CRACK SURVEYS OF LOW-CRACKING HIGH-PERFORMANCE CONCRETE BRIDGE DECKS IN KANSAS
2014-2015

By

Abdallah Alhmood

David Darwin

Matt O'Reilly

A Report on Research Sponsored by

CONSTRUCTION OF CRACK-FREE BRIDGE DECKS

TRANSPORTATION POOLED-FUND PROGRAM

PROJECT NO. TPF-5(174)

Structural Engineering and Engineering Materials

SL Report 15-3

THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.

LAWRENCE, KANSAS

September 2015

ABSTRACT

Crack surveys were performed on Low-Cracking High-Performance Concrete (LC-HPC) and Control bridge decks as a continuation of the Construction of Crack-Free Concrete Bridge Decks research project. The specifications for LC-HPC and procedures for performing crack surveys are summarized. Sixteen LC-HPC bridge decks and thirteen control bridge decks are included in this study. The first 13 LC-HPC bridge decks are compared to their control decks in terms of crack density as a function of time. The crack densities for the three LC-HPC decks without control decks are also presented. An initial analysis on crack widths was performed on selected decks with widths ranging from 0.006 to 0.025 in. (0.15 to 0.64 mm). Twelve out of thirteen LC-HPC decks exhibit lower crack densities than their control decks. For the bridge decks surveyed in this study, the majority of the cracks are transverse and run parallel to the top layer of the deck's reinforcement. Relatively short cracks are present near the abutments and propagate perpendicular to the abutments (longitudinally). In some decks, longitudnial cracks were observed away from the bridge abutments, as well.

Key Words: bridge decks, cracking, high-performance concrete

ACKNOWLEDGEMENTS

This report is based on research performed by Abdallah Alhmood in partial fulfillment of the requirements for the MSCE degree from the University of Kansas. Funding for this research was provided by the Kansas Department of Transportation (DOT) serving as the lead agency for the "Construction of Crack-Free Bridge Decks" Transportation Pooled Fund Program, Project No. TPF-5(174). The Colorado DOT, Idaho Transportation Department, Indiana DOT, Michigan DOT, Minnesota DOT, Mississippi DOT, New Hampshire DOT, New York DOT, North Dakota DOT, Ohio DOT, Oklahoma DOT, Texas DOT, and Wisconsin DOT also provided funding for this project. Representatives from each sponsor served on a Technical Advisory Committee that provided advice and oversight for the project.

INTRODUCTION

According to ASCE (2013), 11% of bridges in the U.S. are rated as structurally deficient. More than 200 million cars travel over these deficient bridges daily. Cracking of concrete bridge decks is one major factor that causes bridges to become deficient. Cracks allow chlorides and moisture to reach the decks' reinforcement, which can result in corrosion of the reinforcement steel. This can lead to spalling of the concrete and a reduction in the service life of the bridge. (Lindquist, Darwin, and Browning 2005, 2006). Moreover, bridge cracking increases the potential of freeze-thaw damage occurring.

Much research has been done at the University of Kansas to study cracking in bridge decks. As part of that effort, Low-Cracking High-Performance Concrete (LC-HPC) specifications have been developed at the University of Kansas to eliminate concrete cracking in bridge decks. In 2005, the Kansas Department of Transportation (KDOT) with the contribution from the University of Kansas started constructing bridge decks following LC-HPC specifications for aggregate, concrete, and construction practices. Thirteen of these decks were paired with control decks that have similar traffic volume, age, and environmental conditions.

Every year, crack surveys are performed to compare the cracking performance of the LC-HPC decks against the control decks. Seventeen LC-HPC bridges were planned for construction. The specifications were followed on 16 of the 17 bridges; all 17, however, are included in the study. Bridges that were constructed in accordance with the LC-HPC specifications are labeled as LC-HPC-1 through 13, 15, 16, and 17. The single bridge that was not constructed in accordance with LC-HPC specifications is labeled as OP-14 (Overland Park 14). Control bridges are labeled Control-1 through 13. LC-HPC-1 and LC-HPC-2 are paired to one control deck, designated as Control 1/2, and LC-HPC-8 and LC-HPC-10 are paired to one control deck, designated as Control-

8/10. The bridge number reflects the order in which the bridges were bid, not the order in which they were constructed. Most of the bridge decks in this study are supported by steel girders. However, LC-HPC-8, LC-HPC-10, and Control-8/10 are supported by precast-prestressed concrete girders.

In this report, crack survey data for years 2014 and 2015 are summarized. Three reports were published previously summarizing the crack survey data for years 2006 through 2013. Gruman, Darwin, and Browning (2009) summarized crack survey data for years 2006, 2007, and 2008. Pendergrass, Darwin, and Browning (2011) summarized crack survey data for years 2009 and 2010. Bohaty, Riedel, and Darwin (2013) summarized crack survey data for years 2011, 2012 and 2013. In addition, more in-depth analysis, discussing the influence on deck age on deck cracking, is provided by Lindquist, Darwin, and Browning (2008). McLeod, Darwin, and Browning (2009) summarized the construction experiences for LC-HPC decks and the effects of environmental conditions and bridge design parameters on deck cracking. Yuan et al. (2011) described the development of the LC-HPC specifications. Pendergrass and Darwin (2014) studied crack reducing technologies, shrinkage-reducing admixtures and internal curing, and their effects on concrete durability.

SPECIFICATIONS

Three special provisions of the Kansas Department of Transportation (KDOT) standard specifications have been developed for LC-HPC bridge decks. These special provisions cover the requirements for aggregate, concrete, and construction practices with the goal of reducing cracking of concrete bridge decks (Kansas Department of Transportation 2007a,b,c).

Aggregate

LC-HPC specifications cover the requirements for coarse and fine aggregate. The coarse aggregate must be gravel, chat, or crushed stone. The minimum soundness and the maximum absorption should be 0.9 and 0.7, respectively. Table 1 lists the maximum allowable percentages of deleterious substance.

Table 1 – Deleterious Substance Requirements for Coarse Aggregate

Substance	Maximum % Allowable by Weight
Material passing No. 200 sieve	2.5%
Shale or shale-like material	0.5%
Clay lumps and friable particles	1.0%
Sticks (including absorbed water)	0.1%
Coal	0.5%

For the fine aggregate, natural sand (Type FA-A) or chat (Type FA-B) are the two acceptable types. Moreover, these types must meet both the KDOT and the AASHTO requirements for mortar strength and organic impurities, respectively. Tables 2 and 3 show the deleterious substance provisions for natural sand and chat, respectively.

Table 2 – Deleterious Substance Requirements for Type FA-A (Natural Sand)

Substance	Maximum % Allowable by Weight
Material passing No. 200 sieve	2.0%
Shale or shale-like material	0.5%
Clay lumps and friable particles	1.0%
Sticks (including absorbed water)	0.1%

Table 3 – Deleterious Substance Requirements for Type FA-B (Chat)

Substance	Maximum % Allowable by Weight
Material passing No. 200 sieve	2.0%
Clay lumps and friable particles	0.25%

The combined aggregate gradation must be obtained by implementing a proven optimization method such as KU Mix Method (Lindquist et al. 2008) or Shilstone (1990).

Concrete

According to the Kansas Department of Transportation (2007b), the minimum and maximum cement content that meets LC-HPC requirements are values between 500 and 540 lb/yd^3 of concrete (297 and 320 kg/m^3), respectively. Furthermore, the water-cement ratio (by weight) should range from 0.44 to 0.45. The engineer in charge can approve a reduction in the water-cement ratio to 0.43 at the bridge construction site. For LC-HPC bridge decks 1 through 7, the LC-HPC specifications permitted a cement content between 522 and 563 lb/yd^3 of concrete (310 to 334 kg/m^3), with a maximum water/cement ratio of 0.45. For LC-HPC bridge decks 8 through 13, the LC-HPC specifications permitted a cement content between 500 and 535 lb/yd^3 of concrete (297 to 317 kg/m^3) with a maximum water-cement ratio of 0.42. For LC-HPC bridge decks 15, 16, and 17, LC-HPC specifications permitted a cement content between 500 and 540 lb/yd^3 of concrete (297 to 320 kg/m^3) with minimum and maximum water-cement ratios of 0.44 and 0.45, respectively. All of the LC-HPC bridge decks discussed in this report, with the exception of LC-HPC 15 and 16, were constructed using 535 or 540 lb/yd^3 of concrete (317 and 320 kg/m^3). Bridge decks for LC-HPC 15 and 16 contained concrete with cement contents of 500 lb/yd^3 (297 kg/m^3) and 520 - 540 lb/yd^3 (308 to 320 kg/m^3), respectively.

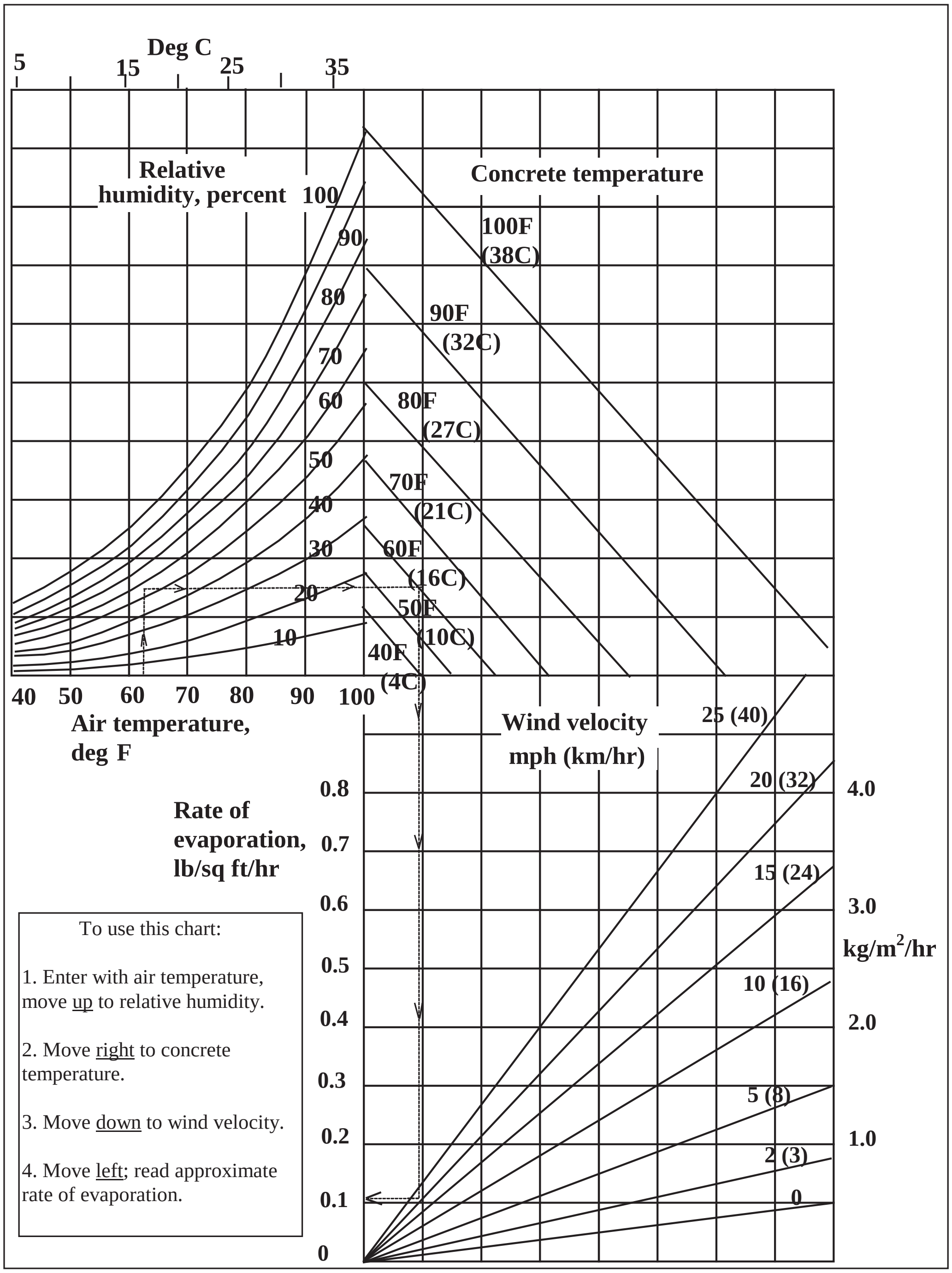
Concrete samples for fresh concrete property tests, such as those for slump or air content, should be collected at the discharge of the pump, conveyor, or bucket. The allowable air content (by volume) ranges from 6.5 to 9.5%. Current specifications state that the concrete slump should range from 1½ to 3 in. (38 to 76 mm); if concrete is discharged with a slump above 3½ in. (90 mm), it must be discarded. When LC-HPC 1 through 13 were constructed, the specifications at that time had a limit on slump of 4 in. (100 mm). The concrete temperature at the time of placement should not exceed 70°F (21°C) and should not be lower than 55°F (13°C). The construction engineer in charge can approve adjusting the range 5°F (3°C) higher or lower depending on the construction situation. After the construction of LC-HPC 1 through 13, the LC-HPC specifications were modified to set a lower and upper limit for the compressive strength of concrete. The 28-day compressive strength of concrete must be between 3500 and 5500 psi (24.1 and 37.0 MPa).

