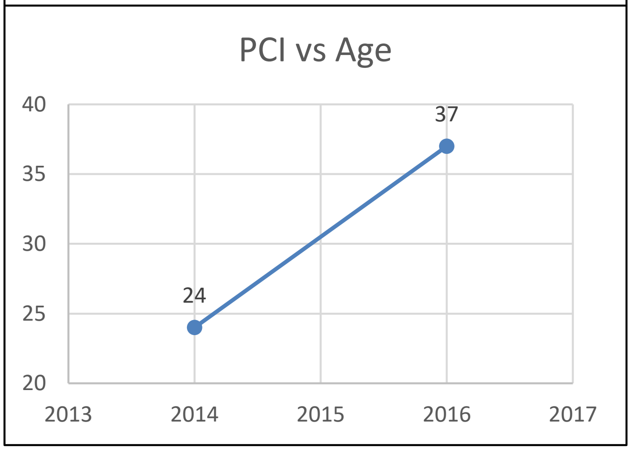
Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack

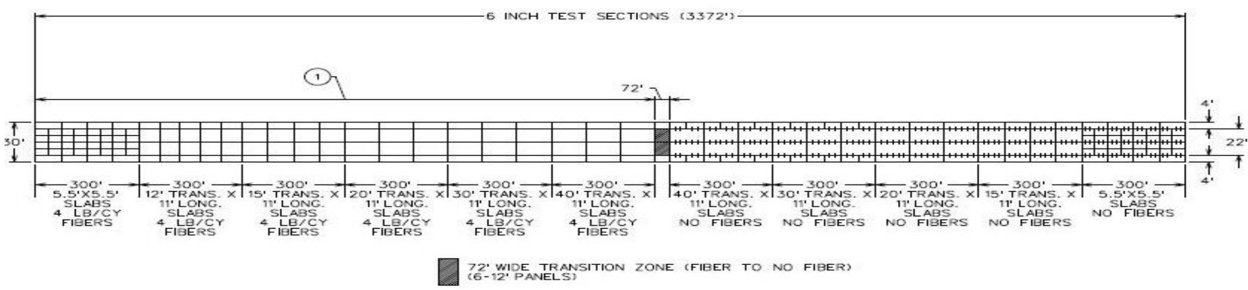
Buchanan County Test Sections

Location	Buchanan Co.
Road	V62
Thickness	6.0"
Overlay Type	UBCOC
Traffic (AADT)	1180
Date	4/3/2019
Time	9:45 AM
Temp	57°









Visual Inspection of Test Sections without Fiber (August 2018)

6-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	No Crack
T3	No Crack
T4	No Crack
T5	No Crack
T6	Crack
T7	No Crack
T8	No Crack
T9	Crack
T10	No Crack
T11	No Crack
T12	No Crack
T13	Crack
T14	No Crack
T15	No Crack
T16	Crack
T17	No Crack
T18	No Crack

15-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	No Crack
T3	Crack
T4	No Crack
T5	Crack
T6	No Crack
T7	Crack

12-ft Joint Spacing

Joint number	Joint activation
T1	No Crack
T2	No Crack
T3	No Crack
T4	No Crack
T5	Crack
T6	No Crack
T7	Crack
T8	No Crack

20-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack

30-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack

40-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack

MIRA Test at 240 Days on Test Sections without Fiber

5.5-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	No Crack
T3	Crack
T4	No Crack
T5	No Crack
T6	Crack
T7	No Crack
T8	No Crack
T9	Crack
T10	No Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	No Crack
L5	No Crack

12-ft Joint Spacing

Test No	MIRA Result
T1	No Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

Visual Inspection of Test Sections with Fiber (August 2018)

6-ft Joint Spacing

Joint number	Joint activation
T1	No Crack
T2	Crack
T3	No Crack
T4	No Crack
T5	Crack
T6	No Crack
T7	No Crack
T8	No Crack
T9	Crack
T10	No Crack
T11	Crack
T12	No Crack
T13	No Crack
T14	No Crack
T15	Crack
T16	No Crack
T17	Crack
T18	No Crack

15-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	No Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack

12-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	No Crack
T4	Crack
T5	No Crack
T6	Crack
T7	Crack
T8	No Crack

20-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack

30-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack

40-ft Joint Spacing

Joint number	Joint activation
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack

MIRA Test at 240 Days on Test Sections with Fiber

5.5-ft Joint Spacing

Test No	MIRA Result
T1	No Crack
T2	Crack
T3	No Crack
T4	Crack
T5	No Crack
T6	Crack
T7	No Crack
T8	Crack
T9	No Crack
T10	Crack

Test No	MIRA Result
L1	No Crack
L2	No Crack
L3	No Crack
L4	Crack
L5	Crack

12-ft Joint Spacing

Test No	MIRA Result
T1	No Crack
T2	Crack
T3	No Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

15-ft Joint Spacing

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

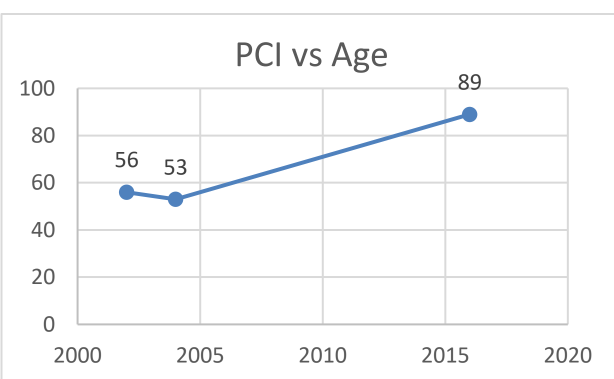
Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

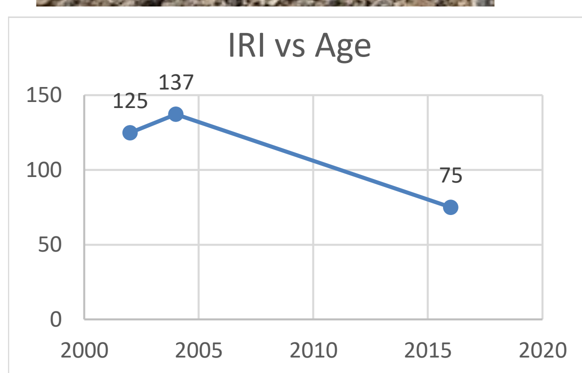
Field Test Summary Sheets

Location	Worth County
Road	510th St
Road ID	1476
Thickness	5.0"
Overlay Type	UBCOC
Traffic (AADT)	570
Transverse Joint Spacing	5.5'
Date	8/2/2017
Time	10:15 AM
Temp	-

Test No	MIRA Result
T1	Unknown
T2	No Crack
T3	No Crack
T4	Crack
T5	No Crack
T6	No Crack
T7	Crack
T8	No Crack
T9	Crack
T10	No Crack

Test No	MIRA Result
L1	Crack
L2	No Crack
L3	No Crack
L4	Crack
L5	Crack

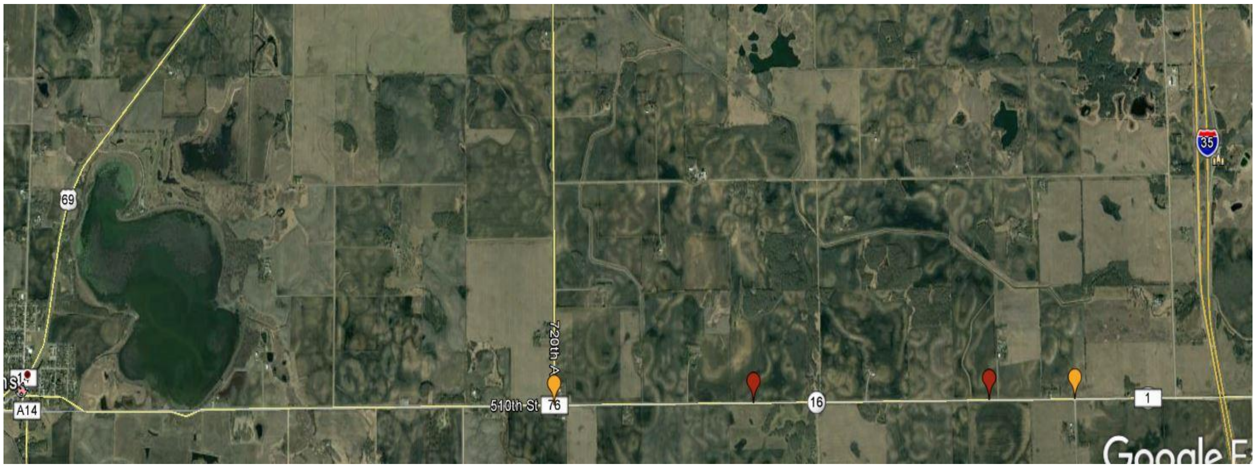




Location	Worth County
Road	510th St
Road ID	1476
Thickness	5.0"
Overlay Type	BCOA
Traffic (AADT)	480
Transverse Joint Spacing	5.5'
Date	8/2/2017
Time	11:00 AM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Unknown
T3	Crack
T4	No Crack
T5	Crack
T6	No Crack
T7	Crack
T8	No Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack



Location	Worth County
Road	Mallard Ave
Road ID	1368
Thickness	4.0"
Overlay Type	BCOA
Traffic (AADT)	310
Transverse Joint Spacing	5.5'
Date	8/2/2017
Time	12:00 PM
Temp	-

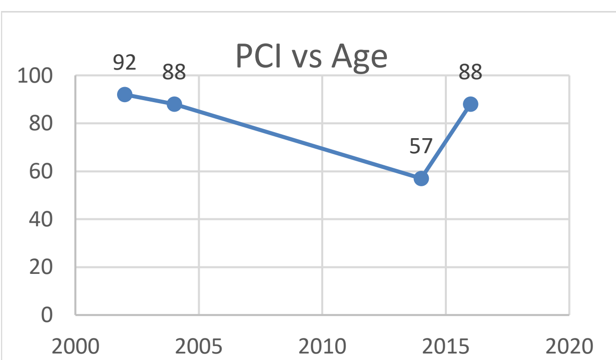
Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

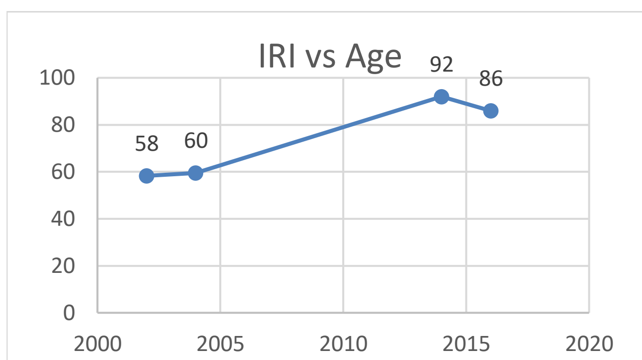
Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack

Location	**Mitchell County**
Road	A23/465th St
Road ID	1498
Thickness	4.0"
Overlay Type	BCOA
Traffic (AADT)	460
Transverse Joint Spacing	5.5'
Date	8/2/2017
Time	1:30 PM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	No Crack
T5	No Crack
T6	Crack
T7	No Crack
T8	No Crack
T9	No Crack
T10	No Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack

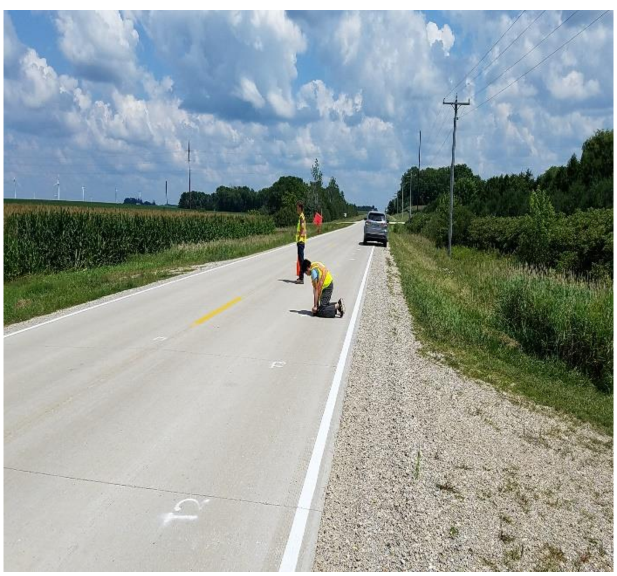




Location	Mitchell County
Road	A23/465th St
Road ID	1498
Thickness	4.0"
Overlay Type	BCOA
Traffic (AADT)	460
Transverse Joint Spacing	11'
Date	8/2/2017
Time	2:15 PM
Temp	-

Test No	MIRA Result
T1	Crack
T2	No Crack
T3	Unknown
T4	Crack
T5	No Crack
T6	No Crack
T7	Crack
T8	Unknown
T9	Crack
T10	Crack

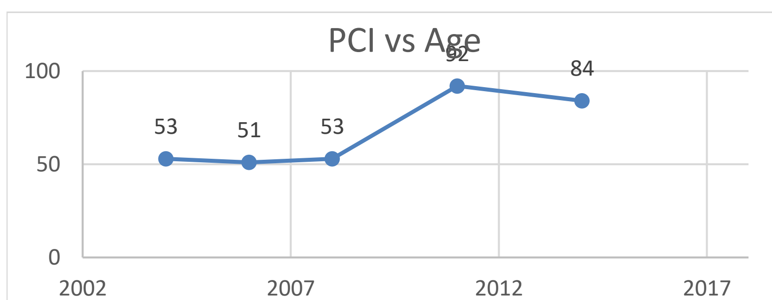
Test No	MIRA Result
L1	Crack
L2	Crack
L3	-
L4	-
L5	-

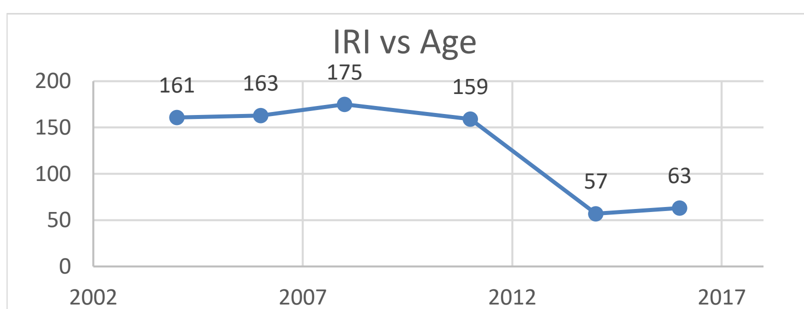


Location	Buchanan Co.
Road	D22
Road ID	1433
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	1410
Transverse Joint Spacing	Varies
Date	8/9/2017
Time	11:00 AM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	-
L2	-
L3	-
L4	-
L5	-

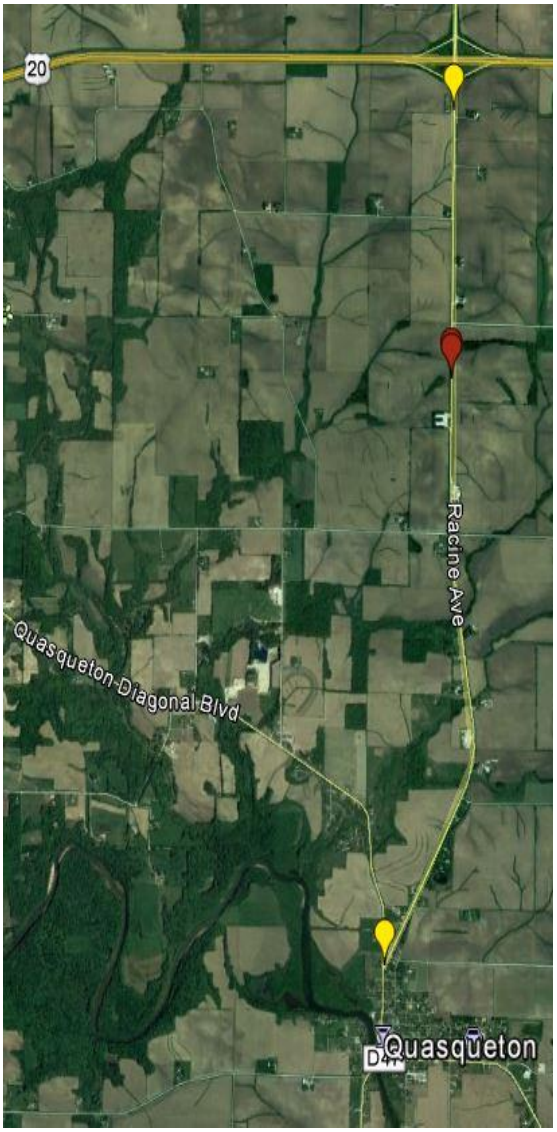


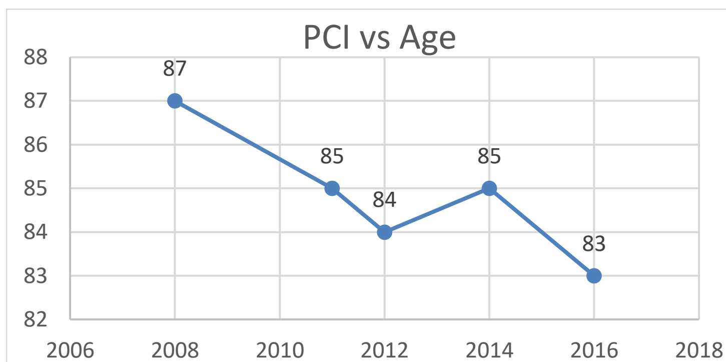


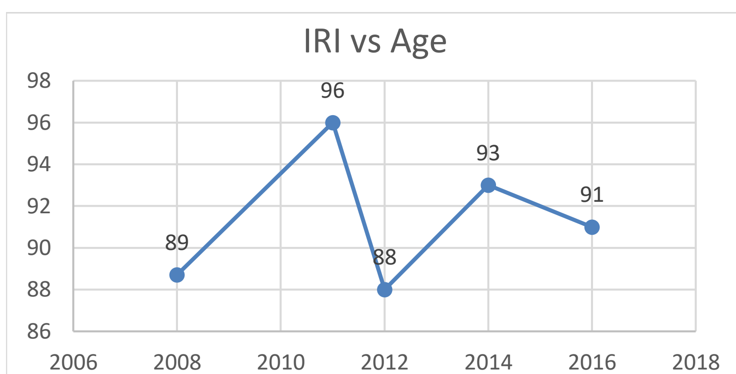
Location	**Buchanan Co.**
Road	W40
Road ID	1274
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	1640
Transverse Joint Spacing	11'
Date	8/9/2017
Time	12:00 PM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



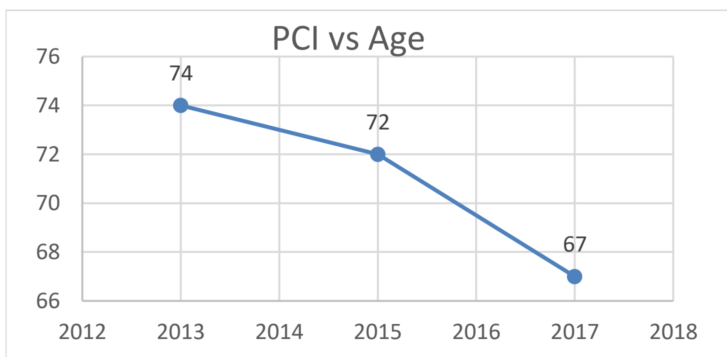


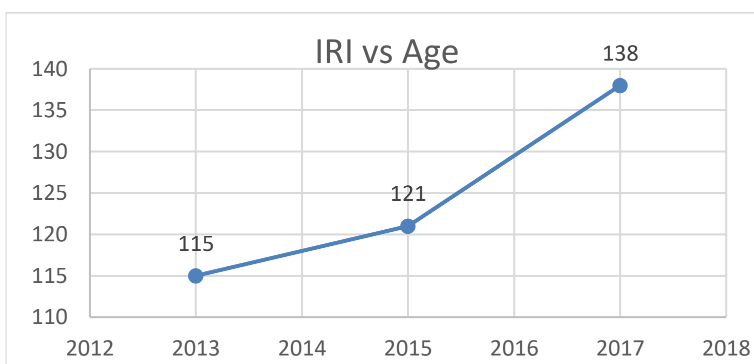


Location	Delaware Co.
Road	220th Ave
Road ID	1217
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	650
Transverse Joint Spacing	15'
Date	8/9/2017
Time	1:30 PM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	No Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

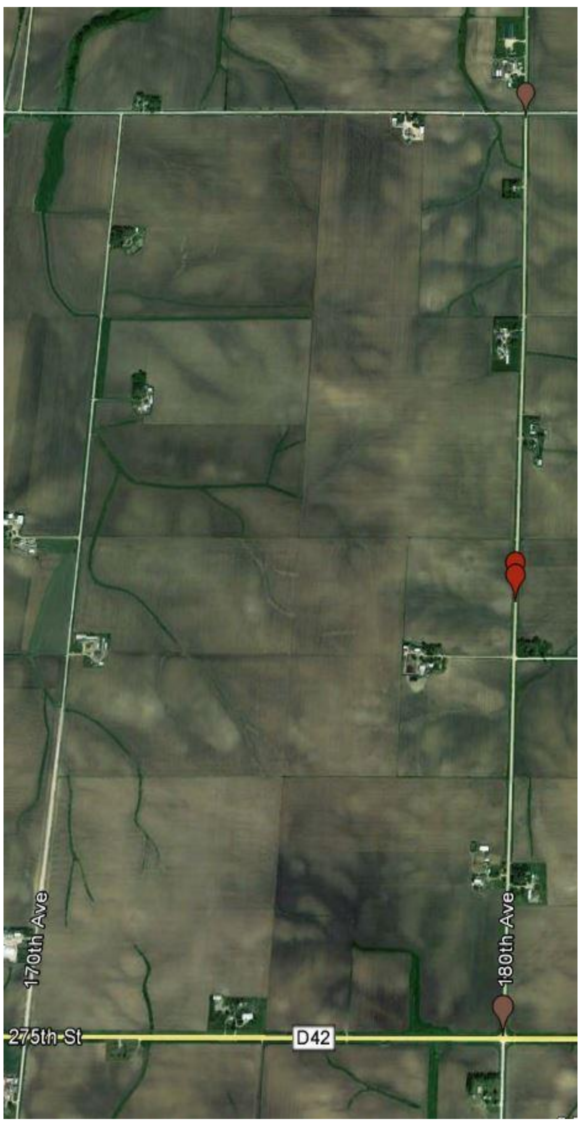


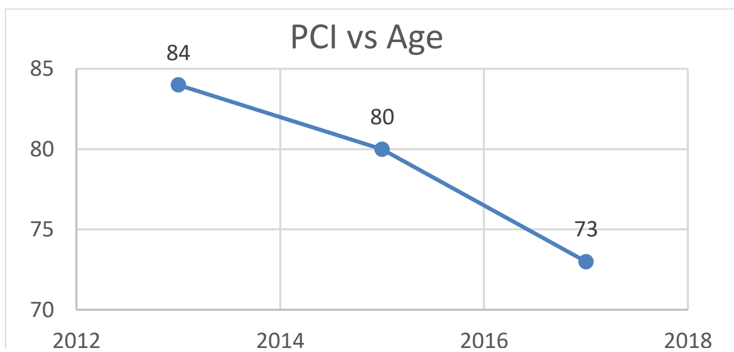


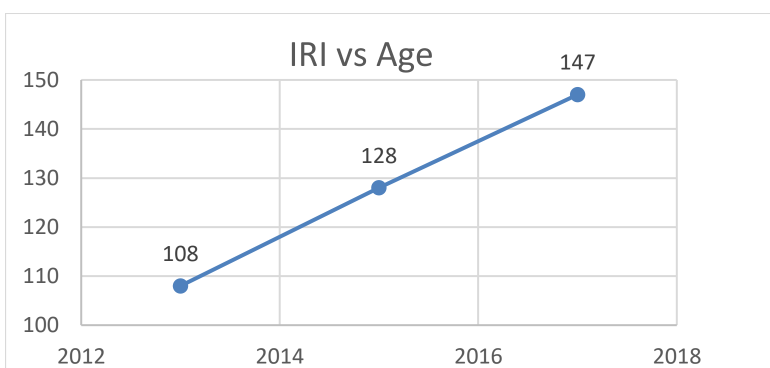
Location	Delaware Co.
Road	180th St
Road ID	1216
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	134
Transverse Joint Spacing	15'
Date	8/9/2017
Time	2:15 PM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



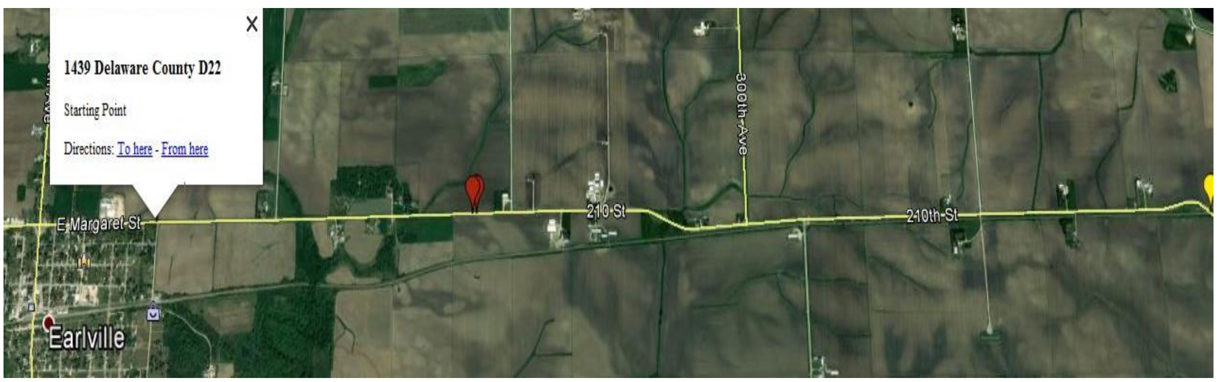


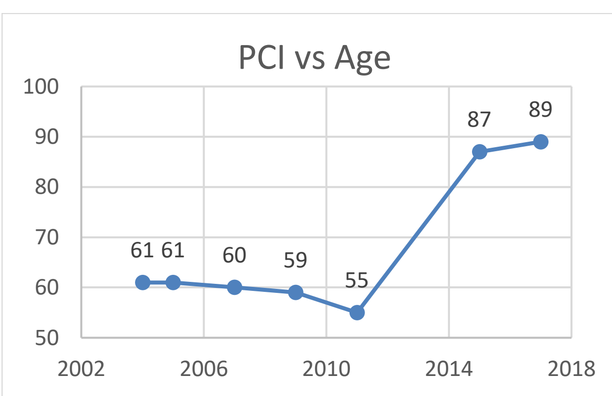


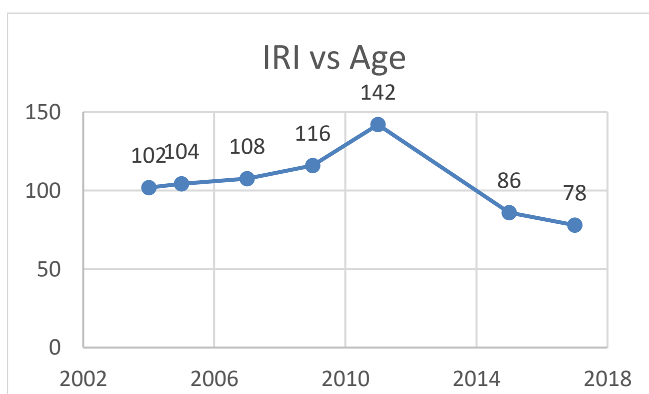
Location	Delaware Co.
Road	D22
Road ID	1439
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	1100
Transverse Joint Spacing	11'
Date	8/9/2017
Time	3:00 PM
Temp	-

Test No	MIRA Result
T1	No Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	OOB
T8	-
T9	-
T10	-

Test No	MIRA Result
L1	-
L2	-
L3	-
L4	-
L5	-



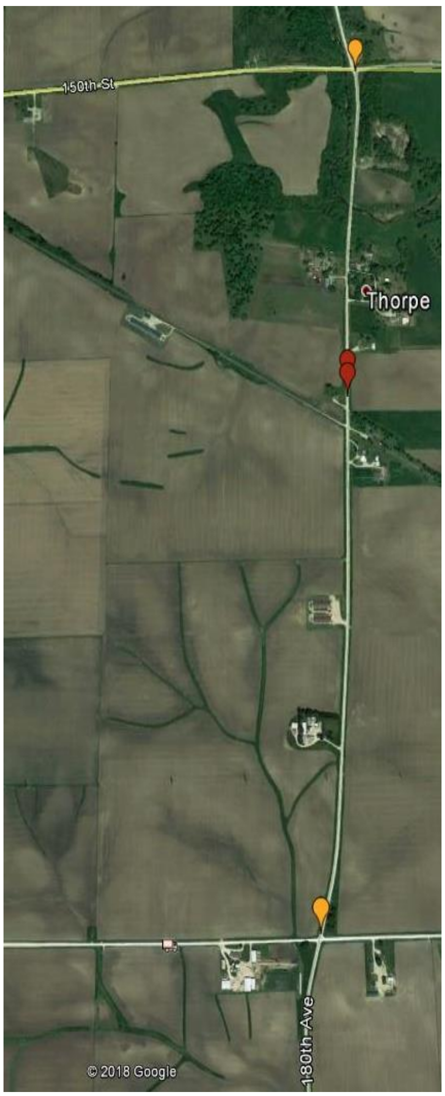


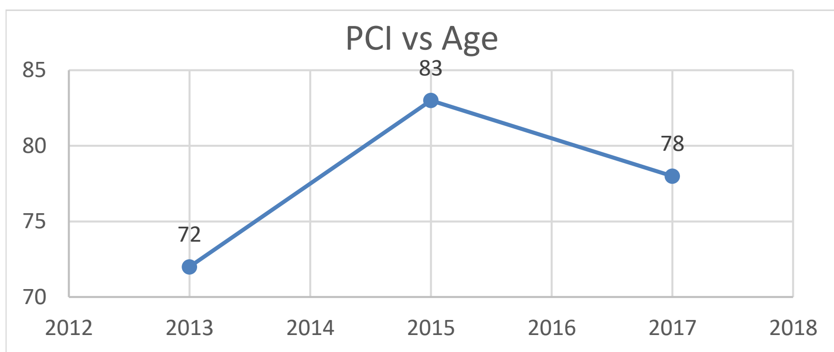


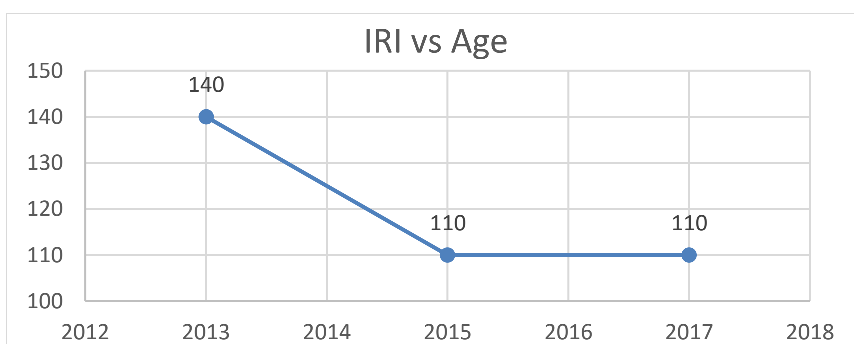
Location	Delaware Co.
Road	180th St
Road ID	1215
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	1060
Transverse Joint Spacing	15'
Date	8/10/2017
Time	8:30 AM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



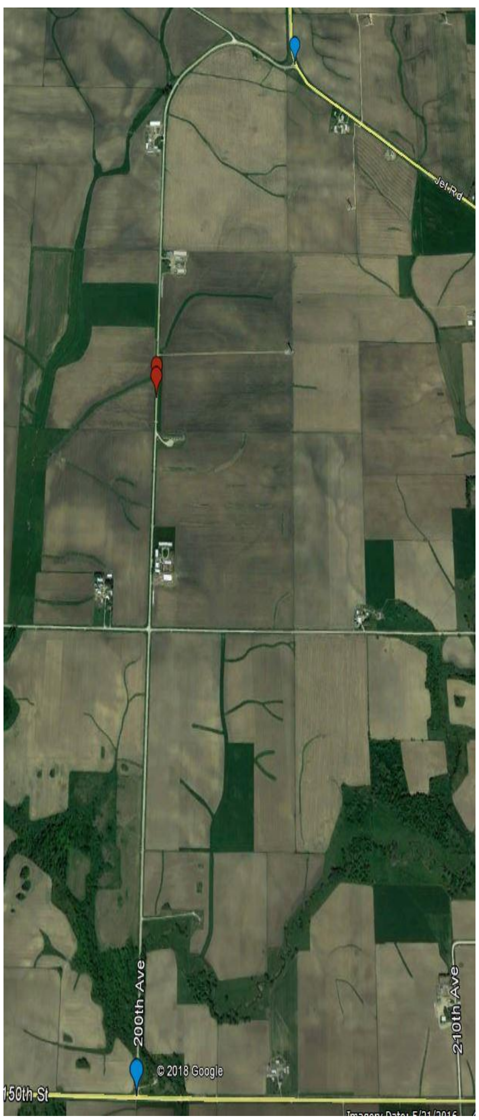


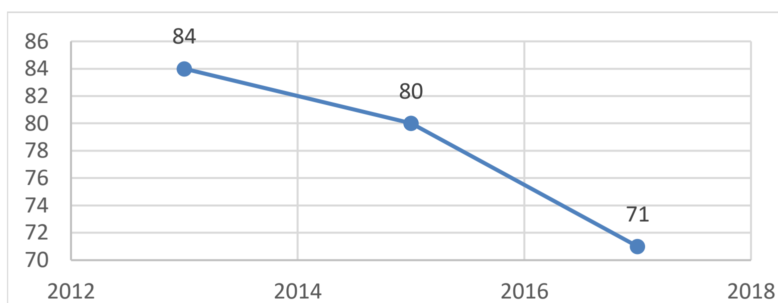


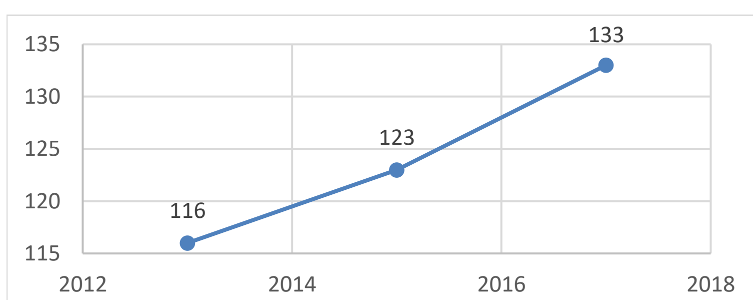
Location	Delaware Co.
Road	200th St
Road ID	1218
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	50
Transverse Joint Spacing	15'
Date	8/10/2017
Time	9:15 AM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Unknown
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