The use of Vinsol resin or tall oil-based air-entraining admixtures is permitted per the LC-HPC specifications. The use of mineral, set-accelerating, or set-retarding admixtures is prohibited. At the time of construction for LC-HPC 1 through 11, the specifications permitted the use of water-reducing, set-retarding, and Type C or E set-accelerating admixtures only if approved by the engineer in charge. Nevertheless, only water-reducing admixtures were used in these decks. The current specification allows for a Type A water-reducer or dual-rated Type A-F water-reducer. A Type F high-range water-reducer can be used if concrete made with it complies with the plastic and hardened concrete properties specifications. If slump on site needs to be adjusted, only adding water-reducing or high-range water-reducing admixtures is allowed. Withholding a portion of water during batching is not allowed.

The concrete supplier and contractor must demonstrate the ability to meet all the specifications by preparing both a qualification batch and a qualification concrete slab using LC-HPC concrete before the bridge deck is constructed (Kansas Department of Transportation 2007c). Before the qualification batch is verified, the actual jobsite haul time must be simulated. All admixtures must be included in the qualification batch. The same personnel and equipment must place both the qualification slab and the LC-HPC bridge deck. If the concrete meets the LC-HPC specifications during the construction of the qualification slab, then those mixture proportions can be used in the LC-HPC deck.

Construction

Ambient temperature, wind speed, relative humidity 12 in. (30 cm) above the deck, and the plastic temperature of concrete must be measured at least once per hour by KDOT personnel. This information can be used to estimate the evaporation rate by using an evaporation rate chart (Figure 1). At all times during the construction process, the evaporation rate must remain under 0.2 lb/ft^2/hr (1 kg/m^2/hr). If the evaporation rate upper limit is exceeded, concrete cooling, wind break installation, or other methods must be implemented to reduce the evaporation rate. Reducing the evaporation rate by concrete fogging is prohibited.



Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. To use the chart, follow the four steps outlined above. When the evaporation rate exceeds 0.2 lb/ft^2/hr (1.0 kg/ m^2/hr), measures shall be taken to prevent excessive moisture loss from the surface of unhardened concrete; when the rate is less than 0.2 lb/ft^2/hr (1.0 kg/m^2/hr) such measures may be needed. When excessive moisture loss is not prevented, plastic cracking is likely to occur.

Figure 1: Evaporation Rate Chart (ACI Committee 308)

LC-HPC specifications allow contractors to use buckets or conveyors to place concrete. A concrete pump may be used if the contractor demonstrated the ability to pump the LC-HPC concrete during the construction of the qualification slab. To avoid loss of entrained air in concrete, it is not acceptable to drop concrete from a height greater than 5 ft (1.5 m), and concrete pumps must have an air cuff or bladder valve.

CRACK SURVEY PROCEDURE

Crack surveys for both LC-HPC and control bridge decks are performed annually. The surveys are performed in accordance with the specifications presented in Appendix A and summarized next.

Procedure

To provide accurate and comparable results, a standard procedure is followed for crack surveys. Crack surveys should be performed only on a day that is at least mostly sunny. The air temperature should not be less than 60°F (16°C) at the time of survey. Moreover, the bridge deck should be completely dry. The crack survey is invalid if it rains during the time of survey or if the sky becomes overcast.

A scaled plan (map) for the bridge deck should be developed and printed before the survey. These plans serve as the template to indicate the location and length of the cracks on the actual bridge deck, and they should include a compass indicating north. Plans should be developed at a scale of 1 in. = 10 ft (25.4 mm = 3.048 m). Furthermore, a 5 ft × 5 ft (1.524 m × 1.524 m) grid should be printed on a separate paper and placed underneath the deck plan; this grid should match the bridge grid that will be discussed later in this section. The grid helps the surveyor keep track of crack location and length. Some human error is involved when drawing the cracks. This, however, has not been an issue from year to year based on the results.

Traffic control is provided to ensure the safety of the surveyors during the bridge survey. After closing at least one lane of the bridge to traffic, two surveyors start drawing a 5 ft × 5 ft (1.524 m × 1.524 m) grid on the bridge deck using sidewalk chalk or lumber crayons. This grid is called the bridge grid and should match the plan grid discussed earlier. Afterwards, surveyors mark any cracks they can see while bending at waist height. Surveyors should not mark any crack that cannot be seen from waist height. When surveyors see a crack, they may bend closer and trace the crack to its end, even tracing portions of the same crack that cannot be seen from waist height. If the surveyors see another crack while tracing a crack (not attached to the crack being traced), they should not mark it unless it can also be seen when bending from waist height. After marking a crack, the surveyors should return to the location where they started marking the crack and continue surveying. At least two surveyors should inspect each section of the bridge. This method will result in more consistent crack survey results between bridges (Lindquist et al. 2005, 2008). After cracks are marked on the bridge, another surveyor draws the marked cracks on the scaled bridge plan.

Later, bridge plans are scanned into a computer, and converted to AutoCAD files. In AutoCAD, any lines from the bridge plan not representing cracks (such as bridge abutments or boundaries) are erased. Afterwards, the total length of the cracks can be measured using AutoCAD. Crack density can be calculated afterwards by dividing the total length of the cracks by the known bridge deck area. Crack densities are reported in m/m^2 for the whole bridge, each placement, and each span.

Starting in the summer of 2015, crack widths were measured for most of the bridges that were surveyed. Crack widths were measured using a wallet-sized crack comparator. Most of the crack widths for cracks that can be seen from waist height have widths between 0.006 and 0.025 in. (0.150 mm to 0.635 mm). The details of the crack width study will be available in future reports.

RESULTS

Tables 4 and 5 summarize the crack density for the bridge decks surveyed in 2014 and 2015, respectively. The crack maps for these surveys are included in this section. The results of the surveys performed in 2006, 2007, and 2008 were reported by Gruman, Darwin, and Browning (2009), those performed in 2009 and 2010 were reported by Pendergrass, Darwin, and Browning (2011), and those performed in 2011, 2012, and 2013 were reported by Bohaty, Riedel, and Darwin (2013); the earlier results are summarized in Appendix B. Figure 2 shows crack densities over time for all the bridges included in this study. It can be concluded that the average trend of the LC-HPC decks is lower than the average trend of the control decks. The fact that some LC-HPC decks exhibited greater crack density values than some control decks is because they have experienced different conditions. This report includes individual comparisons for each LC-HPC and control deck pair. In most cases, LC-HPC decks performed better than their controls.

Table 4 – 2014 Crack Density Comparison of LC-HPC vs. Control Decks

	Deck Age (months)	2014 Crack Density (m/m²)	Lower Crack Density	Bridge Girder Type
LC-HPC-1	102.5/103.1	0.033	LC-HPC	Steel
Control-1/2	102.7/103.3	0.151		
LC-HPC-2	92.2	0.116	LC-HPC	Steel
Control-1/2	102.7/103.3	0.151		
LC-HPC-3	79.4	0.759	Control	Steel
Control-3	83.2	0.376		
LC-HPC-4	80.4/80.3	0.225	LC-HPC	Steel
Control-4	80.7	0.667		
LC-HPC-5	79.4	0.229	N/A	Steel
Control-5	-	Did not survey		
LC-HPC-6	79.7	0.356	LC-HPC	Steel
Control-6	68.2	0.646		
LC-HPC-7	95.7	0.087	N/A	Steel
Control-7	-	Did not survey		
LC-HPC-8	81.6	0.425	LC-HPC	Prestressed Concrete
Control-8/10	87.2	0.566		
LC-HPC-9	62.0	0.454	LC-HPC	Steel
Control-9	73.8/74.1	0.733		
LC-HPC-10	86.2	0.117	LC-HPC	Prestressed Concrete
Control-8/10	87.2	0.566		
LC-HPC-11	84.8	0.842	LC-HPC	Steel
Control-11	98.0	0.922		
LC-HPC-12	64.9/76.3	0.657	LC-HPC	Steel
Control-12	64.0/76.4	1.152		
LC-HPC-13	75.2	0.471	LC-HPC	Steel
Control-13	72.5	0.711		
LC-HPC-15	43.0	0.317	N/A	Steel
LC-HPC-16	43.5	0.311	N/A	Steel
LC-HPC-17	32.5	0.274	N/A	Steel

Table 5 – 2015 Crack Density Comparison of LC-HPC vs. Control Decks

	Deck Age (months)	2015 Crack Density (m/m^2)	Lower Crack Density	Bridge Girder Type
LC-HPC-1	15.1/114.5	0.045	LC-HPC	Steel
Control-1/2	115.6/115.3	0.189		
LC-HPC-2	104.2	0.222	LC-HPC	Steel
Control-1/2	115.6/115.3	0.189		
LC-HPC-3	91.5	0.487	Control	Steel
Control-3	96.9	0.391		
LC-HPC-4	93.3/93.2	0.217	LC-HPC	Steel
Control-4	92.9	0.775		
LC-HPC-5	91.8	0.247	N/A	Steel
Control-5	-	Did not survey		
LC-HPC-6	92.2	0.386	LC-HPC	Steel
Control-6	81.9	0.628		
LC-HPC-7	106.9	0.036	N/A	Steel
Control-7	-	Did not survey		
LC-HPC-8	92.0	0.462	LC-HPC	Prestressed Concrete
Control-8/10	98.1	0.680		
LC-HPC-9	73.6	0.430	LC-HPC	Steel
Control-9	84.4/84.1	0.779		
LC-HPC-10	96.8	0.125	LC-HPC	Prestressed Concrete
Control-8/10	98.1	0.680		
LC-HPC-11	-	Did not survey	N/A	Steel
Control-11	-	Did not survey		
LC-HPC-12	-	Did not survey	N/A	Steel
Control-12	-	Did not survey		
LC-HPC-13	85.9	0.486	LC-HPC	Steel
Control-13	84.1	0.718		
LC-HPC-15	56.2	0.299	N/A	Steel
LC-HPC-16	55.0	0.397	N/A	Steel
LC-HPC-17	45.5	0.308	N/A	Steel