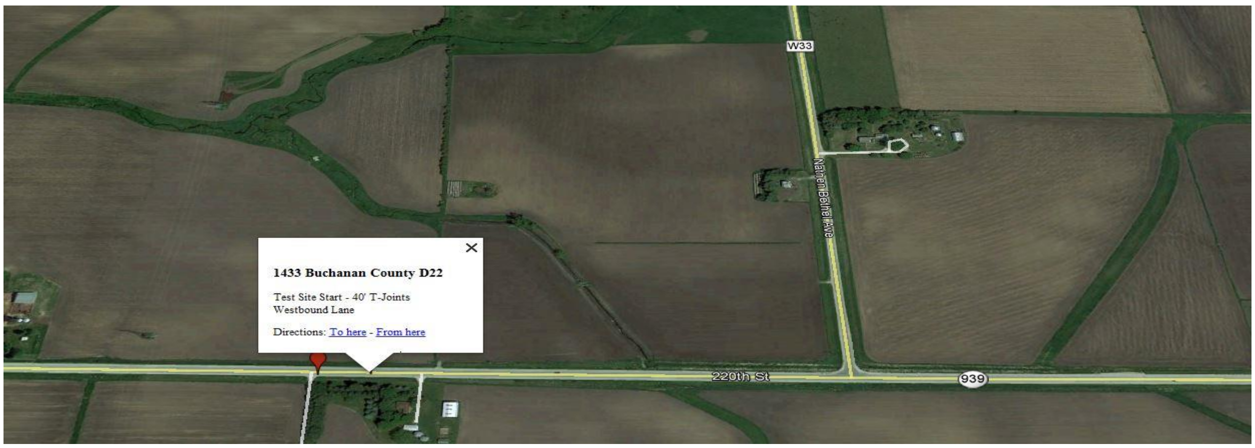




Location	**Buchanan Co.**
Road	D22
Road ID	1433
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	1410
Transverse Joint Spacing	40'
Date	8/10/2017
Time	10:30 AM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	No Crack
T5	Crack
T6	-
T7	-
T8	-
T9	-
T10	-

Test No	MIRA Result
L1	-
L2	-
L3	-
L4	-
L5	-



Location	Buchanan Co.
Road	D22
Road ID	1433
Thickness	6.0"
Overlay Type	UBCOA/Fibers
Traffic (AADT)	1410
Transverse Joint Spacing	10'
Date	8/10/2017
Time	11:30 AM
Temp	-

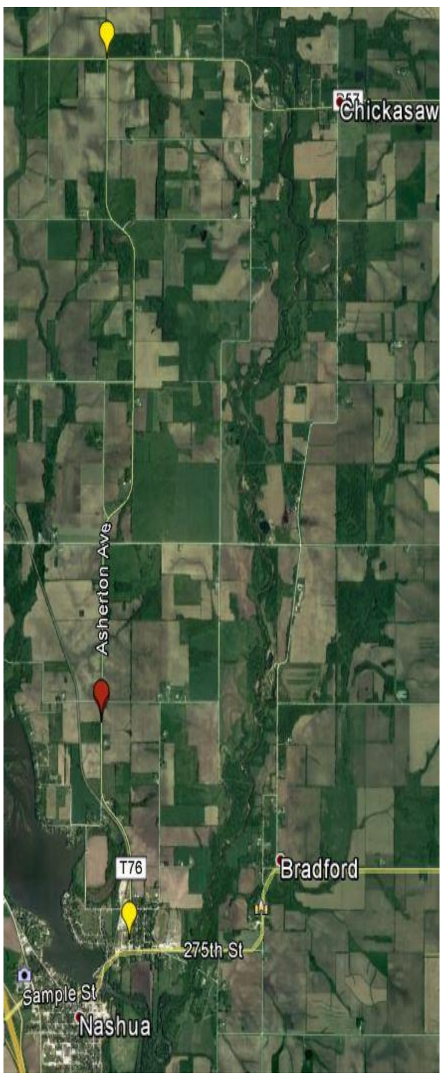
Test No	MIRA Result
T1	Crack
T2	No Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

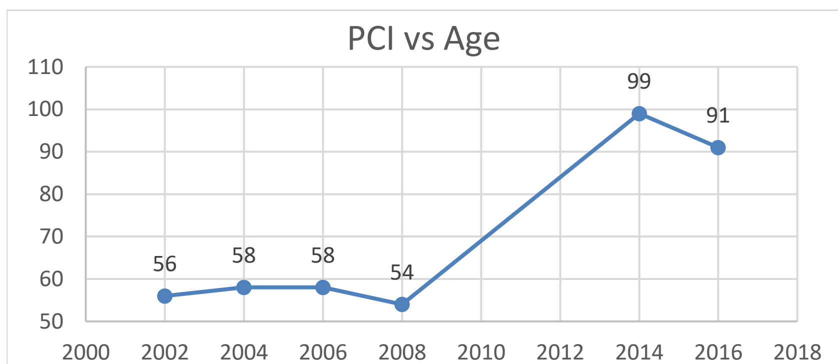
Test No	MIRA Result
L1	-
L2	-
L3	-
L4	-
L5	-

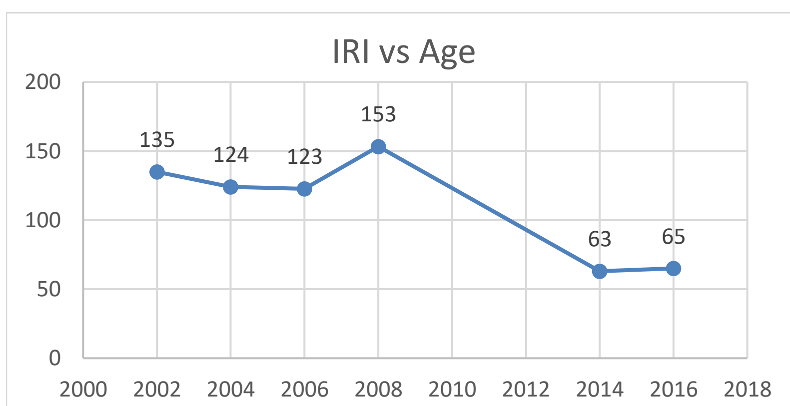
Location	**Chickasaw Co.**
Road	T76
Road ID	1411
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	37-71
Transverse Joint Spacing	12'
Date	8/10/2017
Time	2:00 PM
Temp	-

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	OOB
T8	-
T9	-
T10	-

Test No	MIRA Result
L1	-
L2	-
L3	-
L4	-
L5	-



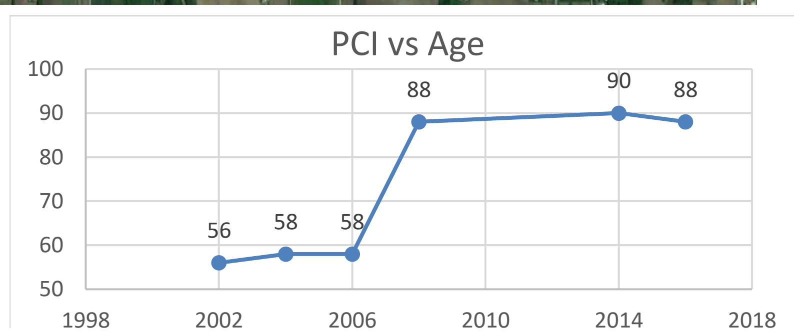


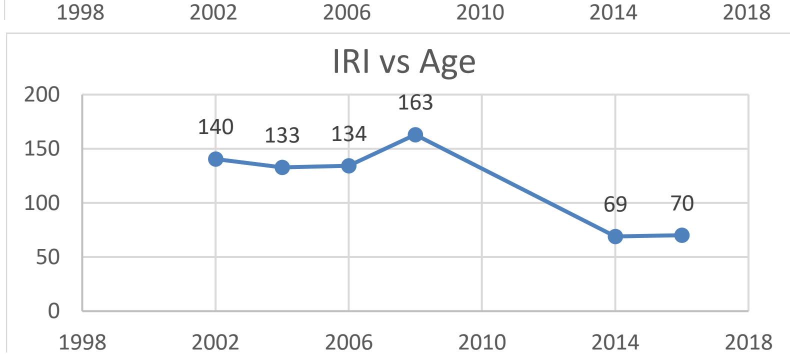


Location	Floyd County
Road	B57
Road ID	1416
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	54
Transverse Joint Spacing	12'
Date	8/14/2017
Time	10:15 AM
Temp	70°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

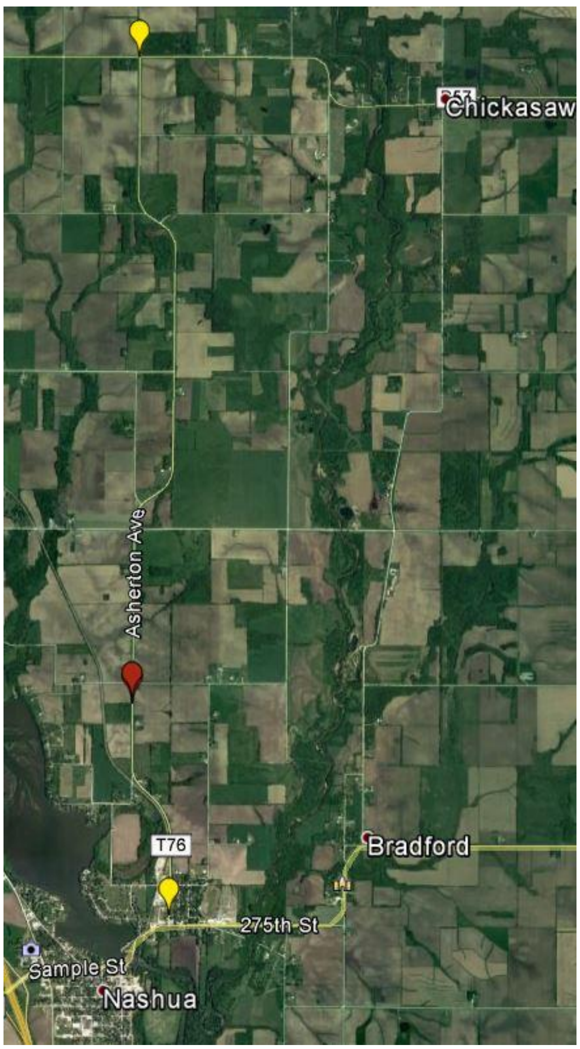




Location	Chickasaw Co.
Road	T76
Road ID	1411
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	37-71
Transverse Joint Spacing	12'
Date	8/14/2017
Time	2:00 PM
Temp	73°F

Test No	MIRA Result
T1	-
T2	-
T3	-
T4	-
T5	-
T6	-
T7	Crack
T8	Crack
T9	Crack
T10	Crack

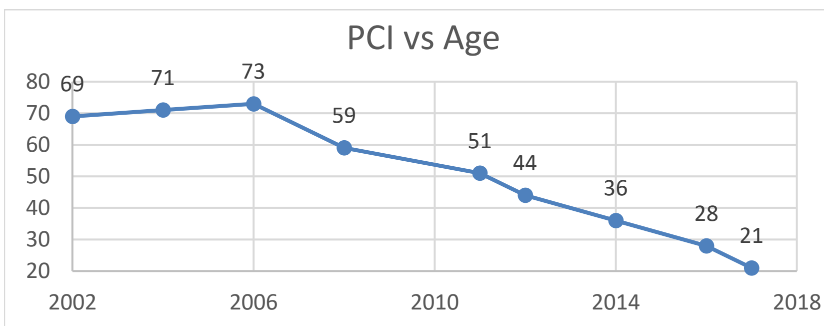
Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

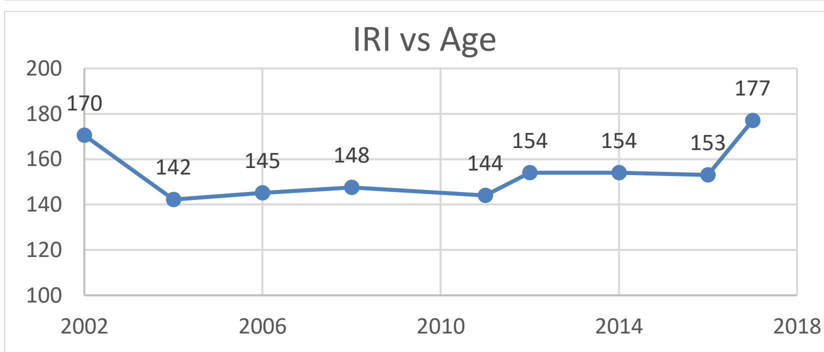


Location	Chickasaw Co.
Road	V18
Road ID	1079
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	760
Transverse Joint Spacing	20'
Date	8/14/2017
Time	12:00 PM
Temp	73°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

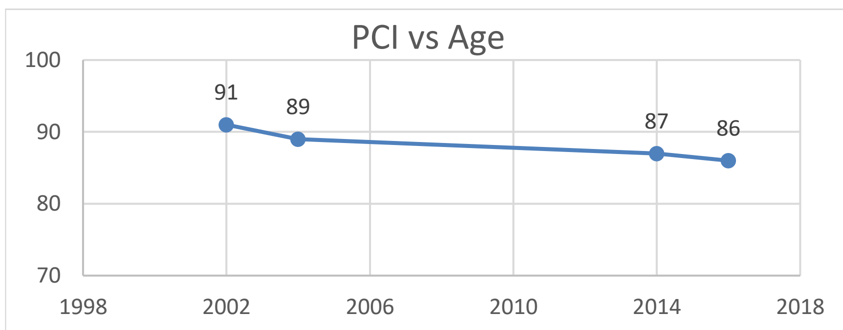


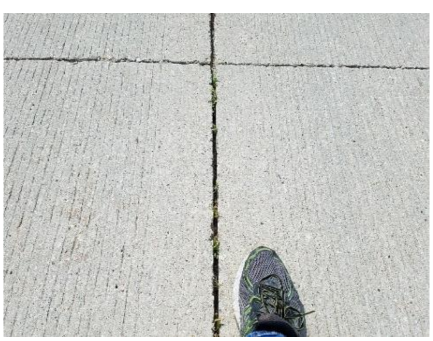


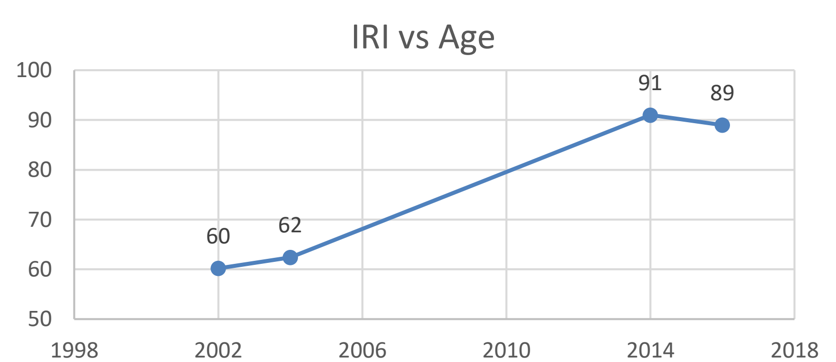
Location	Mitchell Co.
Road	A23
Road ID	1328
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	210
Transverse Joint Spacing	5.5'
Date	8/14/2017
Time	1:15 PM
Temp	74°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	No Crack
T4	Crack
T5	Unknown
T6	No Crack
T7	Crack
T8	No Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack