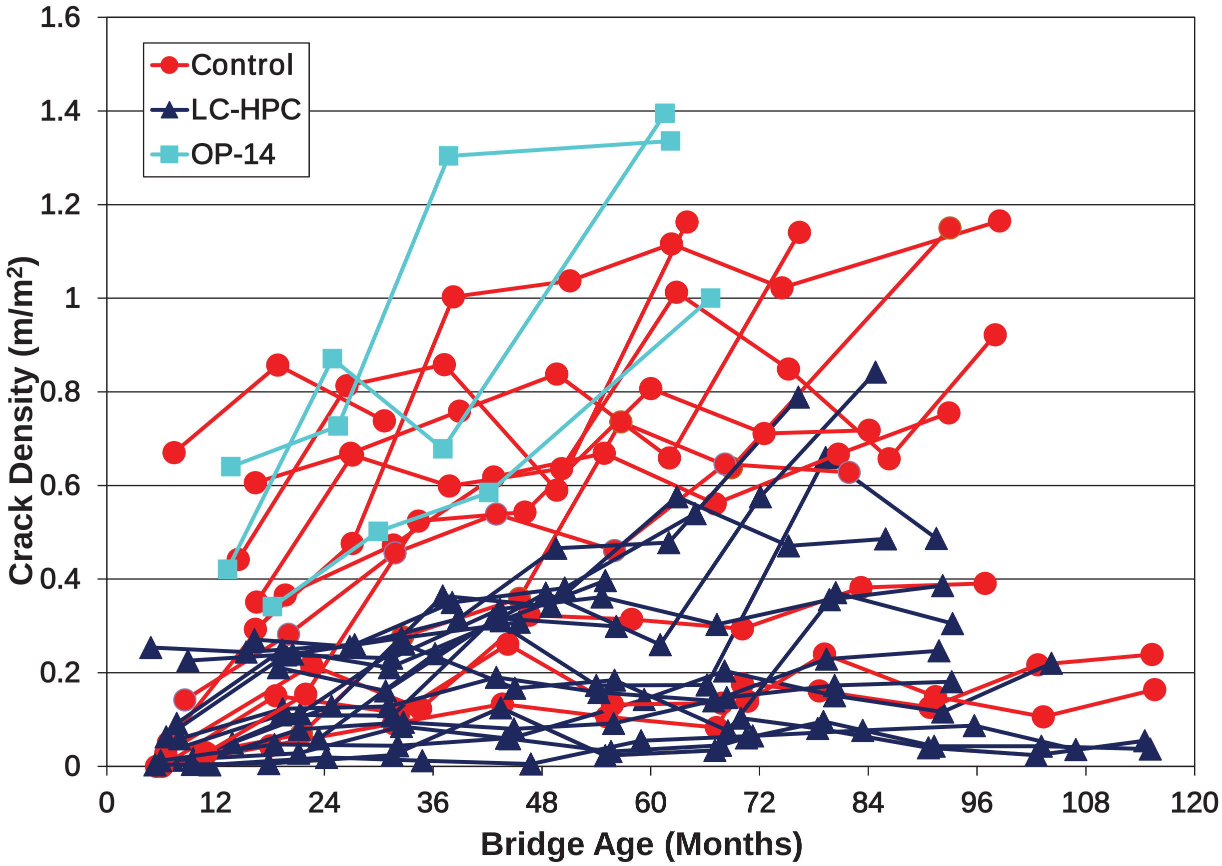
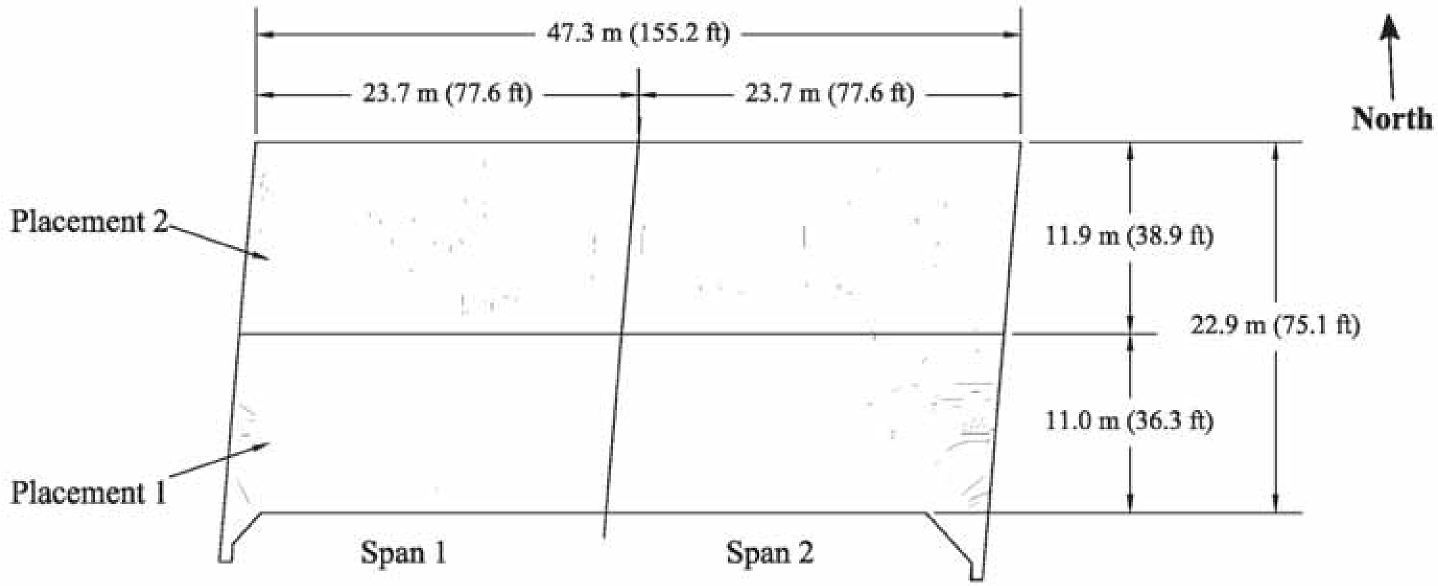


Figure 2: LC-HPC and Control Decks Crack Densities Versus Deck Age

LC-HPC-1

The bridge deck of LC-HPC-1 was constructed in two placements; Placement 1 was placed on 10/14/2005 and Placement 2 was placed on 11/2/2005. This bridge has been surveyed ten times; the results of Surveys 9 and 10 of LC-HPC-1 are included in this report. Survey 9 was performed at a deck age of 103.1 months for Placement 1 and 102.5 months for Placement 2; the crack map from this survey is shown in Figure 3. Survey 10 was performed at a deck age of 115.1 months for Placement 1 and 114.5 months for Placement 2; the crack map from this survey is shown in Figure 4. Crack densities of 0.050 and 0.027 m/m^2 were observed in Survey 9 (Figure 3) for Placements 1 and 2, respectively. These values are similar to the crack densities from Survey 8, reported by Bohaty et al. (2013). Crack densities of 0.037 and 0.055 m/m^2 were observed in Survey 10 (Figure 4) for Placements 1 and 2, respectively. Survey 10 for Placement 1 showed that the bridge deck had a slightly lower crack density compared to Survey 9. The surveys showed that the deck has experienced some scaling, making it harder to identify cracks during the survey. As shown in Figures 3 and 4, most of the cracks that were marked for both placements are relatively small transverse cracks, parallel to the deck's top reinforcement, with longitudinal cracks near the abutments.

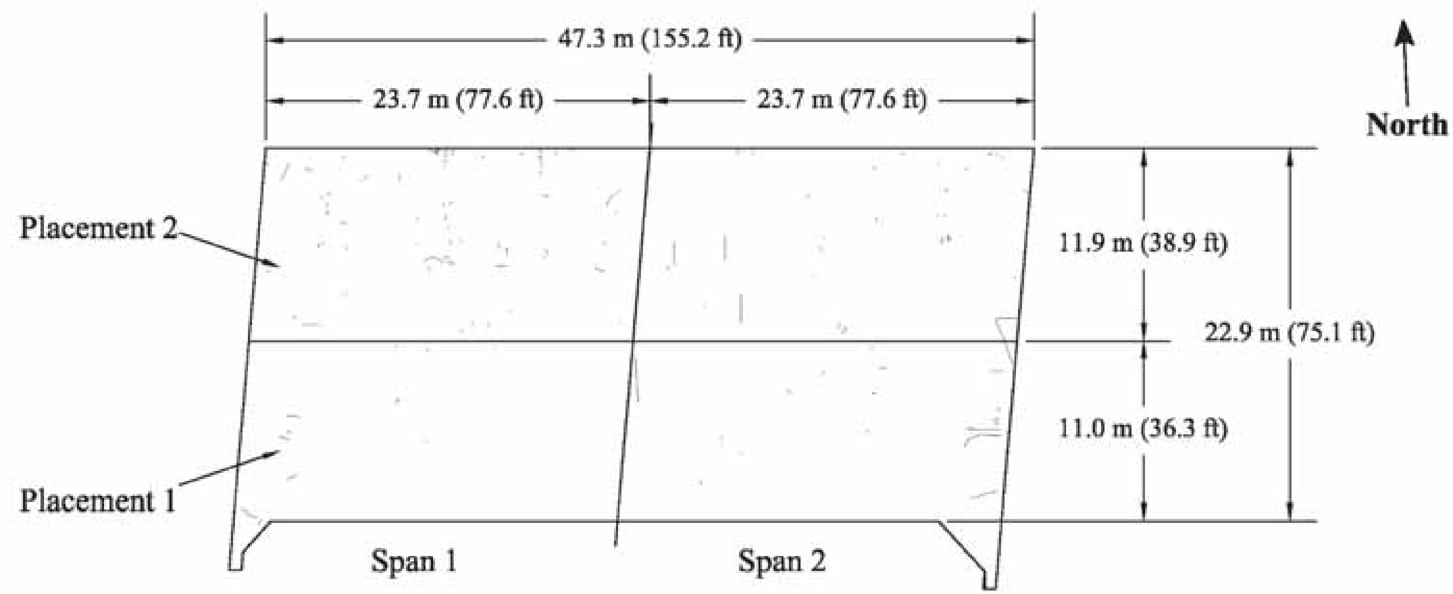


Bridge Number: 105-304 (KU #1)
Bridge Location: EB Parallel Pkwy over I-635
Construction Date:
Placement 1 (South): 10/14/2005
Placement 2 (North): 11/2/2005
Crack Survey Date: 5/19/2014

Bridge Length: 47.3 m (155.2 ft)
Bridge Width: 22.9 m (75.1 ft)
Skew: -5°
Number of Spans: 2
Span 1 (West): 23.7 m (77.6 ft)
Span 2 (East): 23.7 m (77.6 ft)
Number of Placements: 2

Bridge Age:
Placement 1: 103.1 months
Placement 2: 102.5 months
Crack Density: 0.038 m/m²
Placement 1: 0.050 m/m²
Placement 2: 0.027 m/m²
Span 1: 0.022 m/m²
Span 2: 0.051 m/m²

Figure 3: LC-HPC-1 (Survey 9)



Bridge Number: 105-304 (KU #1)
Bridge Location: EB Parallel Pkwy over I-635
Construction Date:
Placement 1 (South): 10/14/2005
Placement 2 (North): 11/2/2005
Crack Survey Date: 5/18/2015

Bridge Length: 47.3 m (155.2 ft)
Bridge Width: 22.9 m (75.1 ft)
Skew: -5°
Number of Spans: 2
Span 1 (West): 23.7 m (77.6 ft)
Span 2 (East): 23.7 m (77.6 ft)
Number of Placements: 2

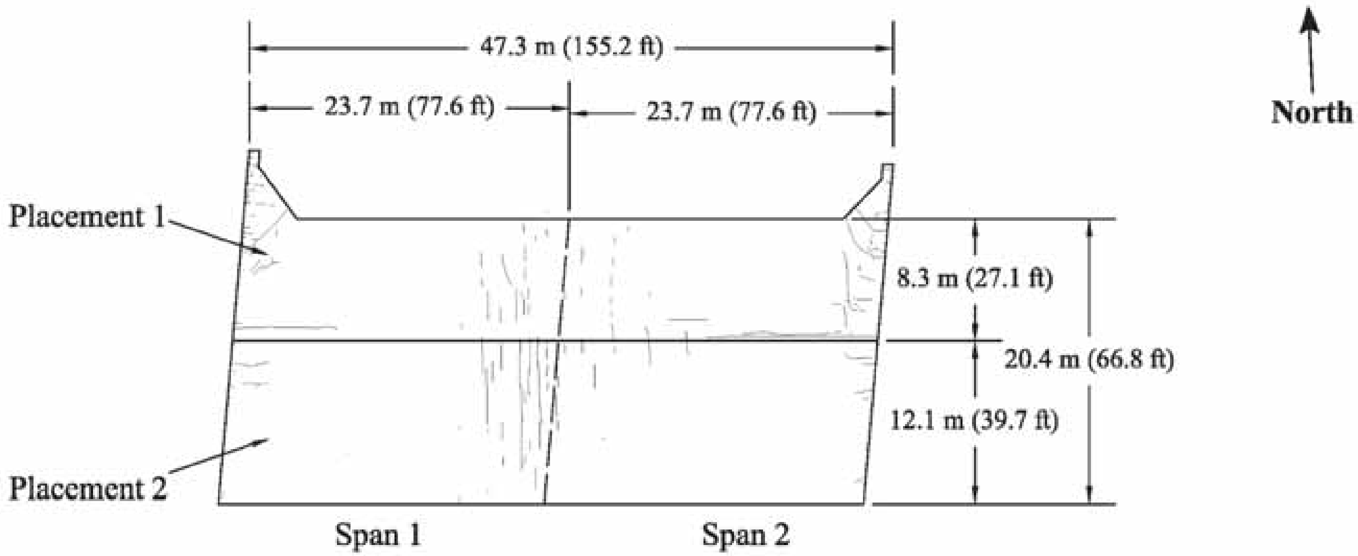
Bridge Age:
Placement 1: 115.1 months
Placement 2: 114.5 months
Crack Density: 0.045 m/m^2
Placement 1: 0.037 m/m^2
Placement 2: 0.055 m/m^2
Span 1: 0.043 m/m^2
Span 2: 0.053 m/m^2

Figure 4: LC-HPC-1 (Survey 10)

Control-1/2

Control-1/2 is paired with both LC-HPC-1 and LC-HPC-2, which have similar environmental conditions, age, and traffic volume. To date, Control-1/2 has been surveyed ten times. The deck was constructed in two placements; Placement 1 was constructed on 9/30/2005 and Placement 2 was constructed on 10/10/2005. The results of Surveys 9 and 10 of Control-1/2 are included in this report. Survey 9 was performed at a deck age of 103.3 months for Placement 1 and 102.7 months for Placement 2; the crack map from this survey is shown in Figure 5. Survey 10 was completed at a deck age of 115.6 months for Placement 1 and 115.3 months for Placement 2; the crack map from this survey is shown in Figure 6. Crack densities of 0.106 and 0.217 m/m^2 were observed in Survey 9 for Placements 1 and 2, respectively (Figure 5). Crack densities of 0.164 and 0.239 m/m^2 were observed in Survey 10 for Placements 1 and 2, respectively (Figure 6). These crack densities are greater than the densities from Survey 8 reported by Bohaty et al. (2013). Most of the cracking is transverse and took place above the pier. These cracks are parallel to the top reinforcement. Cracks have propagated longitudinally near the abutments. A limited amount of map cracking has occurred since Survey 9.

The crack densities for LC-HPC-1 and Control-1/2 are compared in Figure 7. The crack densities for both placements of Control-1/2 have been greater than the crack densities for LC-HPC-1. In almost all cases, this has been universally true for the past few surveys.

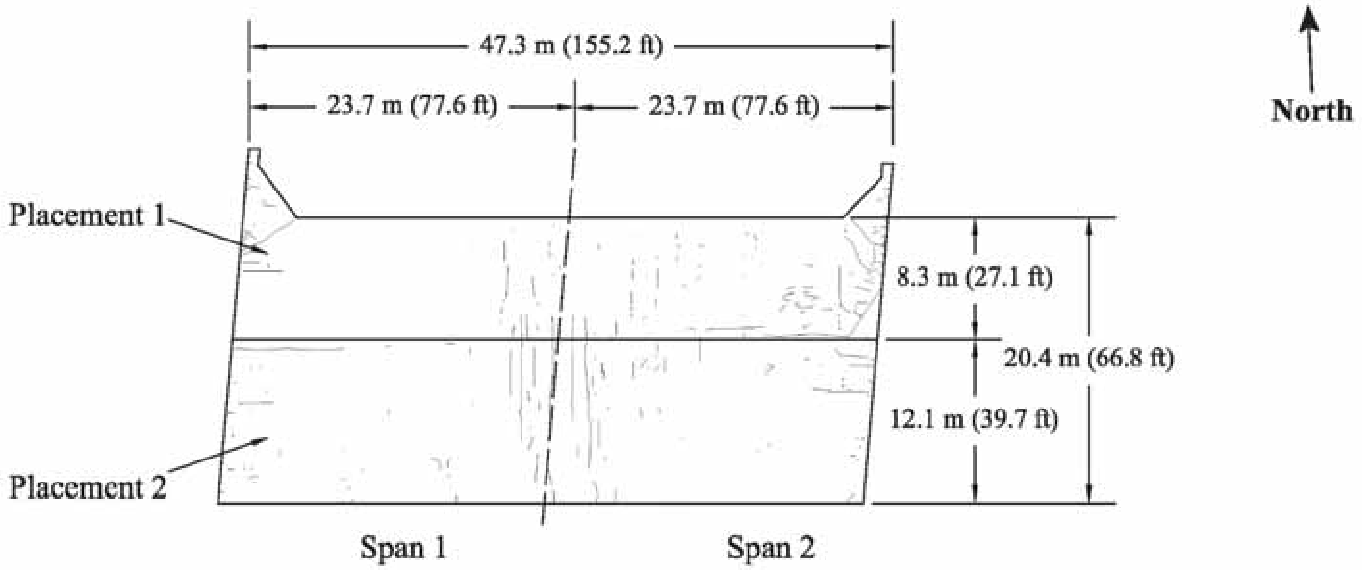


Bridge Number: 105-311 (KU #1/2 Control)
Bridge Location: WB Parallel Pkwy over I-635
Construction Dates:
North Subdeck: 9/30/2005
North Overlay: 10/10/2005
South Subdeck: 10/18/2005
South Overlay: 10/28/2005
Crack Survey Date: 5/19/2014

Bridge Length: 47.3 m (155.2 ft)
Bridge Width: 20.7 m (67.8 ft)
Skew: -5°
Number of Spans: 2
Span 1 (West): 23.7 m (77.6 ft)
Span 2 (East): 23.7 m (77.6 ft)
Number of Placements: 2

Bridge Age:
Placement 1 (N): 103.3 months
Placement 2 (S): 102.7 months
Crack Density: 0.151 m/m²
Placement 1: 0.106 m/m²
Placement 2: 0.217 m/m²
Span 1: 0.184 m/m²
Span 2: 0.118 m/m²

Figure 5: Control-1/2 (Survey 9)



Bridge Number: 105-311 (KU #1/2 Control)
Bridge Location: WB Parallel Pkwy over I-635
Construction Dates:
North Subdeck: 9/30/2005
North Overlay: 10/10/2005
South Subdeck: 10/18/2005
South Overlay: 10/28/2005
Crack Survey Date: 5/18/2015

Bridge Length: 47.3 m (155.2 ft)
Bridge Width: 20.7 m (67.8 ft)
Skew: -5°
Number of Spans: 2
Span 1 (West): 23.7 m (77.6 ft)
Span 2 (East): 23.7 m (77.6 ft)
Number of Placements: 2

Bridge Age:
Placement 1 (N): 115.6 months
Placement 2 (S): 115.3 months
Crack Density: 0.189 m/m^2
Placement 1: 0.239 m/m^2
Placement 2: 0.164 m/m^2
Span 1: 0.139 m/m^2
Span 2: 0.242 m/m^2

Figure 6: Control-1/2 (Survey 10)

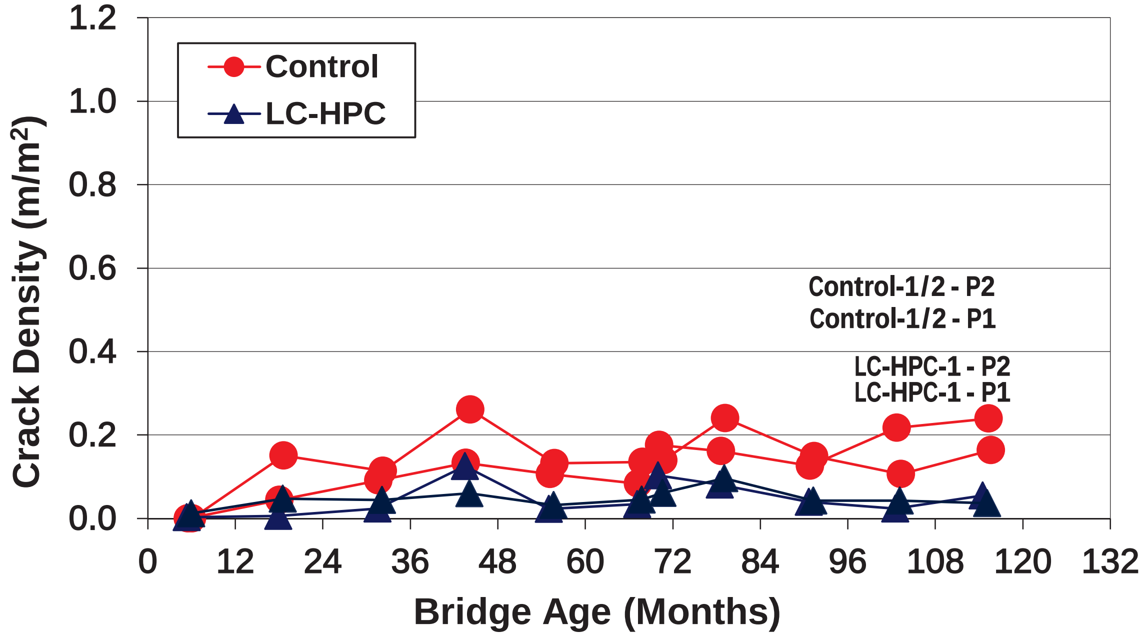
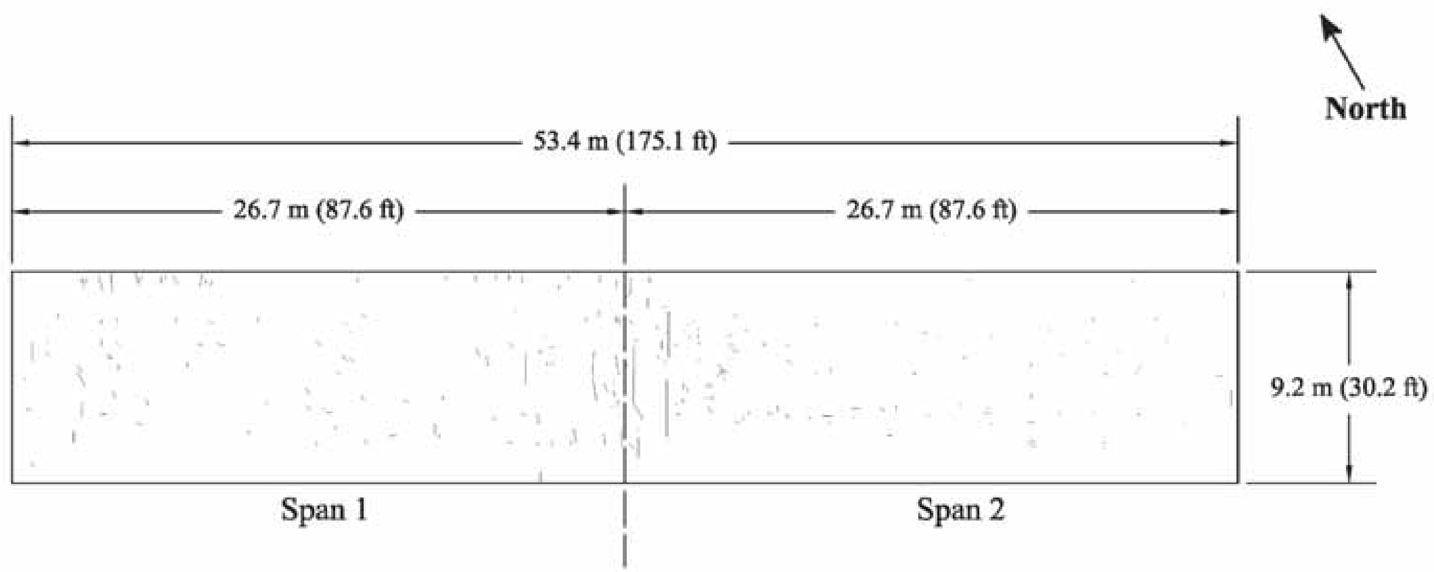