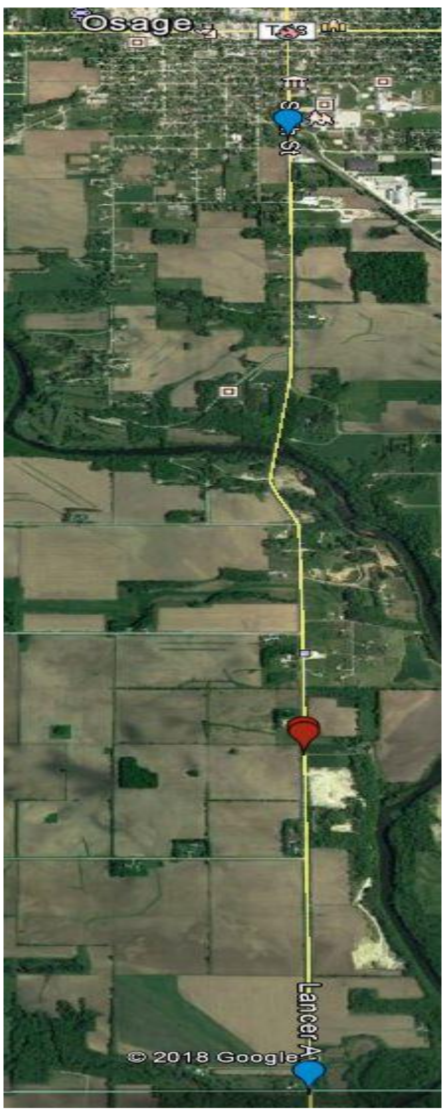


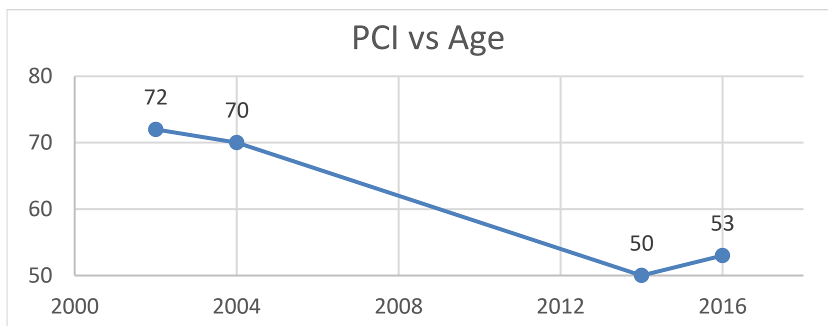


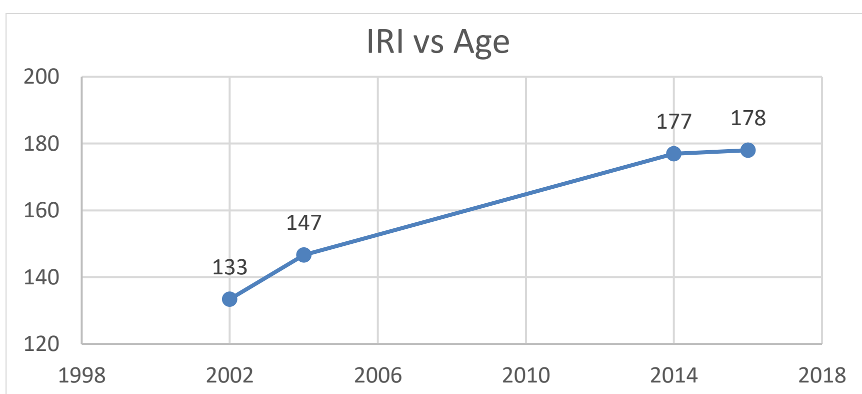
Location	Mitchell Co.
Road	T38
Road ID	1050
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	1150
Transverse Joint Spacing	15'
Date	8/14/2017
Time	2:15 PM
Temp	75°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



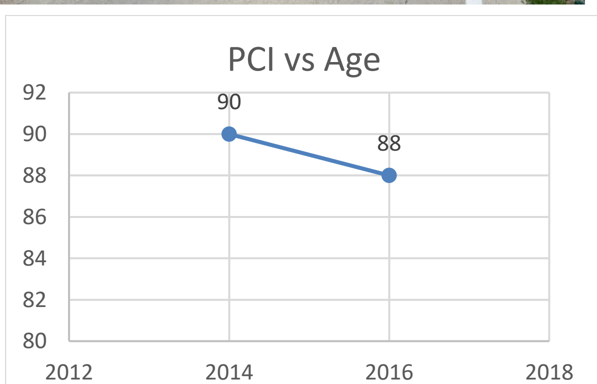


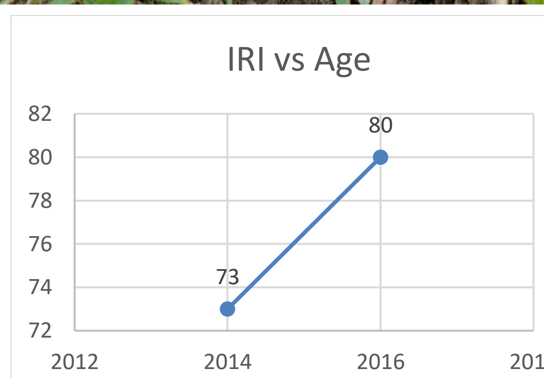


Location	Poweshiek Co.
Road	F29
Road ID	1461
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	270-440
Transverse Joint Spacing	12'
Date	8/15/2017
Time	9:30 AM
Temp	66°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

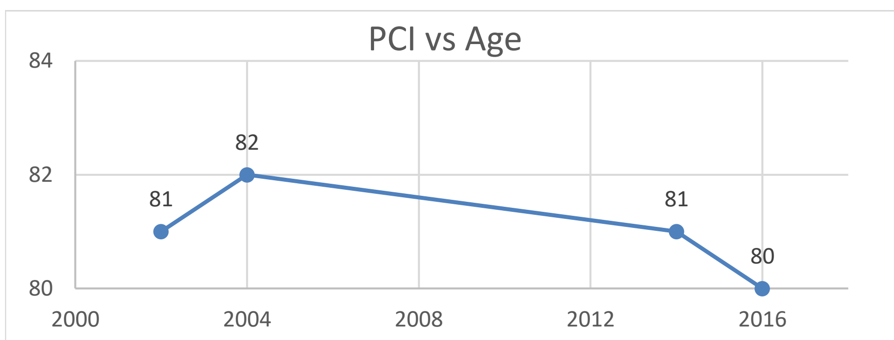


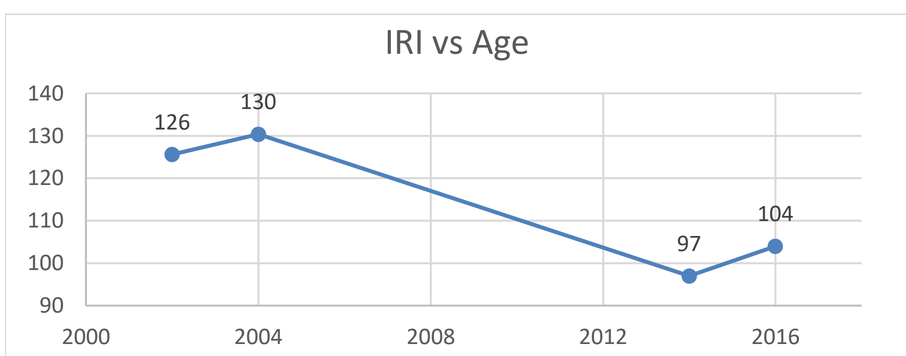


Location	Poweshiek Co.
Road	V18
Road ID	1224
Thickness	6.0"
Overlay Type	UBCOC
Traffic (AADT)	1200
Transverse Joint Spacing	20'
Date	8/15/2017
Time	10:15 AM
Temp	70°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

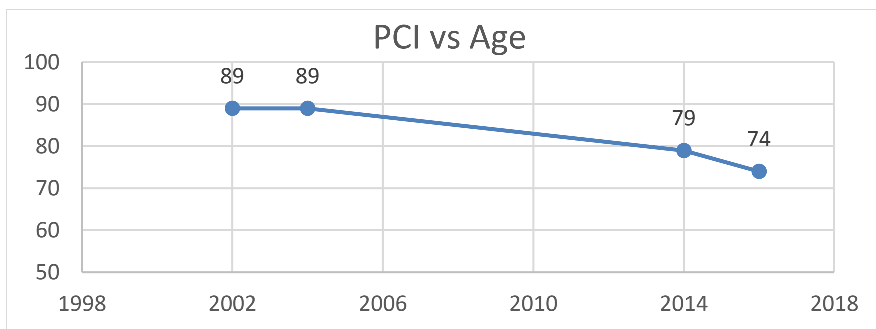


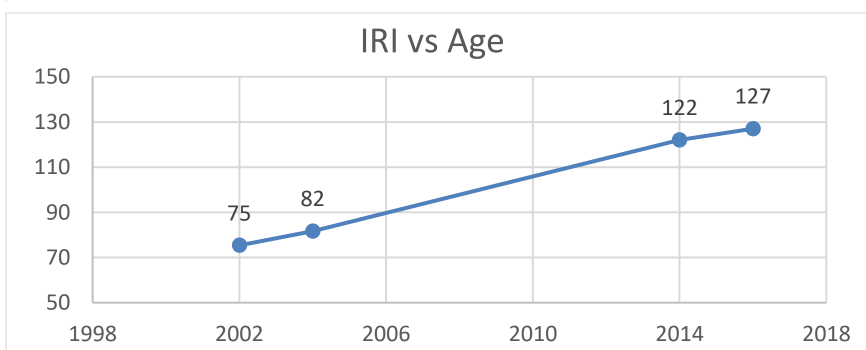


Location	Poweshiek Co.
Road	V30
Road ID	1189
Thickness	6.0"
Overlay Type	UBCOC
Traffic (AADT)	280
Transverse Joint Spacing	20'
Date	8/15/2017
Time	11:00 AM
Temp	68°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

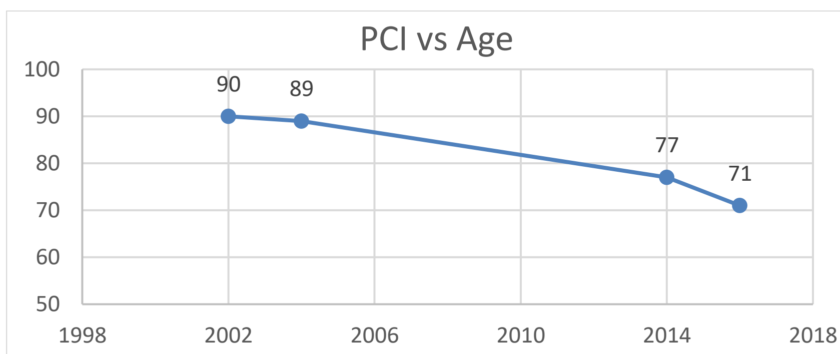


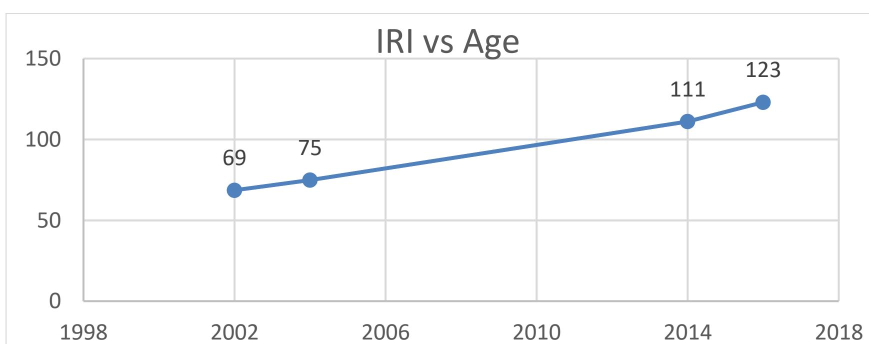


Location	Poweshiek
Road	F52
Road ID	1190
Thickness	6.0"
Overlay Type	UBCOC
Traffic (AADT)	320
Transverse Joint Spacing	20'
Date	8/15/2017
Time	12:15 PM
Temp	68°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

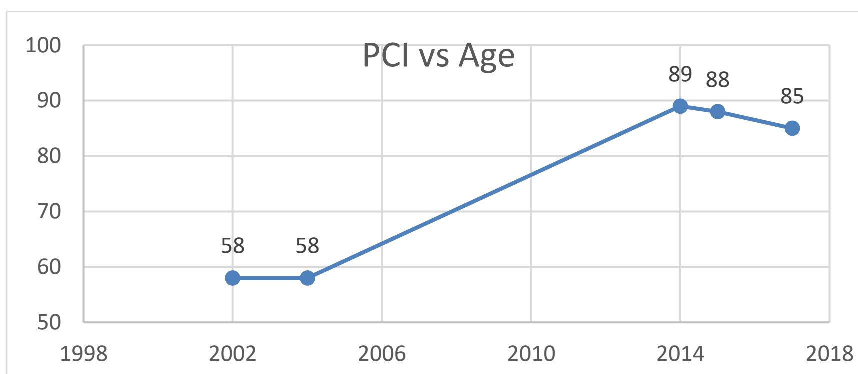


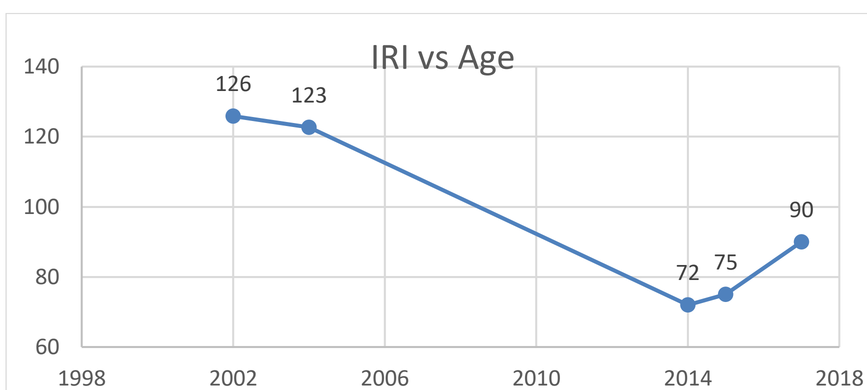


Location	Linn County
Road	X20
Road ID	1427
Thickness	6.0"
Overlay Type	BCOA
Traffic (AADT)	910
Transverse Joint Spacing	12'
Date	8/18/2017
Time	10:15 AM
Temp	71°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

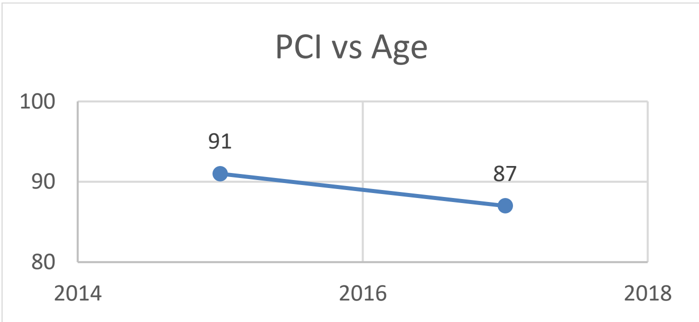


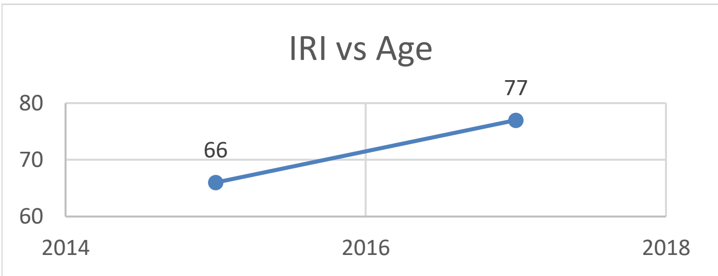


Location	Linn County
Road	E34
Road ID	1387
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	2140
Transverse Joint Spacing	12'
Date	8/18/2017
Time	11:00 AM
Temp	71°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

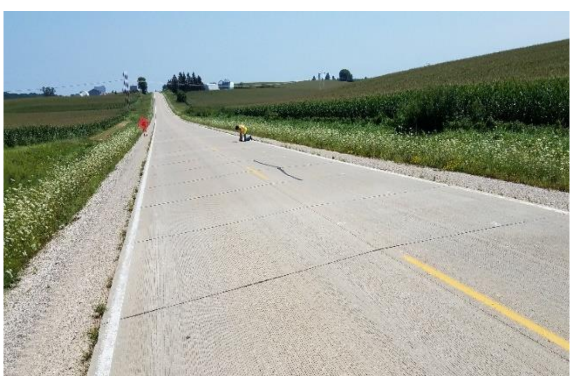


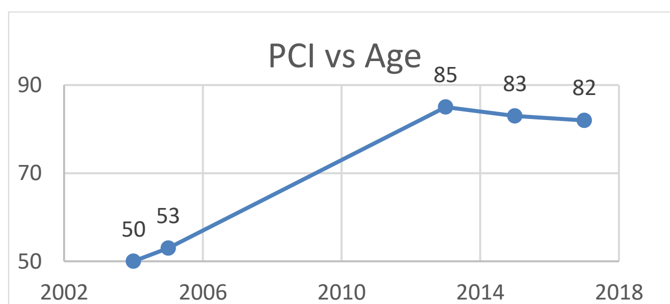


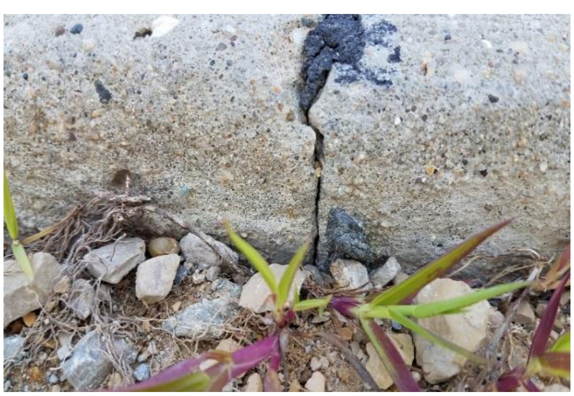
Location	Linn County
Road	E16
Road ID	1323
Thickness	6.0"
Overlay Type	UBOL
Traffic (AADT)	900
Transverse Joint Spacing	12'
Date	8/18/2017
Time	12:30 AM
Temp	74°F

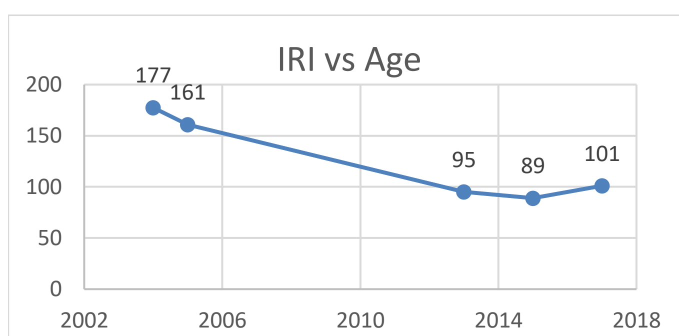
Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-





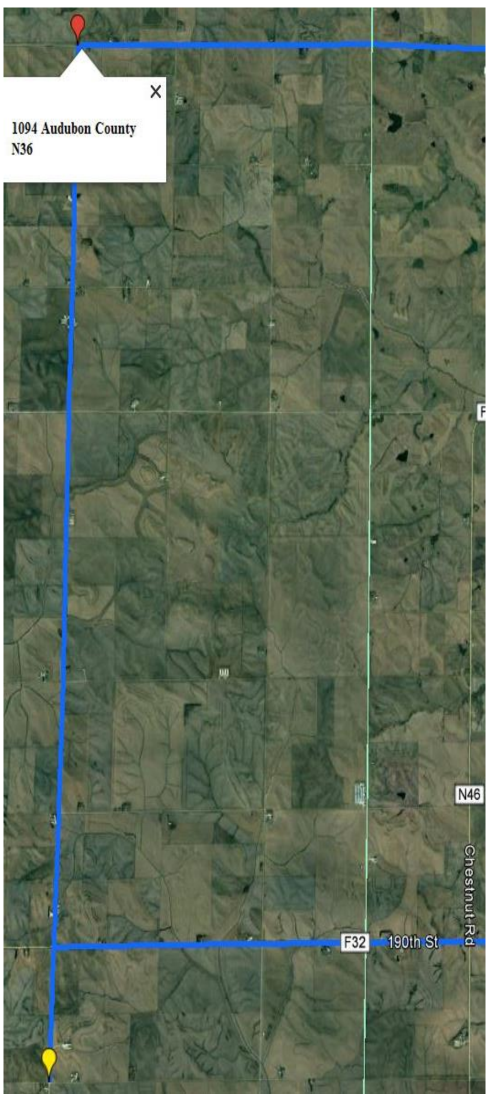


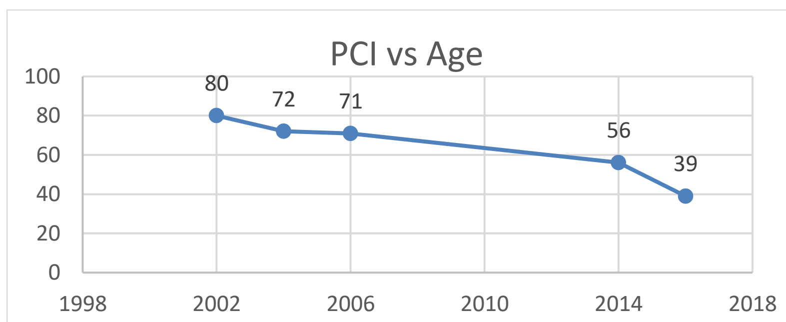


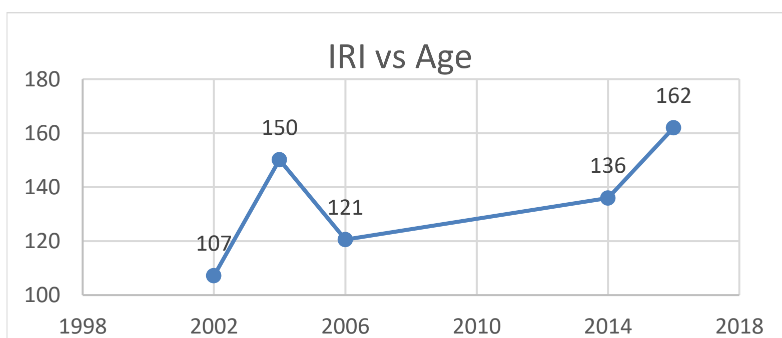
Location	Audubon Co.
Road	N36
Road ID	1094
Thickness	5.0"
Overlay Type	UBCOC
Traffic (AADT)	200
Transverse Joint Spacing	20'
Date	8/21/2017
Time	1:00 PM
Temp	73°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



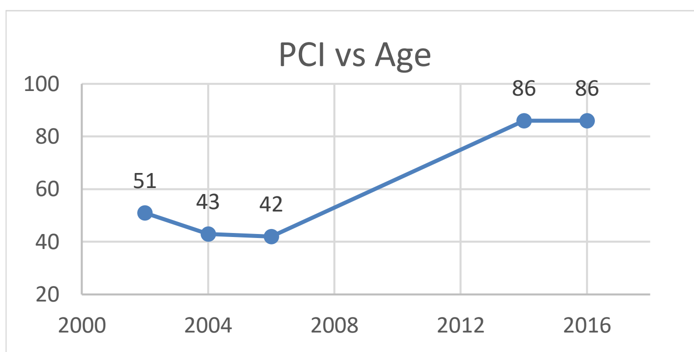


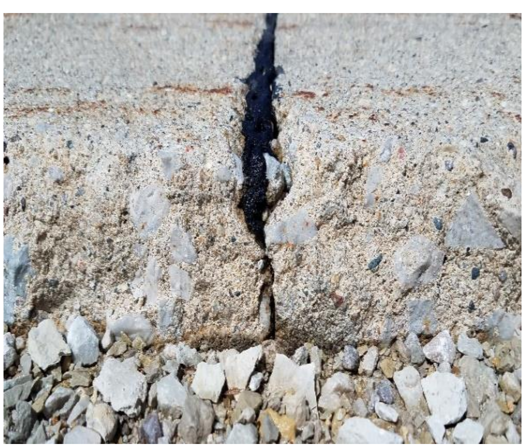


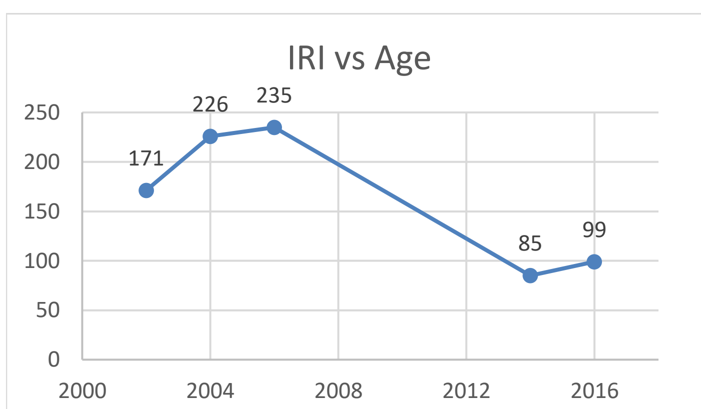
Location	Guthrie Co.
Road	F25
Road ID	1308
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	950
Transverse Joint Spacing	12'
Date	8/21/2017
Time	2:15 PM
Temp	74°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



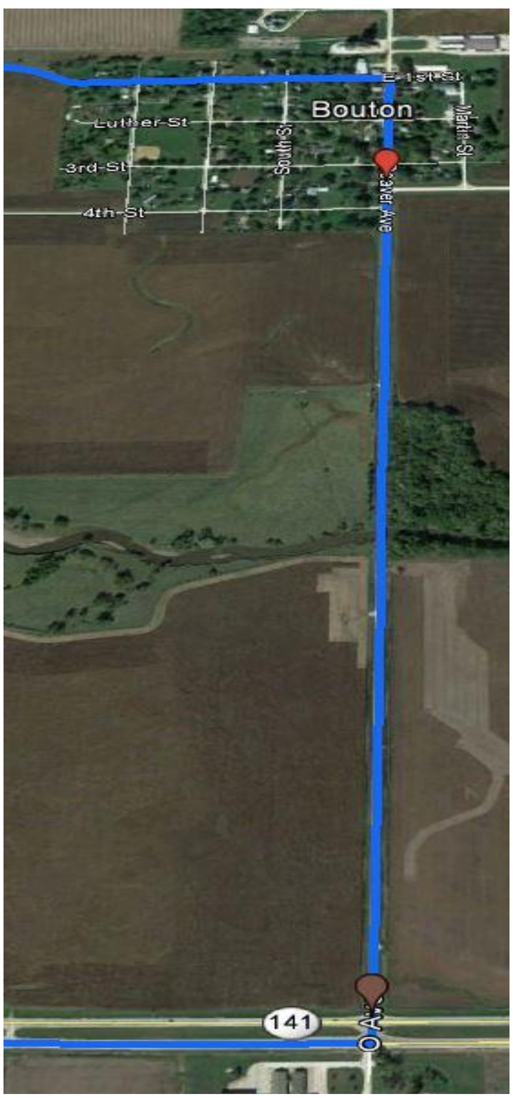


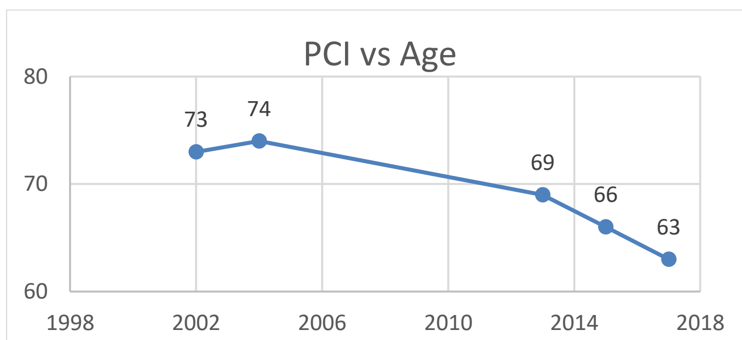


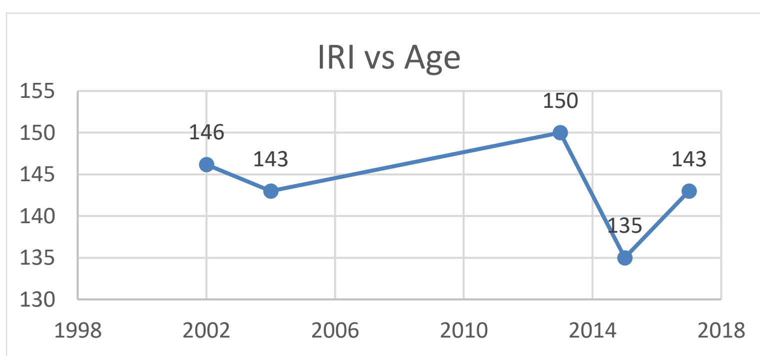
Location	Dallas Co.
Road	O Ave
Road ID	1010
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	2840
Transverse Joint Spacing	20'
Date	8/21/2017
Time	3:15 PM
Temp	81°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



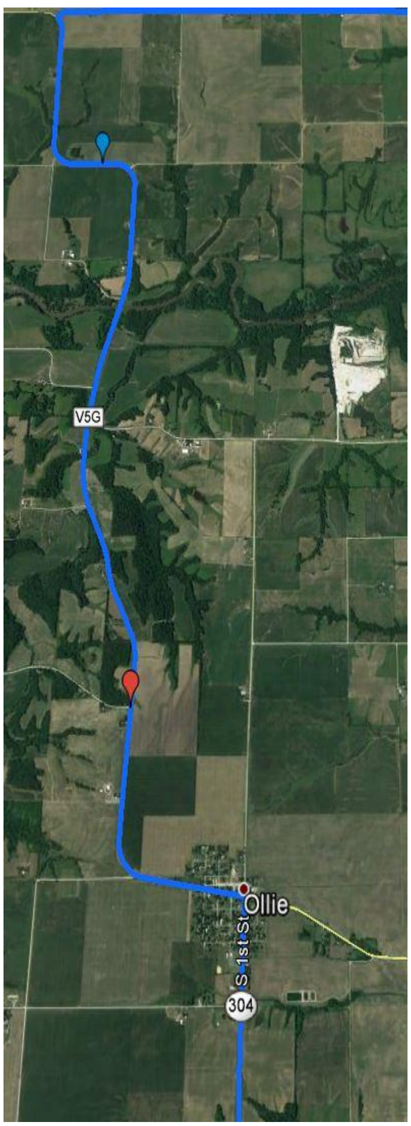


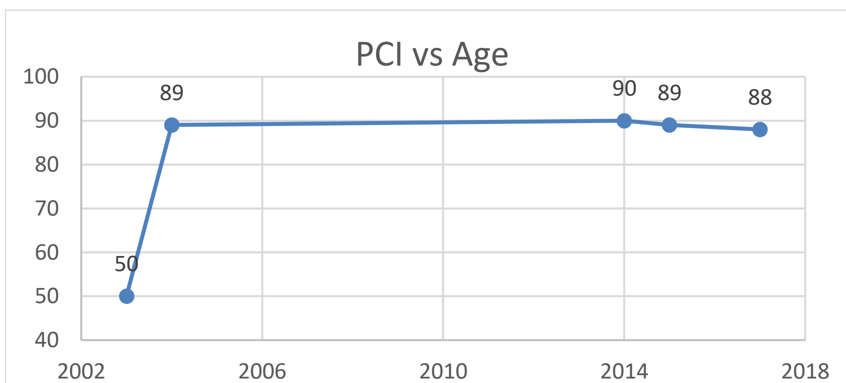


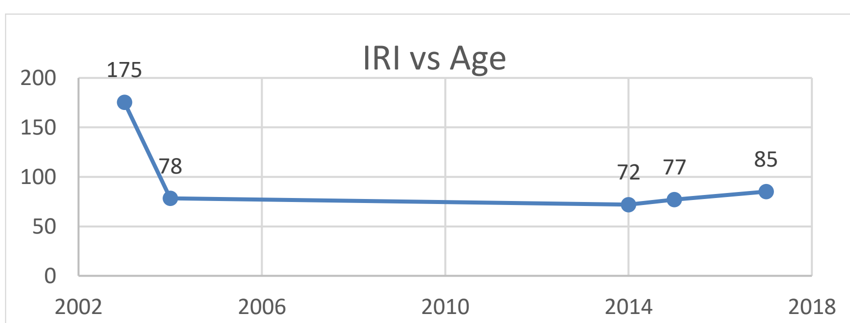
Location	Keokuk Co.
Road	V5G
Road ID	1442
Thickness	6.0"
Overlay Type	UBCOC
Traffic (AADT)	210
Transverse Joint Spacing	12'
Date	8/22/2017
Time	10:30 AM
Temp	69°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