Figure 7: LC-HPC-1 and Control-1/2 Crack Densities Versus Deck Age

LC-HPC-2

Bridge deck LC-HPC-2 was constructed on 9/13/2006, and has been surveyed 9 times. Survey 8 was performed at a deck age of 92.2 months; the crack map from this survey is displayed in Figure 8. Survey 9 was completed at a deck age of 104.2 months; the crack map from this survey is shown in Figure 9. A crack density of 0.116 m/m^2 was observed in Survey 8 (Figure 8). This value is noticeably lower than observed in Survey 7, 0.141 m/m^2, as reported by Bohaty et al. (2013) at an age of 80.3 months. A crack density of 0.220 m/m^2 was observed in Survey 9 (Figure 9), which is higher than all previously reported crack densities. As shown in Figure 10, LC-HPC-2 has a higher overall crack density than Placement 1 of Control-1/2 and a slightly lower crack density than Placement 2 of Control-1/2 at approximately the same age. Map cracking is the dominant type of crack that has been surveyed. Some transverse cracks appear in the middle of the bridge above the pier.

As shown in Figure 10, the two decks are exhibiting similar cracking behavior. Placement 2 of Control-1/2 has a higher crack density than LC-HPC-2 and Placement 1 of Control-1/2. Placement 1 of Control-1/2 has a lower crack density than LC-HPC-2. Control-1/2 is the best performing control deck in the study.

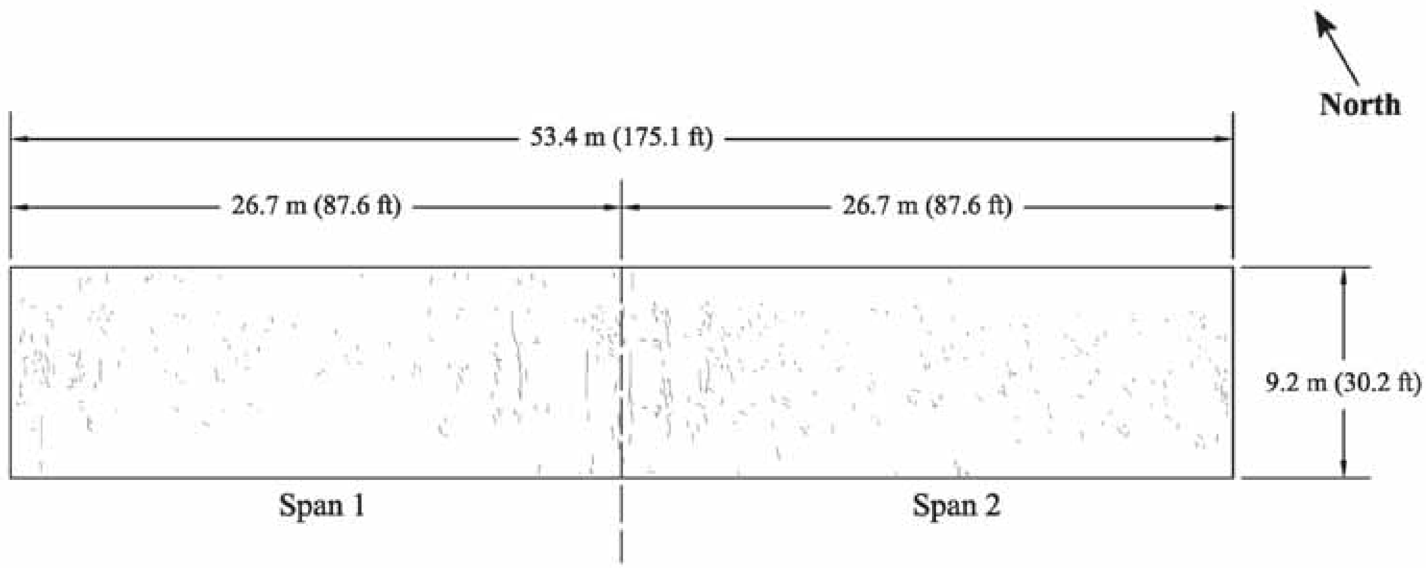


Bridge Number: 105-310 (KU #2)
Bridge Location: 34th St over I-635
Construction Date: 9/13/2006
Crack survey Date: 5/20/2014

Bridge Length: 53.4 m (175.2 ft)
Bridge Width: 9.2 m (30.2 ft)
Skew: 0°
Number of Spans: 2
Span 1 (West): 26.7 m (87.6 ft)
Span 2 (East): 26.7 m (87.6 ft)
Number of Placements: 1

Bridge Age: 92.2 months
Crack density: 0.116 m/m^2
Span 1 (West): 0.131 m/m^2
Span 2 (East): 0.101 m/m^2

Figure 8: LC-HPC-2 (Survey 8)



Bridge Number: 105-310 (KU #2)
Bridge Location: 34th St over I-635
Construction Date: 9/13/2006
Crack survey Date: 5/19/2015

Bridge Length: 53.4 m (175.2 ft)
Bridge Width: 9.2 m (30.2 ft)
Skew: 0°
Number of Spans: 2
Span 1 (West): 26.7 m (87.6 ft)
Span 2 (East): 26.7 m (87.6 ft)
Number of Placements: 1

Bridge Age: 104.2 months
Crack density: 0.222 m/m^2
Span 1 (West): 0.220 m/m^2
Span 2 (East): 0.223 m/m^2

Figure 9: LC-HPC-2 (Survey 9)

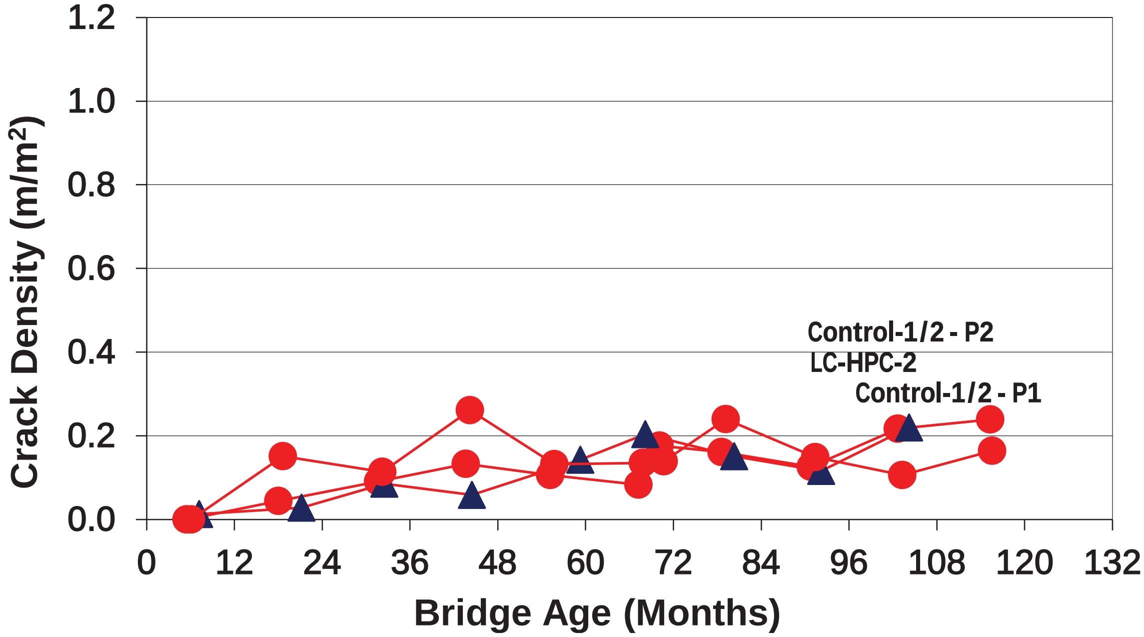
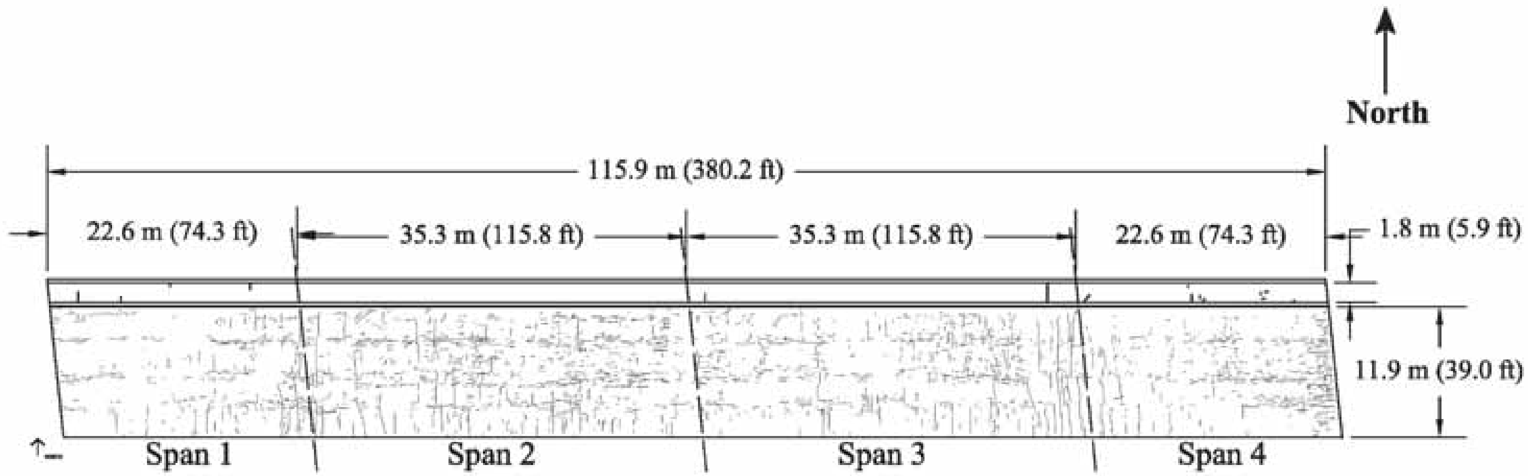