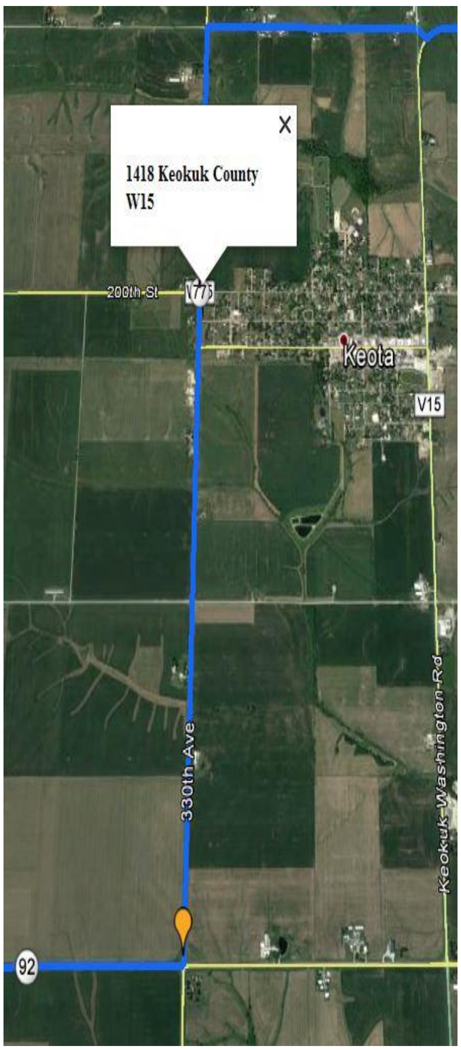


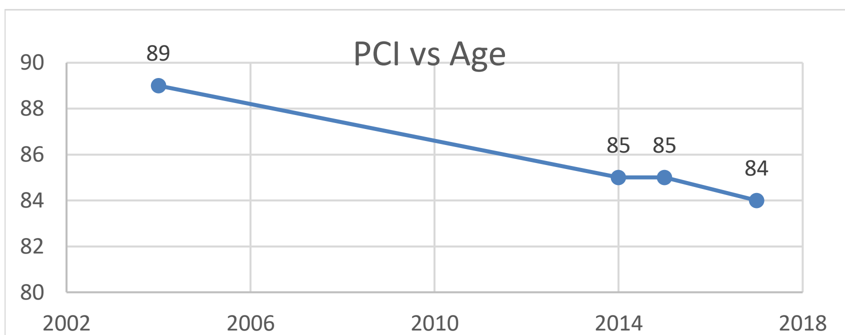


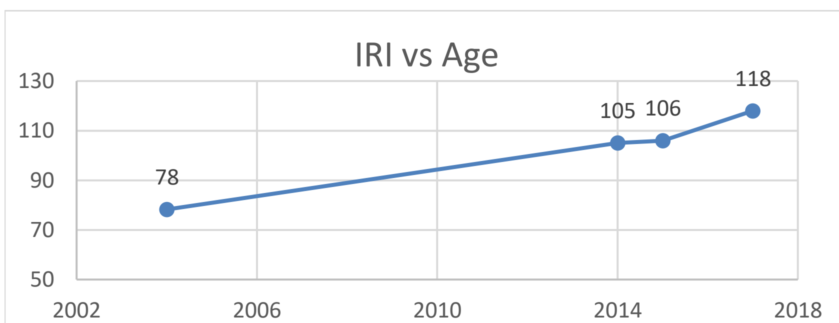
Location	Keokuk Co.
Road	W15
Road ID	1418
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	910
Transverse Joint Spacing	12'
Date	8/22/2017
Time	11:15 AM
Temp	72°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



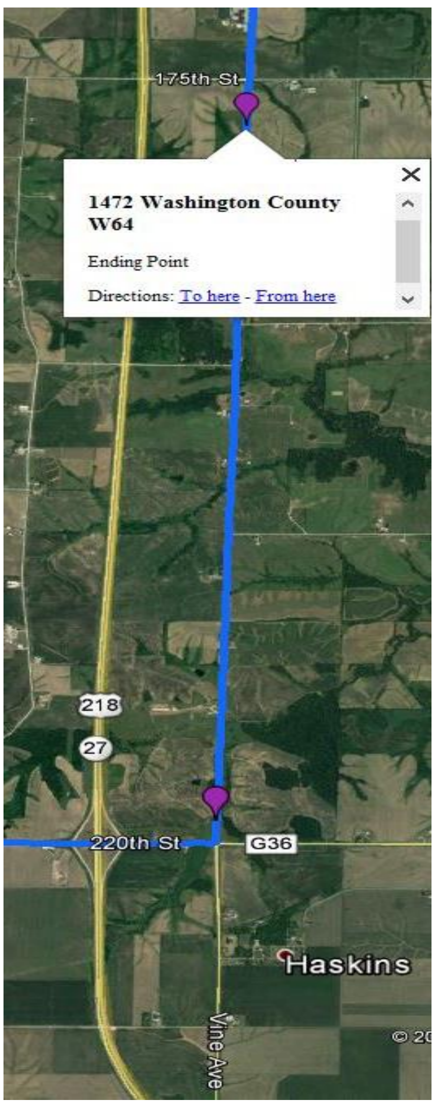


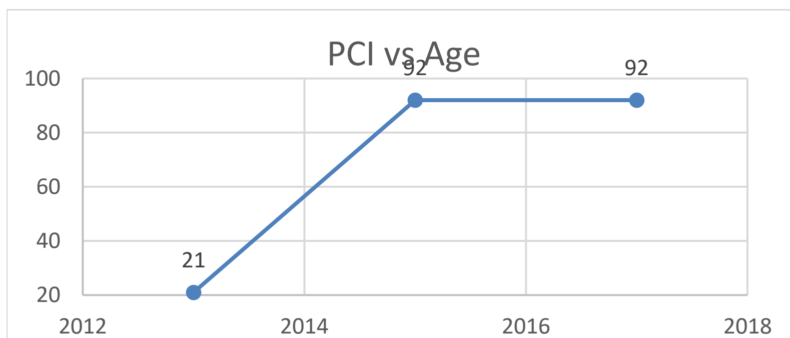


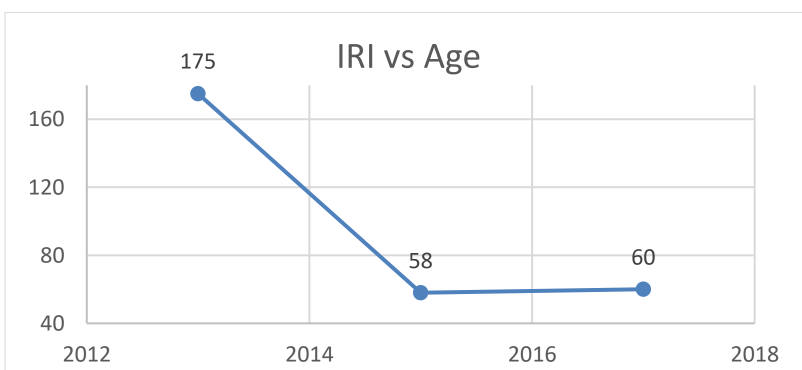
Location	Washington Co.
Road	W64
Road ID	1472
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	250
Transverse Joint Spacing	12'
Date	8/22/2017
Time	1:15 PM
Temp	73°F

Test No	MIRA Result
T1	No Crack
T2	No Crack
T3	No Crack
T4	No Crack
T5	Crack
T6	No Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



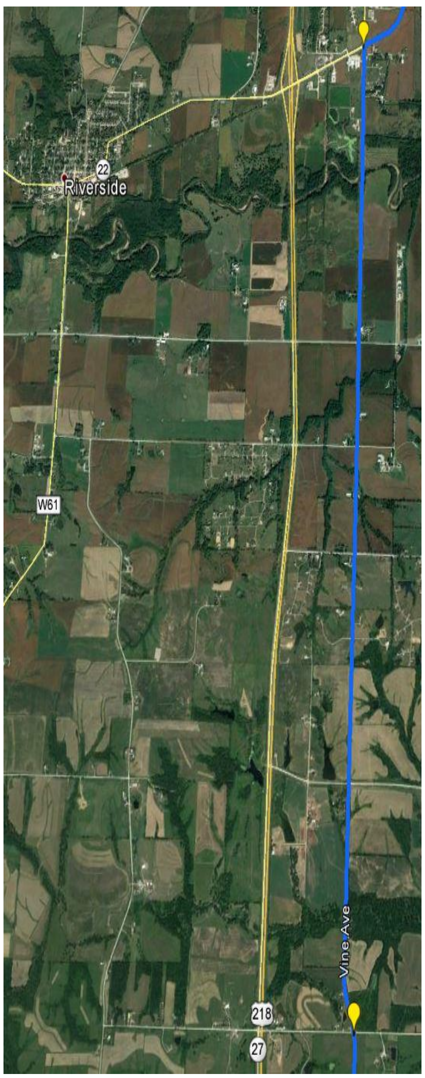


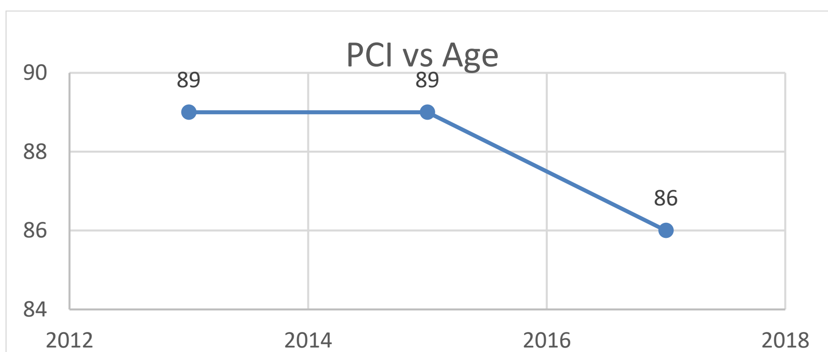


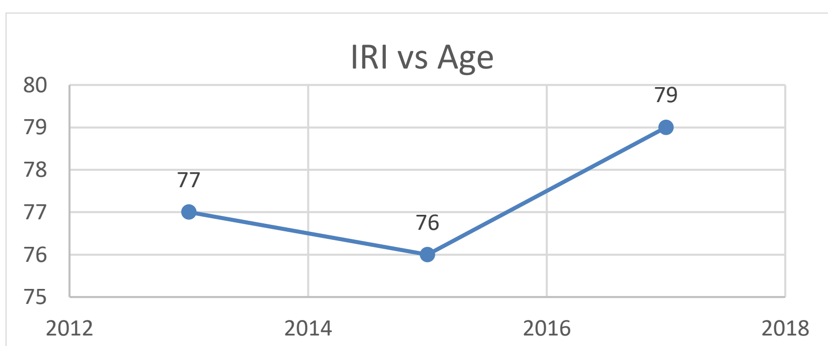
Location	Washington Co.
Road	W64
Road ID	1338
Thickness	6.0"
Overlay Type	UBCOC
Traffic (AADT)	630
Transverse Joint Spacing	12'
Date	8/22/2017
Time	2:00 PM
Temp	77°F

Test No	MIRA Result
T1	No Crack
T2	No Crack
T3	No Crack
T4	Crack
T5	Unknown
T6	Crack
T7	Unknown
T8	Crack
T9	No Crack
T10	No Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



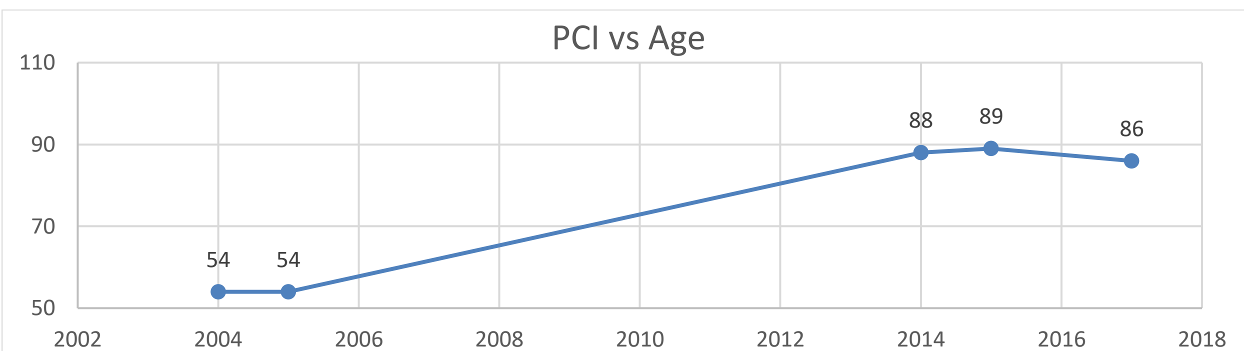


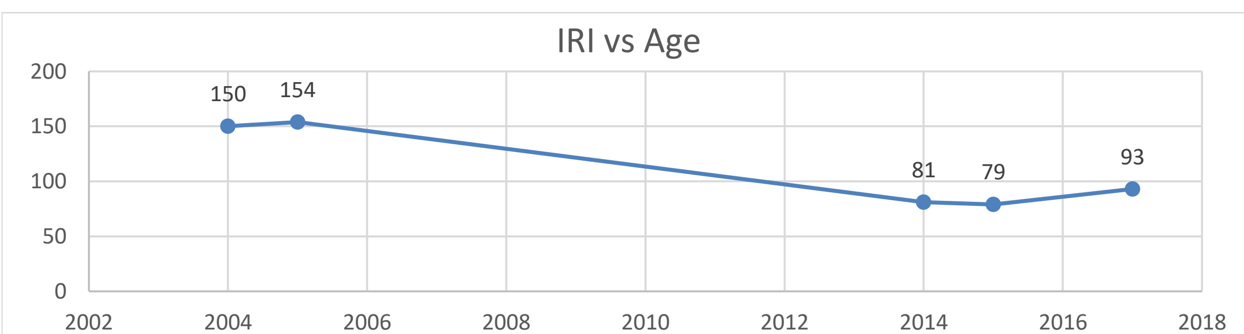


Location	Johnson Co.
Road	F62
Road ID	1417
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	2240
Transverse Joint Spacing	11'
Date	8/22/2017
Time	2:45 PM
Temp	77°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	No Crack
L4	-
L5	-

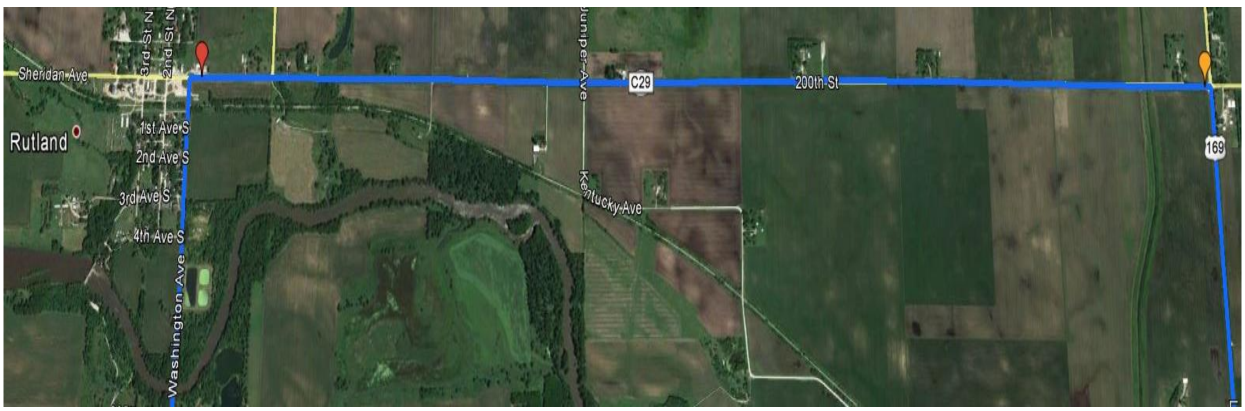


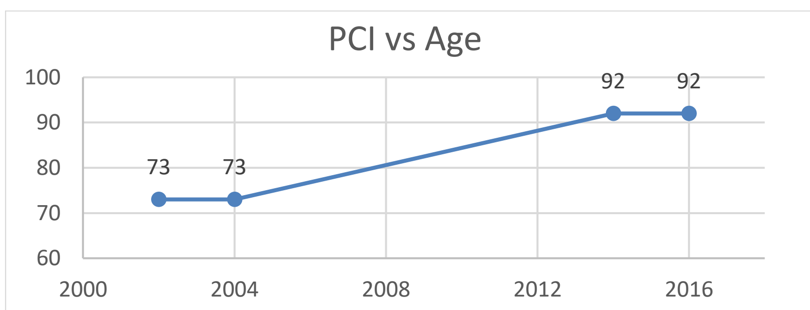


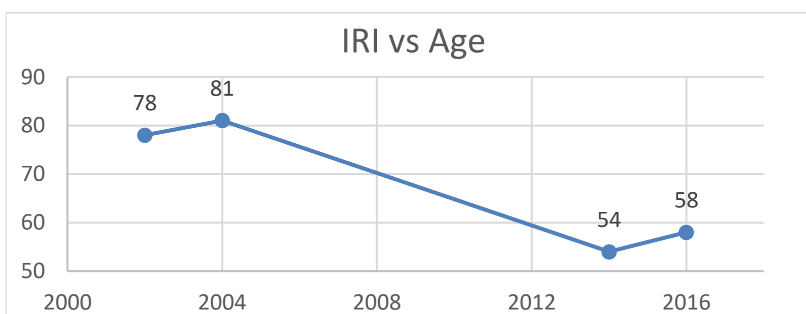
Location	Humboldt Co.
Road	C29
Road ID	1375
Thickness	4.0"
Overlay Type	UBCOC
Traffic (AADT)	570
Transverse Joint Spacing	6'
Date	8/23/2017
Time	9:45 AM
Temp	63°F

Test No	MIRA Result
T1	No Crack
T2	No Crack
T3	Crack
T4	Crack
T5	No Crack
T6	No Crack
T7	No Crack
T8	No Crack
T9	No Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack



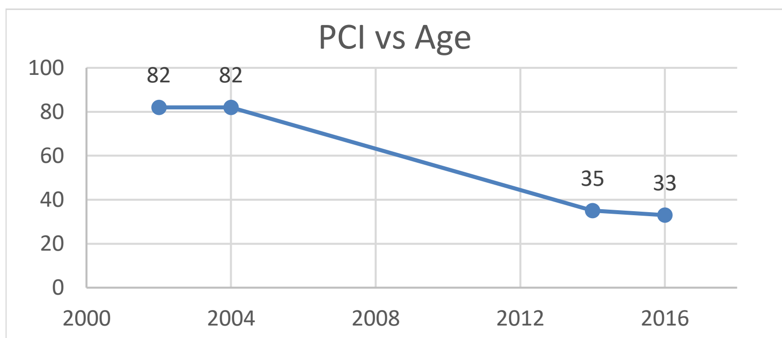


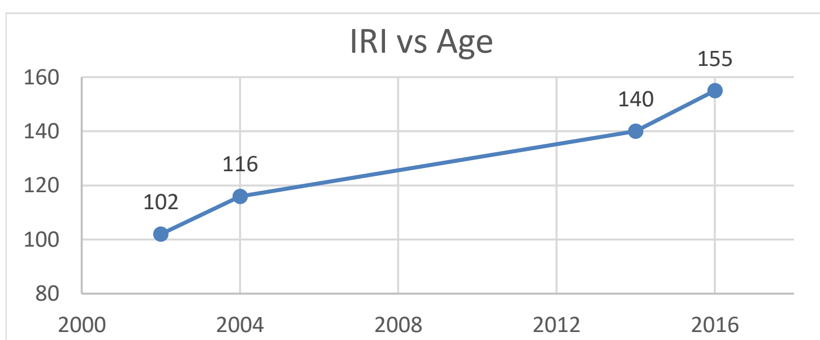


Location	Cherokee Co.
Road	C16
Road ID	1124
Thickness	6.0"
Overlay Type	UBCOA
Traffic (AADT)	300
Transverse Joint Spacing	20'
Date	8/23/2017
Time	11:45 AM
Temp	72°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

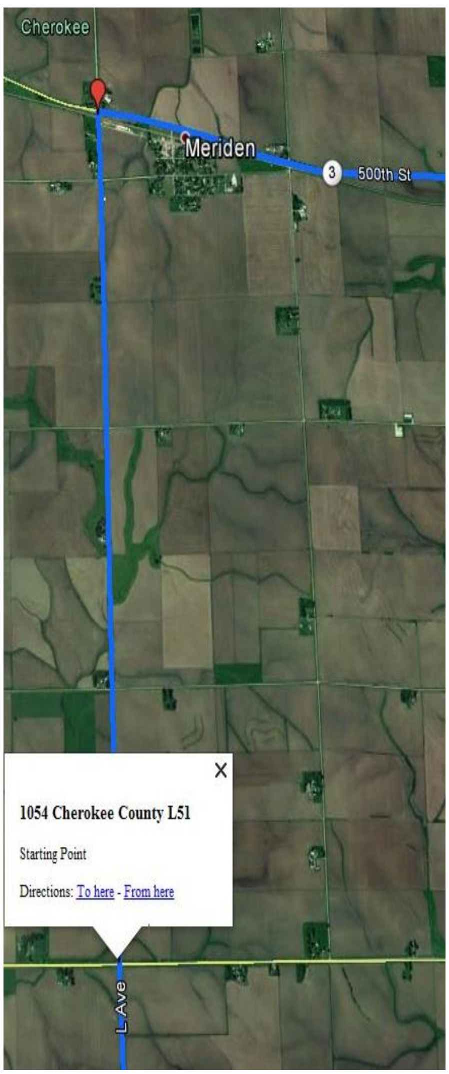


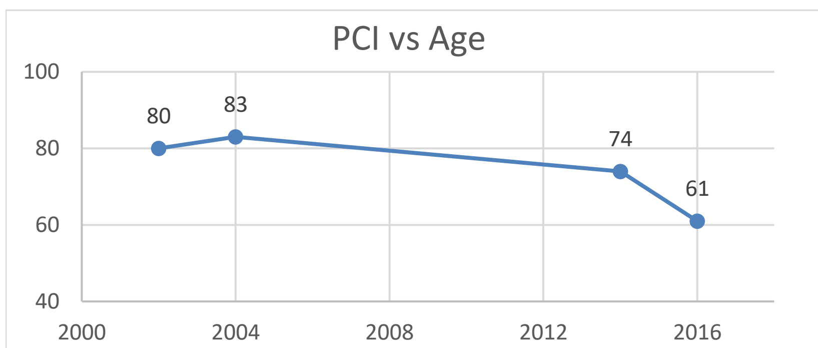


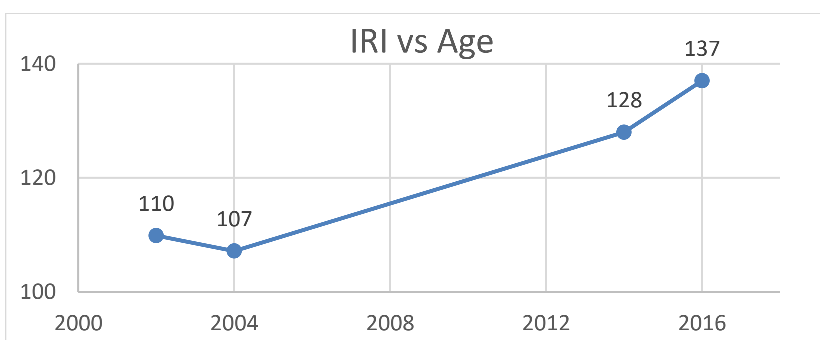
Location	Cherokee Co.
Road	L51
Road ID	1054
Thickness	5.0"
Overlay Type	UBCOA
Traffic (AADT)	290
Transverse Joint Spacing	15'
Date	8/23/2017
Time	1:00 PM
Temp	74°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-





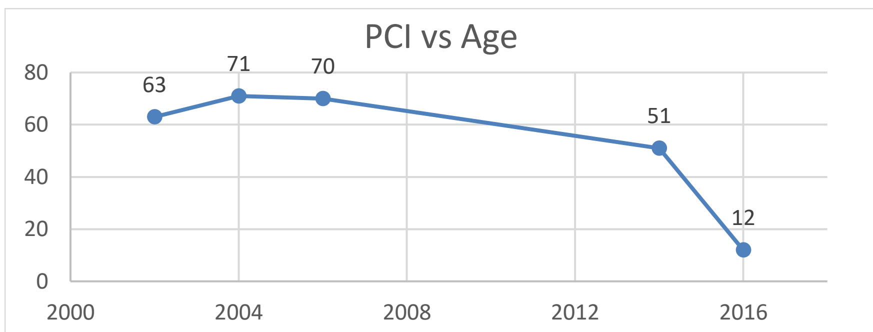


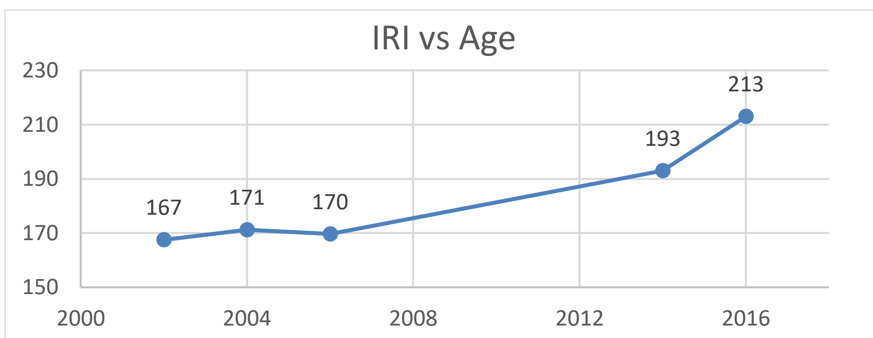
Location	Sac Co.
Road	D15
Road ID	1042
Thickness	5.0"
Overlay Type	UBCOC
Traffic (AADT)	460
Transverse Joint Spacing	15'
Date	8/23/2017
Time	2:30 PM
Temp	74°F

Test No	MIRA Result
T1	
T2	
T3	
T4	
T5	
T6	
T7	OOB
T8	-
T9	-
T10	-

Test No	MIRA Result
L1	-
L2	-
L3	-
L4	-
L5	-

*OOB: MIRA out of battery

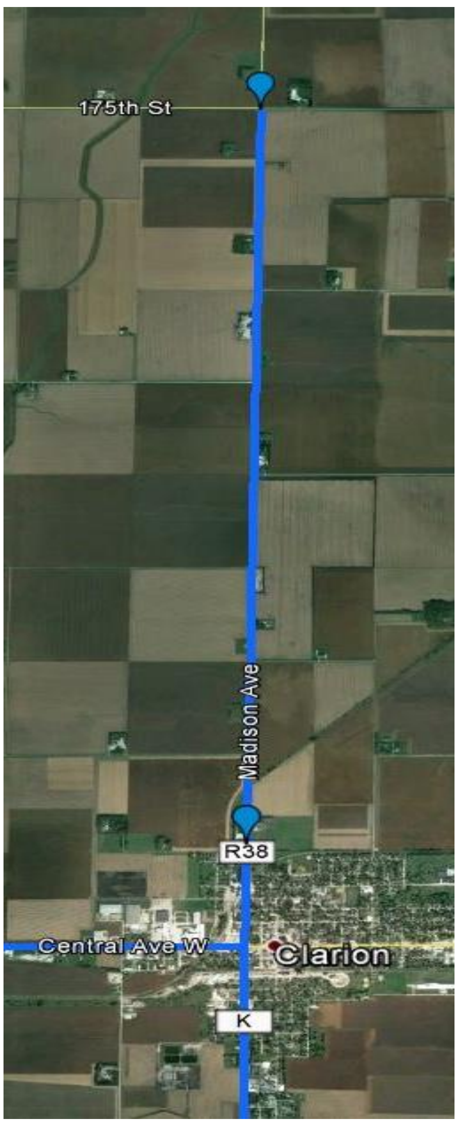


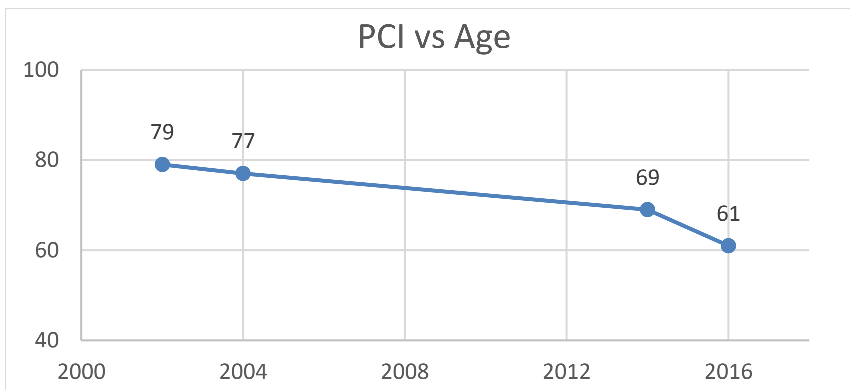


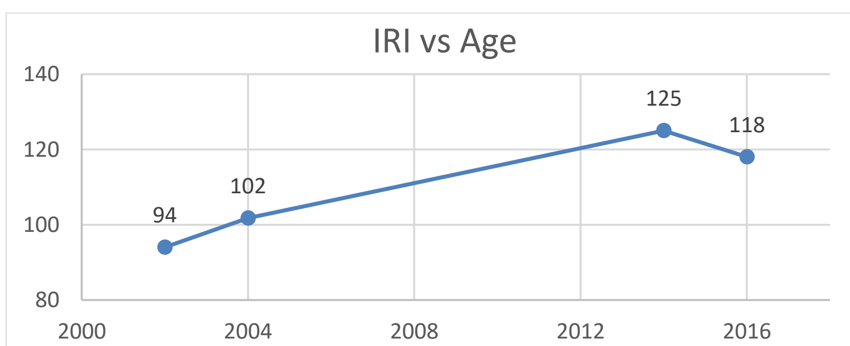
Location	Wright Co.
Road	R38
Road ID	1139
Thickness	5.0"
Overlay Type	UBCOC
Traffic (AADT)	708
Transverse Joint Spacing	15'
Date	8/25/2017
Time	9:30 AM
Temp	63°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



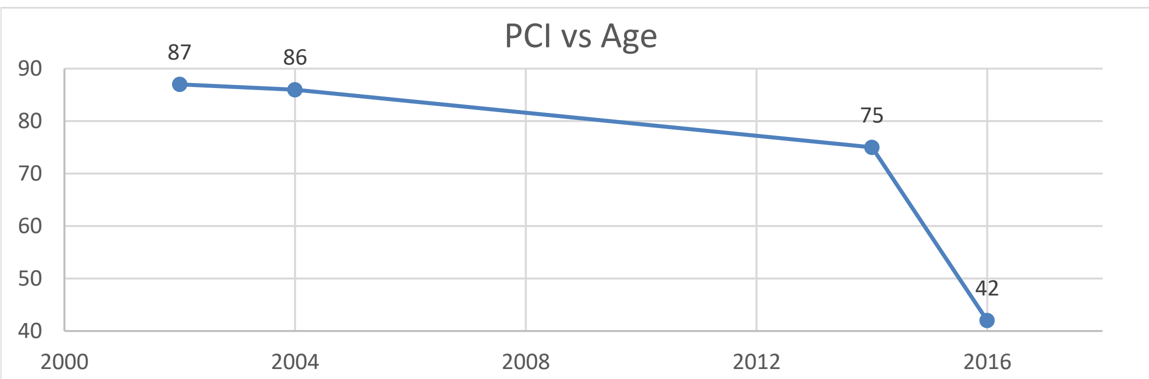


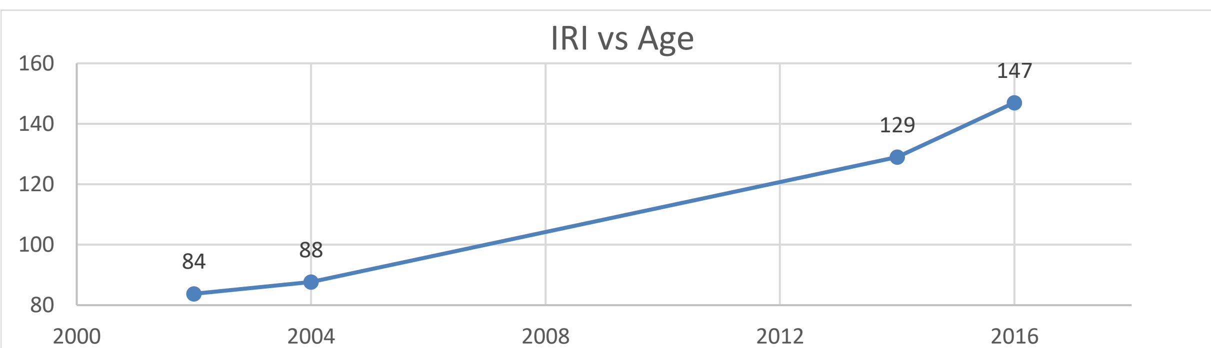


Location	Wright Co.
Road	C54
Road ID	1108
Thickness	5.0"
Overlay Type	BCOA
Traffic (AADT)	810
Transverse Joint Spacing	15'
Date	8/25/2017
Time	10:15 AM
Temp	66°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

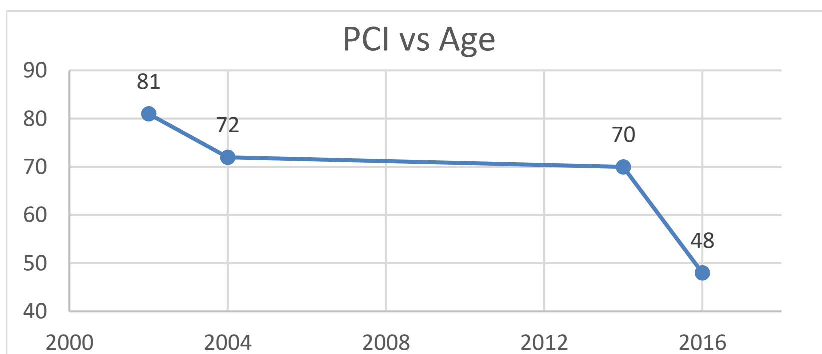


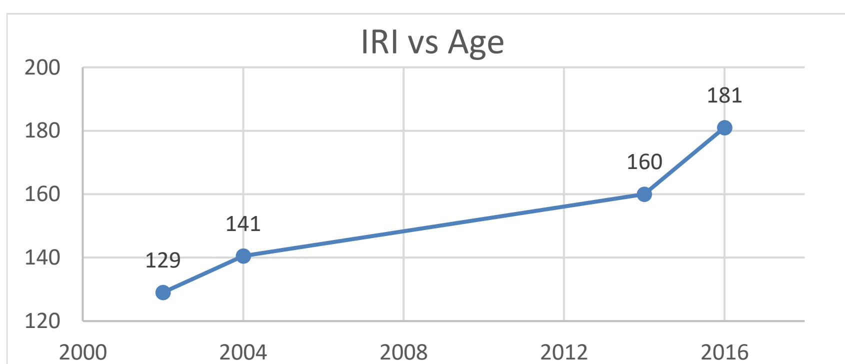


Location	Wright Co.
Road	C54
Road ID	1107
Thickness	5.0"
Overlay Type	UBCOC
Traffic (AADT)	800
Transverse Joint Spacing	15'
Date	8/25/2017
Time	11:00 PM
Temp	68°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