Figure 10: LC-HPC-2 and Control-1/2 Crack Densities Versus Deck Age

LC-HPC-3

Bridge deck LC-HPC-3 was constructed on 11/13/2007. To date, LC-HPC-3 has been surveyed eight times. The results from surveys 7 and 8 are included in this report. Survey 7 of LC-HPC-3 was completed at deck age of 83.2 months; the crack map is shown in Figure 11. Survey 8 of LC-HPC-3 was performed at a deck age of 91.5 months; the crack map is shown in Figure 12. A crack density of 0.663 m/m^2 was observed in Survey 7 (Figure 11), which is significantly higher than obtained in Survey 6 at 0.174 m/m^2 reported by Bohaty et al. (2013). A crack density of 0.487 m/m^2 was observed in Survey 8 (Figure 12). During Survey 7, the surveyors may have mistakenly misidentified the outlines of the aggregate as cracks. Survey 7 could be considered as an outlier. The vast majority of the cracks are relatively short in length. A few medium-length transverse cracks run parallel to the top layer of reinforcement, primarily over the two outer piers.

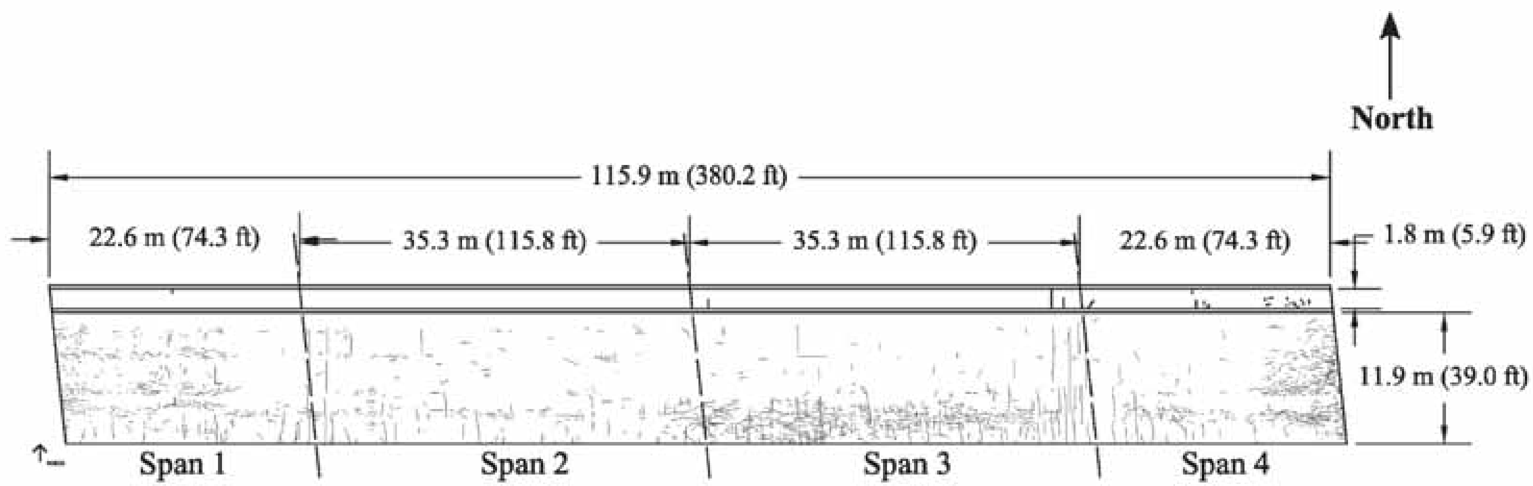


Bridge Number: 46-338 (KU #3)
Bridge Location: WB 103rd St over US 69
Construction Date: 11/13/2007
Crack survey Date: 6/24/2014

Bridge Length: 115.9 m (380.2 ft)
Bridge Width: 11.9 m (39.0 ft)
Skew: 6°
Number of Spans: 4
Span 1 : 22.6 m (74.3 ft)
Span 2 : 35.3 m (115.8 ft)
Span 3 : 35.3 m (115.8 ft)
Span 4 : 22.6 m (74.3 ft)
Number of Placements: 1

Bridge Age: 79.3 months
Crack density: 0.660 m/m^2
Span 1 : 0.488 m/m^2
Span 2 : 0.843 m/m^2
Span 3 : 0.640 m/m^2
Span 4 : 0.576 m/m^2

Figure 11: LC-HPC-3 (Survey 7)



Bridge Number: 46-338 (KU #3)
Bridge Location: WB 103rd St over US 69
Construction Date: 11/13/2007
Crack survey Date: 6/29/2015

Bridge Length: 115.9 m (380.2 ft)
Bridge Width: 11.9 m (39.0 ft)
Skew: 6°
Number of Spans: 4
Span 1 : 22.6 m (74.3 ft)
Span 2 : 35.3 m (115.8 ft)
Span 3 : 35.3 m (115.8 ft)
Span 4 : 22.6 m (74.3 ft)
Number of Placements: 1

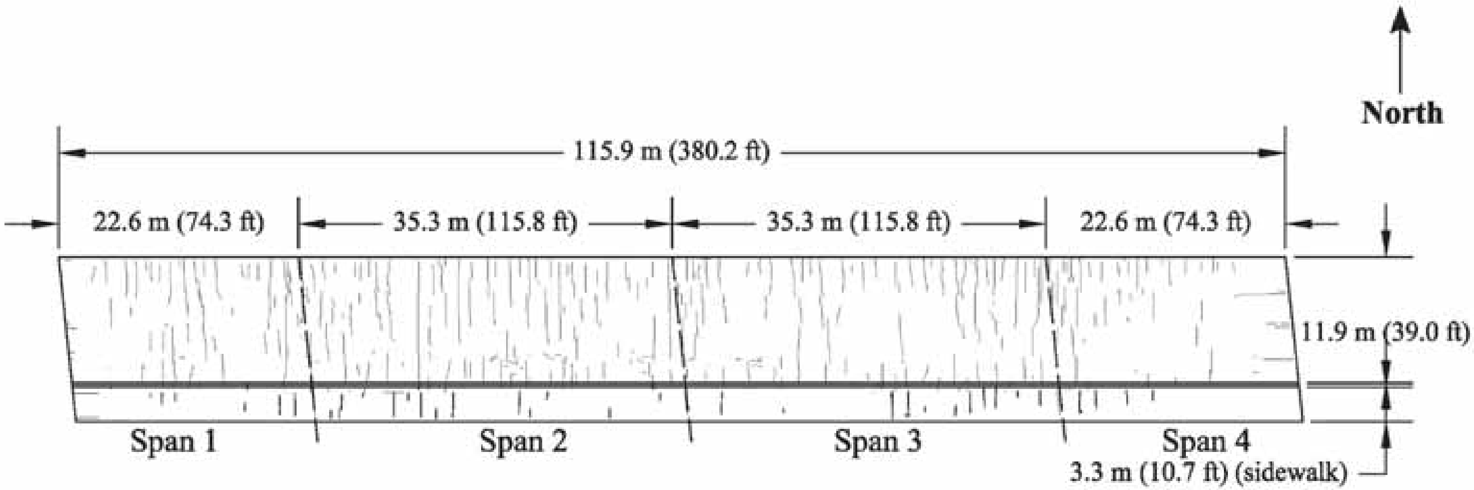
Bridge Age: 91.5 months
Crack density: 0.487 m/m^2
Span 1 : 0.488 m/m^2
Span 2 : 0.294 m/m^2
Span 3 : 0.645 m/m^2
Span 4 : 0.542 m/m^2

Figure 12: LC-HPC-3 (Survey 8)

Control-3

Bridge deck Control-3 was placed on 7/17/2007, and has been surveyed eight times. The results of Surveys 7 and 8 of Control-3 are included in this report. Survey 7 was completed at a deck age of 83.2 months; the crack map appears in Figure 13. Survey 8 was completed at a deck age of 96.9 months; the crack map appears in Figure 14. A crack density of 0.382 m/m^2 was observed in Survey 7 (Figure 13), which is higher than obtained in Survey 6, 0.294 m/m^2, reported by Bohaty et al. (2013). A crack density of 0.391 m/m^2 was observed in Survey 8 (Figure 14), slightly higher than the recorded crack density for Survey 7.

Figure 15 compares crack densities of LC-HPC-3 and Control-3, as a function of age. Control-3 has performed better than LC-HPC-3 during the past three surveys. Further surveys may be needed to understand the cracking behavior of these bridges. The majority of cracks marked on Control-3 are transverse cracks that may have occurred due to settlement cracking. Some cracks propagate longitudinally from both ends of the deck near the abutments.

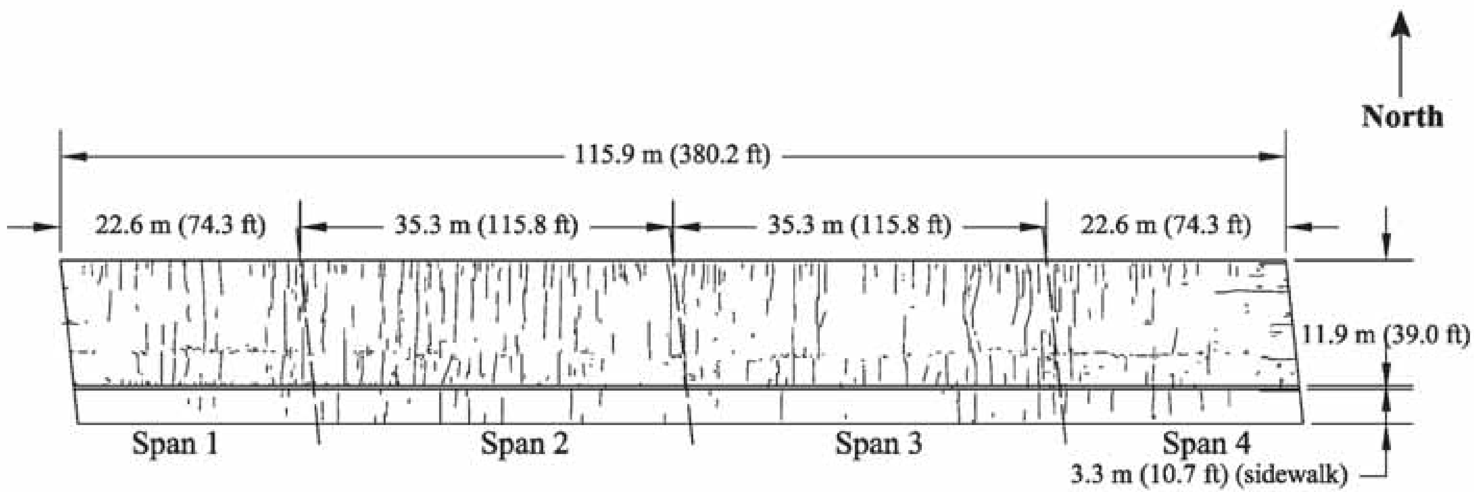


Bridge Number: 46-337 (Control 3)
Bridge Location: EB 103rd St. over US-69
Construction Date: 7/17/2007
Crack survey Date: 6/24/2014

Bridge Length: 115.9 m (380.2 ft)
Bridge Width: 11.9 m (39.0 ft)
Skew: 6°
Number of Spans: 4
Span 1: 22.6 m (74.3 ft)
Span 2: 35.3 m (115.8 ft)
Span 3: 35.3 m (115.8 ft)
Span 4: 22.6 m (74.3 ft)
Number of Placements: 1

Bridge Age: 83.2 months
Crack density: 0.382 m/m²
Span 1: 0.366m/m²
Span 2: 0.445 m/m²
Span 3: 0.388 m/m²
Span 4: 0.291 m/m²

Figure 13: Control-3 (Survey 7)



Bridge Number: 46-337 (Control 3)
Bridge Location: EB 103rd St. over US-69
Construction Date: 7/17/2007
Crack survey Date: 6/30/2015

Bridge Length: 115.9 m (380.2 ft)
Bridge Width: 11.9 m (39.0 ft)
Skew: 6°
Number of Spans: 4
Span 1: 22.6 m (74.3 ft)
Span 2: 35.3 m (115.8 ft)
Span 3: 35.3 m (115.8 ft)
Span 4: 22.6 m (74.3 ft)
Number of Placements: 1

Bridge Age: 96.9 months
Crack density: 0.391 m/m^2
Span 1: 0.340 m/m^2
Span 2: 0.461 m/m^2
Span 3: 0.383 m/m^2
Span 4: 0.347 m/m^2

Figure 14: Control-3 (Survey 8)

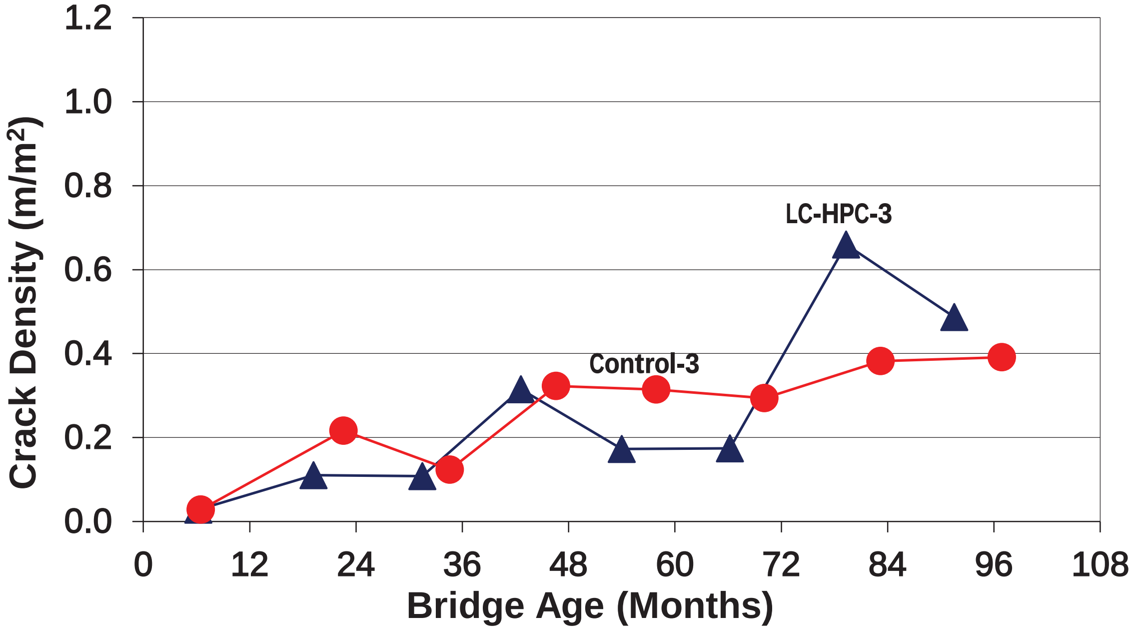
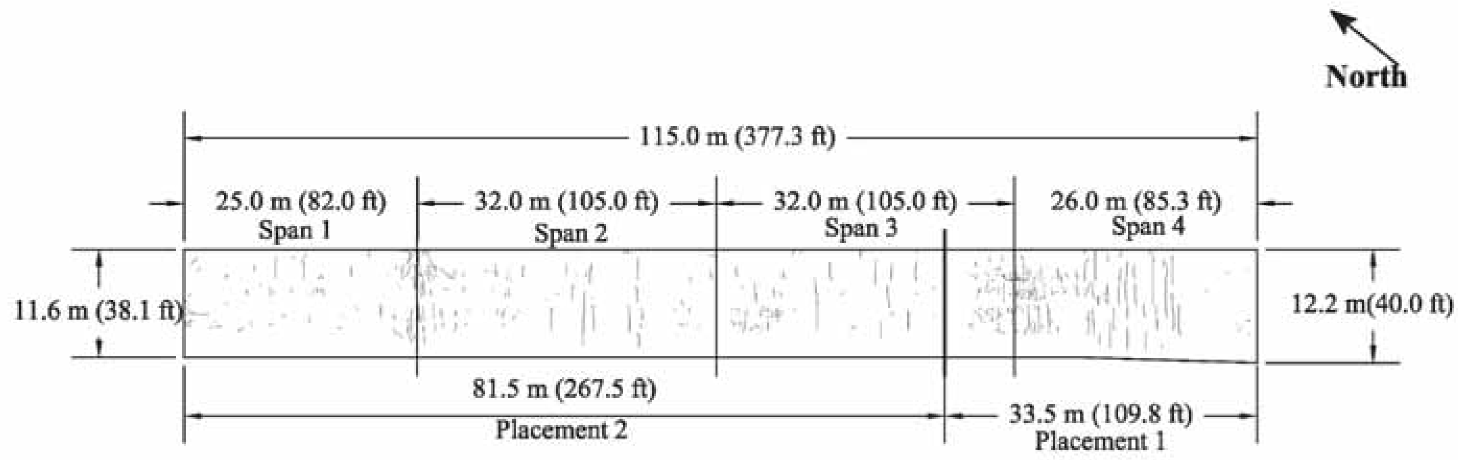


Figure 15: LC-HPC-3 and Control-3 Crack Densities Versus Deck Age

LC-HPC-4

Bridge deck LC-HPC-4 was constructed in two placements. Placement 1 was cast on 9/29/2007 and Placement 2 was cast on 10/2/2007. This deck has been surveyed eight times, and the results of Surveys 7 and 8 of LC-HPC-4 are discussed in this report. Survey 7 (Figure 16) was completed at a deck age of 80.4 and 80.3 months for Placements 1 and 2, respectively; the crack map appears in Figure 16. Survey 8 (Figure 17) was completed at a deck age of 93.3 and 93.2 months for Placements 1 and 2, respectively; the crack map appears in Figure 17. Crack densities of 0.371, 0.173, and 0.225 m/m^2 overall, and for Placements 1 and 2 were observed in Survey 7, respectively. In Survey 7, the crack density for Placement 1 was significantly higher than for Placement 2. Compared to Survey 6, reported by Bohaty et al. (2013), with respective crack densities of 0.147, 0.077, and 0.105 m/m^2. Crack densities of 0.305, 0.181, and 0.217 m/m^2 overall, and for Placements 1 and 2 were observed in Survey 8, respectively. These values are nearly the same to those recorded during Survey 7. Medium-length transverse cracks are present and distributed over the area of the deck. Near the deck's north western abutment, some cracks propagate longitudinally.

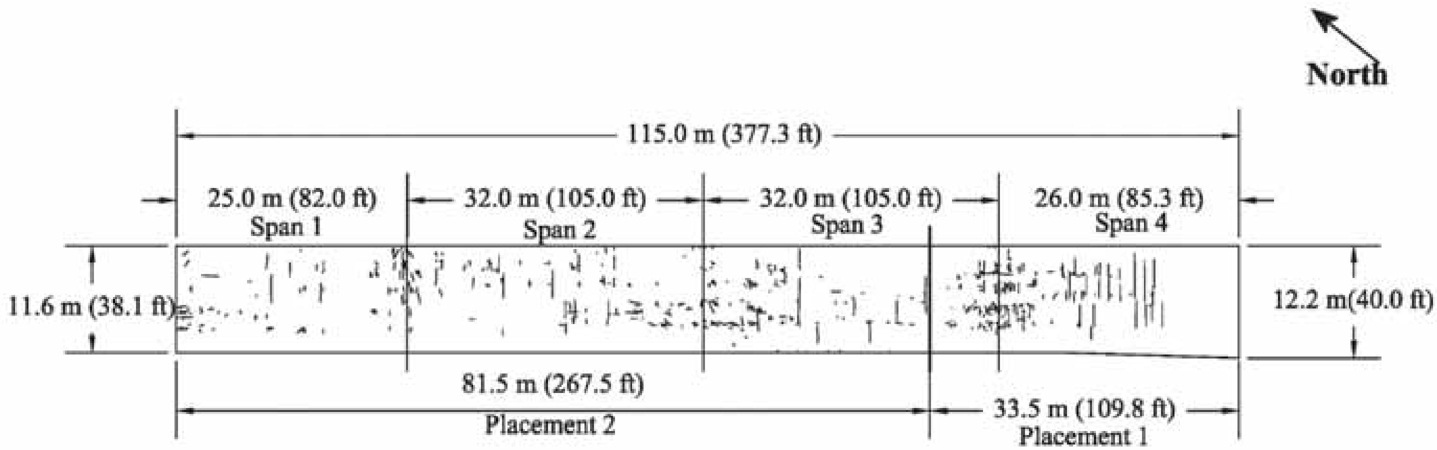


Bridge Number: 46-339 Unit 1 (KU #4)
Bridge Location: Flyover Ramp US-69S to I-435W
Construction Date:
Placement 1 (South): 9/29/2007
Placement 2 (North): 10/2/2007
Crack Survey Date: 6/27/2014

Bridge Length: 115.0 m (377.3 ft)
Bridge Width: 11.6 m (38.1 ft)
Skew: 0°
Number of Spans: 4
Span 1: 25.0 m (82.0 ft)
Span 2: 32.0 m (105.0 ft)
Span 3: 32.0 m (105.0 ft)
Span 4: 26.0 m (85.3 ft)
Number of Placements: 2

Bridge Age:
Placement 1: 80.4 months
Placement 2: 80.3 months
Crack Density: 0.225 m/m^2
Placement 1: 0.371 m/m^2
Placement 2: 0.173 m/m^2
Span 1: 0.159 m/m^2
Span 2: 0.202 m/m^2
Span 3: 0.168 m/m^2
Span 4: 0.412 m/m^2

Figure 16: LC-HPC-4 (Survey 7)



Bridge Number: 46-339 Unit 1 (KU #4)
Bridge Location: Flyover Ramp US-69S to I-435W
Construction Date:
Placement 1 (South): 9/29/2007
Placement 2 (North): 10/2/2007
Crack Survey Date: 7/9/2015

Bridge Length: 115.0 m (377.3 ft)
Bridge Width: 11.6 m (38.1 ft)
Skew: 0°
Number of Spans: 4
Span 1: 25.0 m (82.0 ft)
Span 2: 32.0 m (105.0 ft)
Span 3: 32.0 m (105.0 ft)
Span 4: 26.0 m (85.3 ft)
Number of Placements: 2