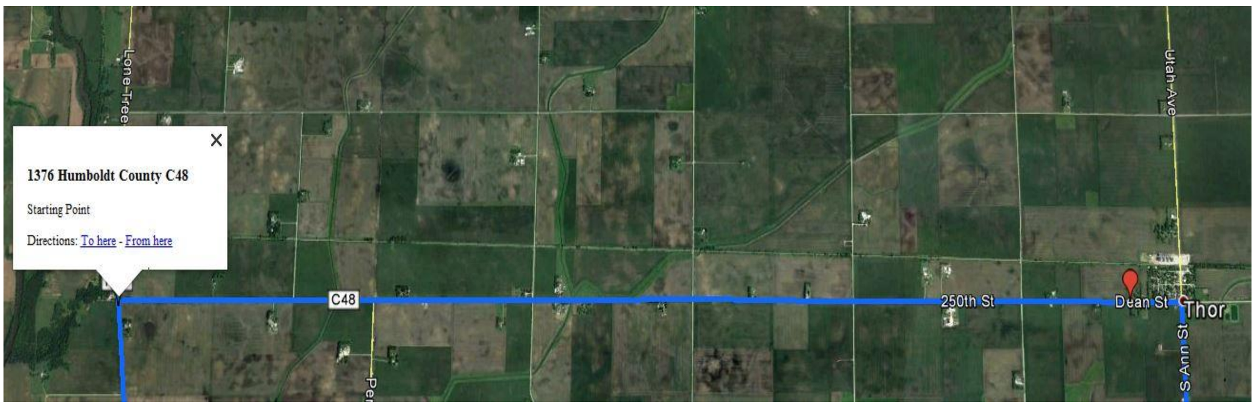


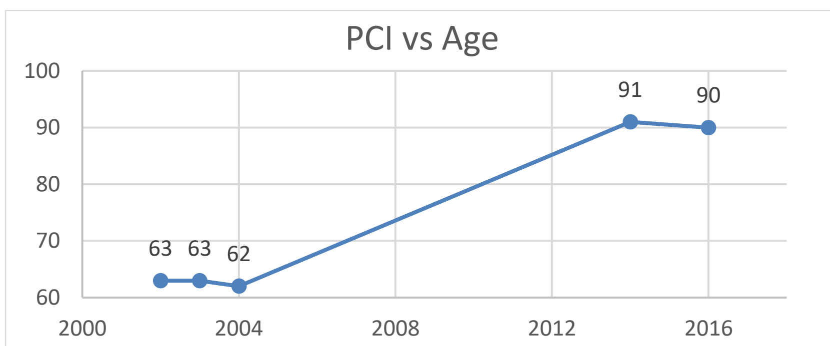


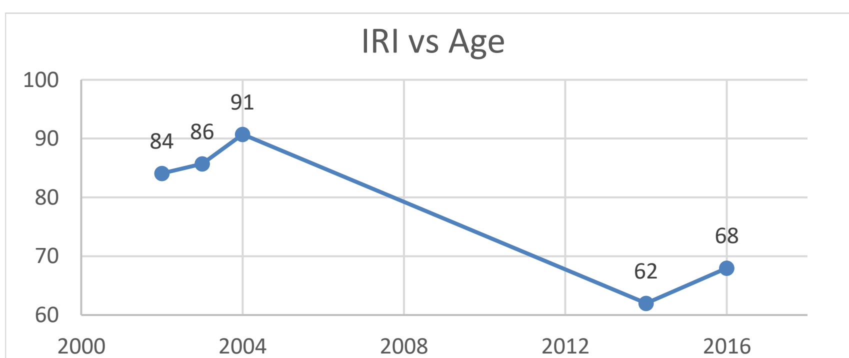
Location	Humboldt Co.
Road	C48
Road ID	1376
Thickness	4.0"
Overlay Type	BCOA
Traffic (AADT)	440-910
Transverse Joint Spacing	6'
Date	8/23/2017
Time	12:00 PM
Temp	70°F

Test No	MIRA Result
T1	Crack
T2	No Crack
T3	Crack
T4	No Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack



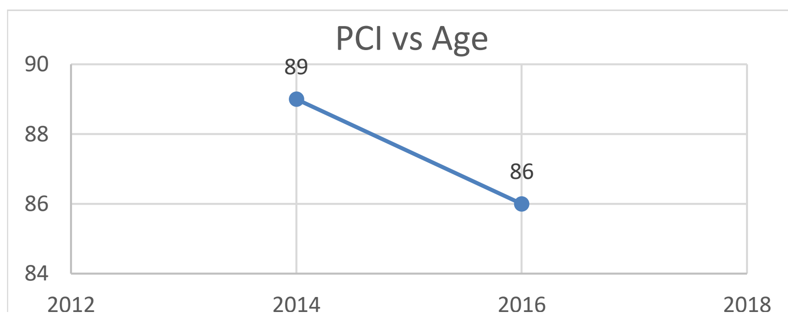


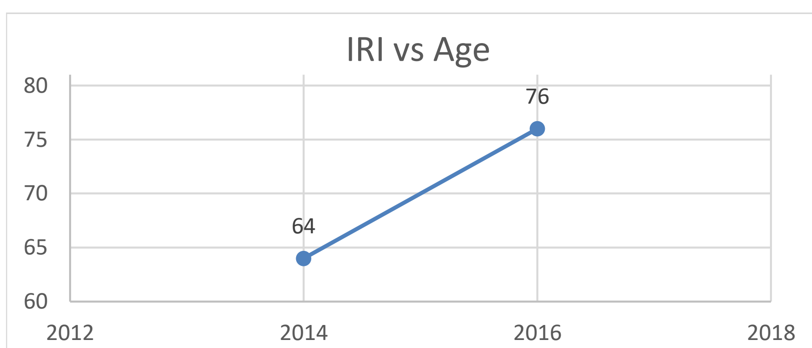


Location	Humboldt Co.
Road	P56
Road ID	1374
Thickness	4.0"
Overlay Type	BCOA
Traffic (AADT)	100-200
Transverse Joint Spacing	6'
Date	8/23/2017
Time	12:45 PM
Temp	72°F

Test No	MIRA Result
T1	No Crack
T2	No Crack
T3	Crack
T4	No Crack
T5	Crack
T6	No Crack
T7	No Crack
T8	Unknown
T9	Crack
T10	No Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	Crack
L5	Crack

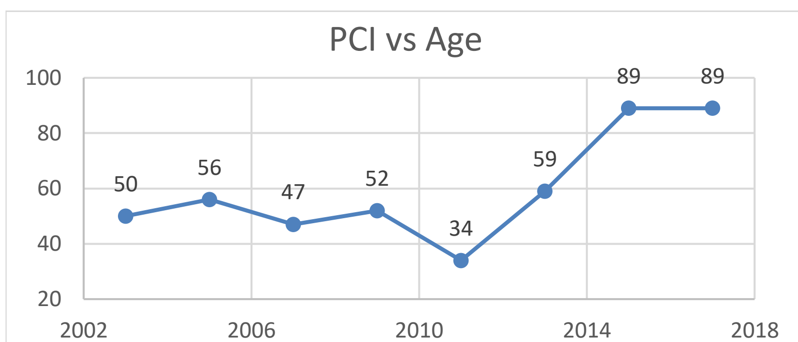


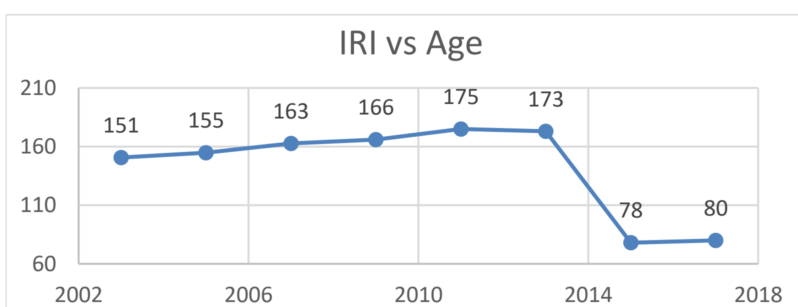


Location	Warren Co.
Road	G24
Road ID	1463
Thickness	7.0"
Overlay Type	UBOL
Traffic (AADT)	1600
Transverse Joint Spacing	12'
Date	9/1/207
Time	9:00 AM
Temp	56°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

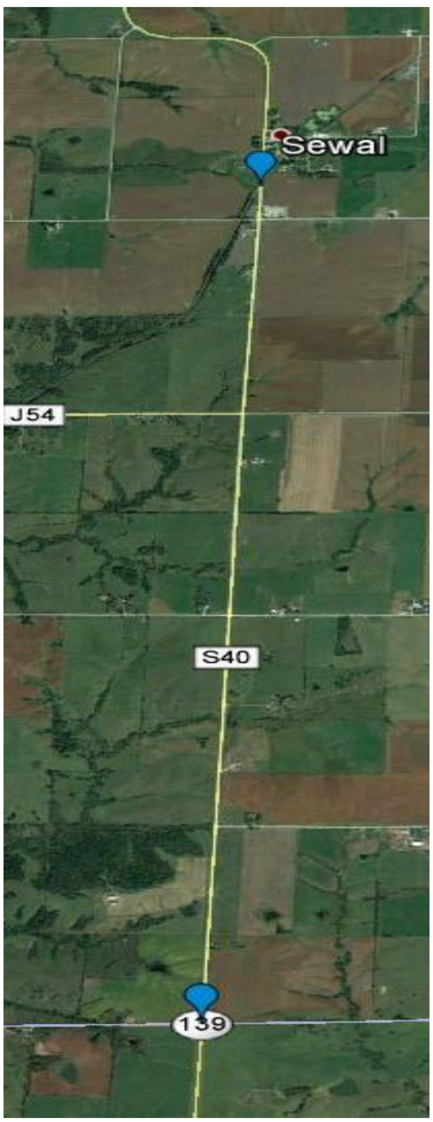


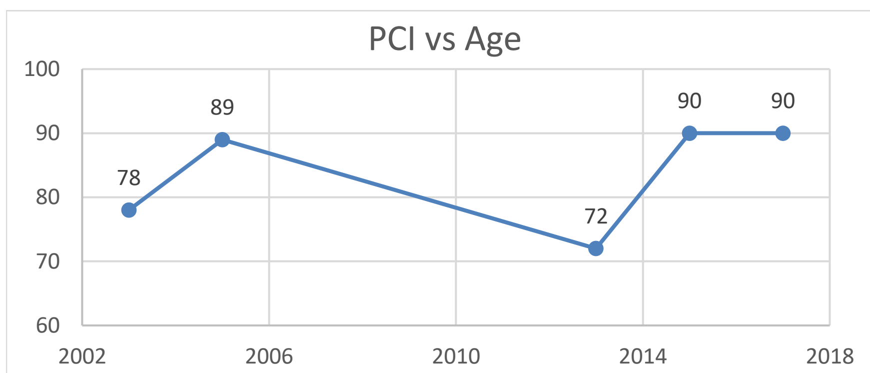


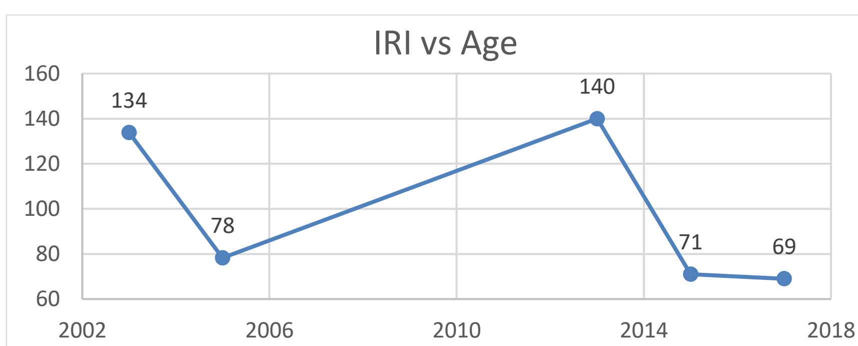
Location	Wayne Co.
Road	S40
Road ID	1508
Thickness	6.0"
Overlay Type	UBOL
Traffic (AADT)	300
Transverse Joint Spacing	20'
Date	9/1/2017
Time	11:00 AM
Temp	67°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-



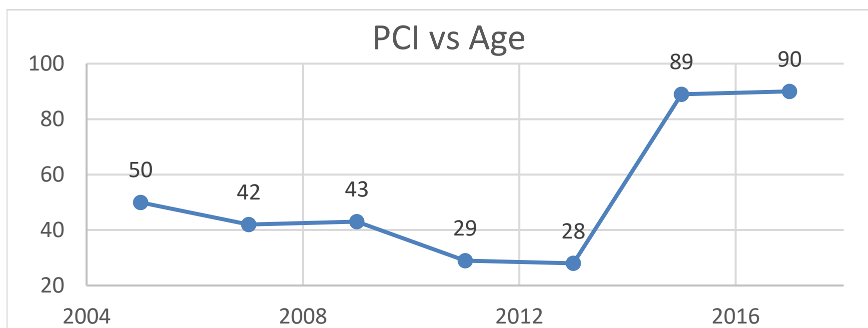


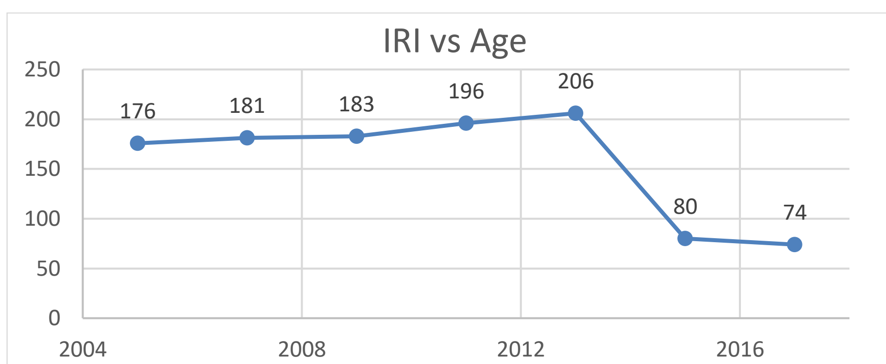


Location	**Jasper Co.**
Road	T38
Road ID	1470
Thickness	7.0"
Overlay Type	UBOL
Traffic (AADT)	680-1160
Transverse Joint Spacing	12'
Date	9/8/2017
Time	9:30 AM
Temp	63°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-

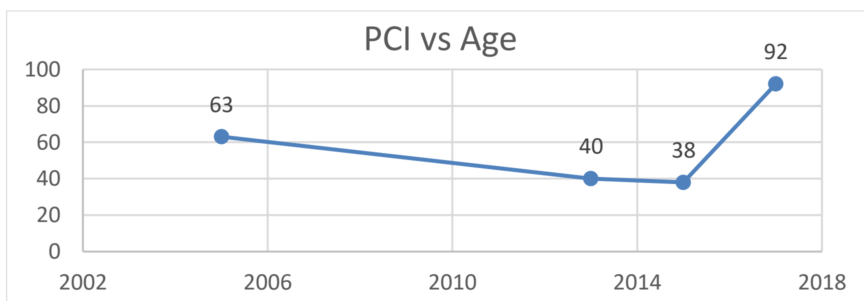


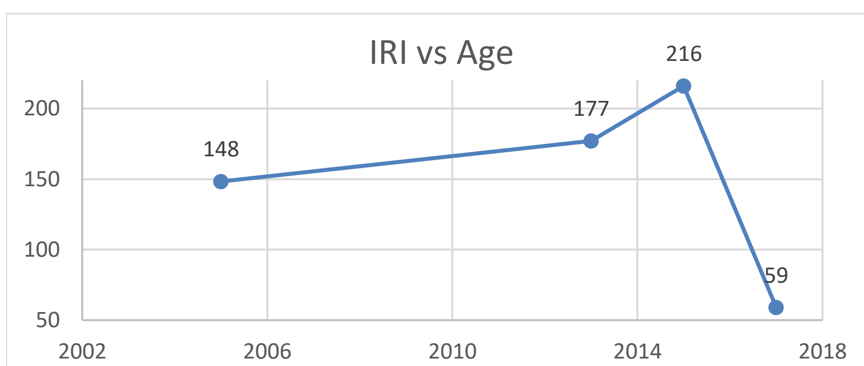


Location	Jones Co.
Road	X44
Road ID	1500
Thickness	7.0"
Overlay Type	UBOL
Traffic (AADT)	850
Transverse Joint Spacing	11'
Date	9/8/2017
Time	11:45 AM
Temp	68°F

Test No	MIRA Result
T1	Crack
T2	Crack
T3	Crack
T4	Crack
T5	Crack
T6	Crack
T7	Crack
T8	Crack
T9	Crack
T10	Crack

Test No	MIRA Result
L1	Crack
L2	Crack
L3	Crack
L4	-
L5	-





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