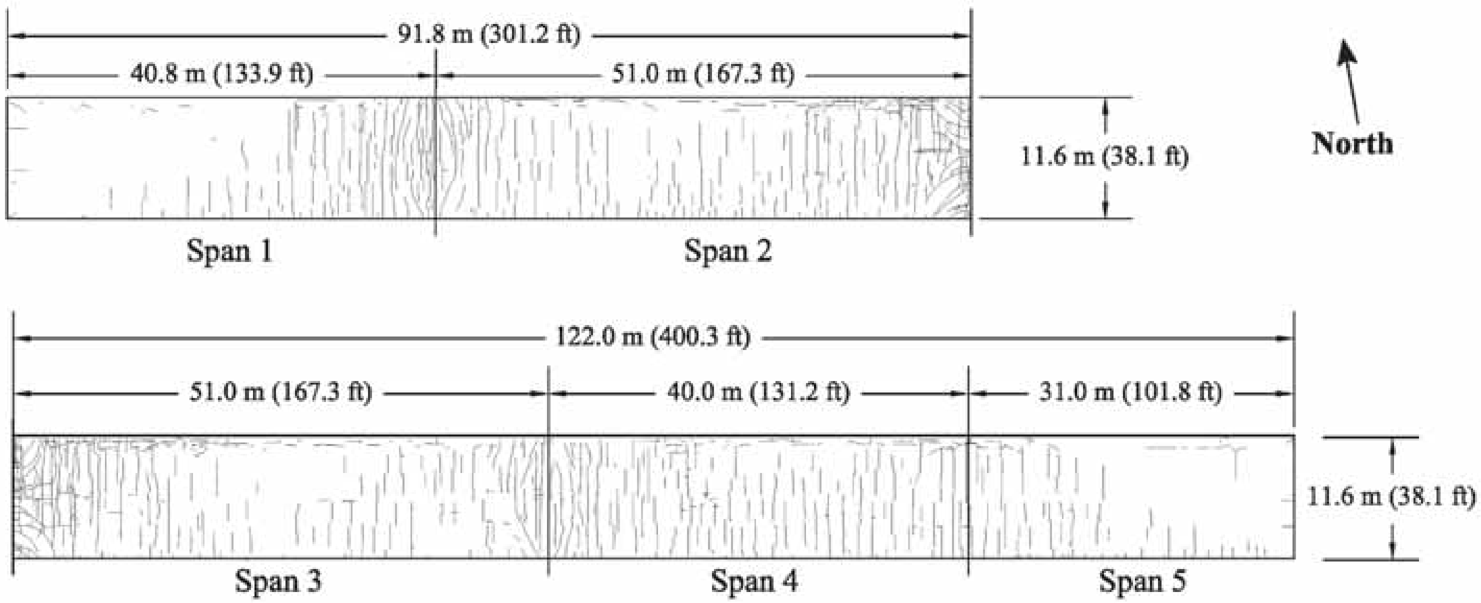
Bridge Age:
Placement 1: 93.3 months
Placement 2: 93.2 months
Crack Density: 0.217 m/m^2
Placement 1: 0.305 m/m^2
Placement 2: 0.181 m/m^2
Span 1: 0.163 m/m^2
Span 2: 0.175 m/m^2
Span 3: 0.245 m/m^2
Span 4: 0.289 m/m^2

Figure 17: LC-HPC-4 (Survey 8)

Control-4

Bridge deck Control-4 was constructed on 8/5/2014. This deck has been surveyed eight times. Surveys 7 and 8 are discussed in this report. Survey 7 was completed at a deck age of 80.7 months, and the crack map for this survey is shown in Figure 18. Survey 8 was completed at a deck age of 92.2 months, and the crack map for this survey is shown in Figure 19. A crack density of 0.667 m/m^2 was observed in Survey 7 (Figure 18), an increase from the value recorded in Survey 6 at 0.561 m/m^2 (Bohaty et al. 2013). A crack density of 0.755 m/m^2 was observed in Survey 8 (Figure 19). Cracking in Control-4 is significant in the outer portions of the end spans. The majority of the cracks are transverse and appear to run parallel to the top layer of reinforcement. Cracks propagate from both abutments. Longitudinal cracks are present near the northern side of the deck parallel to the parapet, and might be a result of the 3.2 ft (0.975-m) overhang at the exterior steel girder.

Figure 20 compares crack densities of LC-HPC 4 and Control-4 over time. As shown in Figure 20, both LC-HPC-4 placements are exhibiting much less cracking than Control-4.



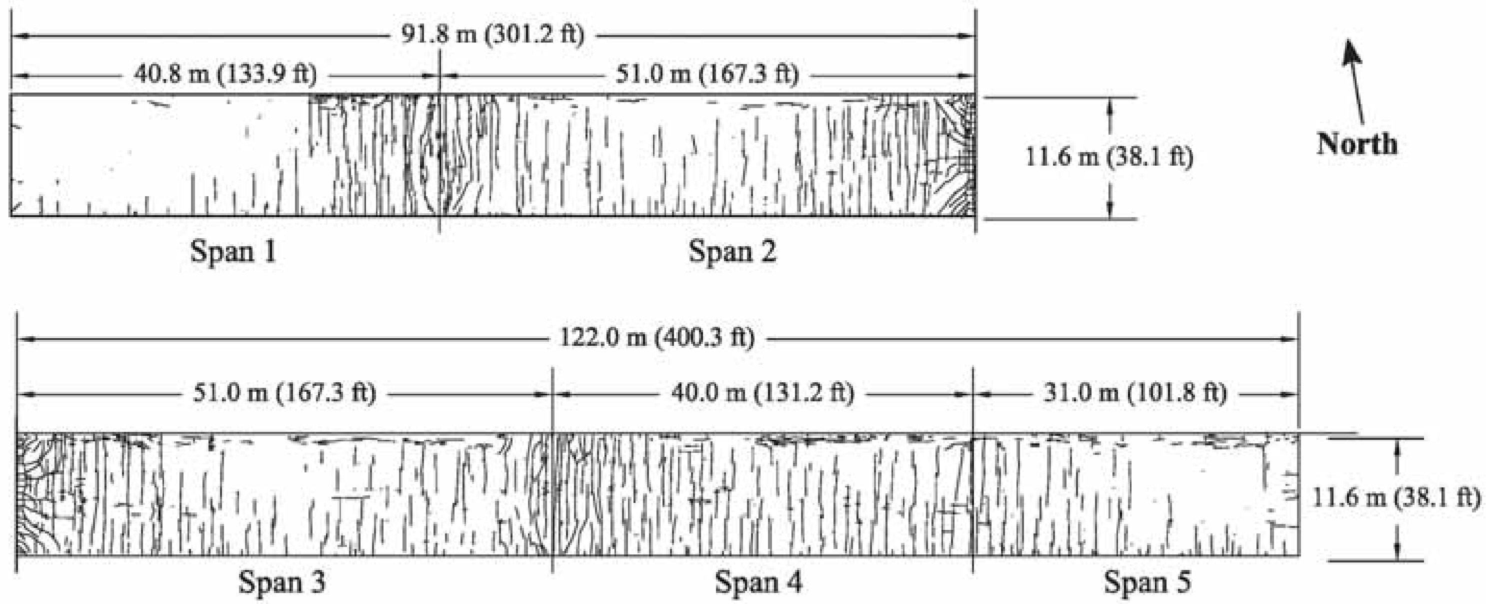
Bridge Number: 46-347 (KU #4 Control)
Bridge Location: NB US-69 Rd
Construction Date: 11/16/2007
Crack survey Date: 8/5/2014

Bridge Length: 213.8 m (701.5 ft)
Bridge Width: 11.6 m (38.1 ft)
Skew: 0°
Number of Spans: 5
- **Span 1:** 40.8 m (133.9 ft)
- **Span 2:** 51.0 m (167.3 ft)
- **Span 3:** 51.0 m (167.3 ft)
- **Span 4:** 40.0 m (131.2 ft)
- **Span 5:** 31.0 m (101.8 ft)

Number of Placements: 1

Bridge Age: 80.7 months
Crack density: 0.667 m/m^2
- **Span 1:** 0.476 m/m^2
- **Span 2:** 0.815 m/m^2
- **Span 3:** 0.782 m/m^2
- **Span 4:** 0.759 m/m^2
- **Span 5:** 0.367 m/m^2

Figure 18: Control-4 (Survey 7)



Bridge Number: 46-347 (KU #4 Control)
Bridge Location: NB US-69 Rd
Construction Date: 11/16/2007
Crack survey Date: 7/17/2015

Bridge Length: 213.8 m (701.5 ft)
Bridge Width: 11.6 m (38.1 ft)
Skew: 0°
Number of Spans: 5
- **Span 1:** 40.8 m (133.9 ft)
- **Span 2:** 51.0 m (167.3 ft)
- **Span 3:** 51.0 m (167.3 ft)
- **Span 4:** 40.0 m (131.2 ft)
- **Span 5:** 31.0 m (101.8 ft)

Number of Placements: 1

Bridge Age: 92.9 months
Crack density: 0.755 m/m^2
- **Span 1:** 0.458 m/m^2
- **Span 2:** 0.774 m/m^2
- **Span 3:** 0.920 m/m^2
- **Span 4:** 0.972 m/m^2
- **Span 5:** 0.568 m/m^2

Figure 19: Control-4 (Survey 8)

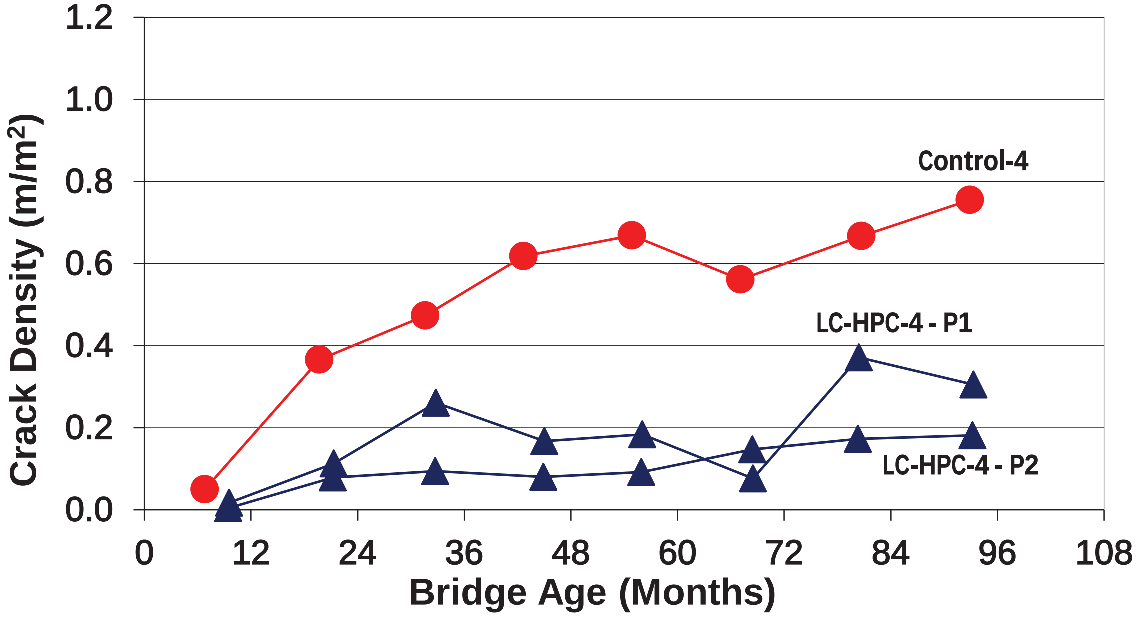


Figure 20: LC-HPC-4 and Control-4 Crack Densities Versus Deck Age

LC-HPC-5

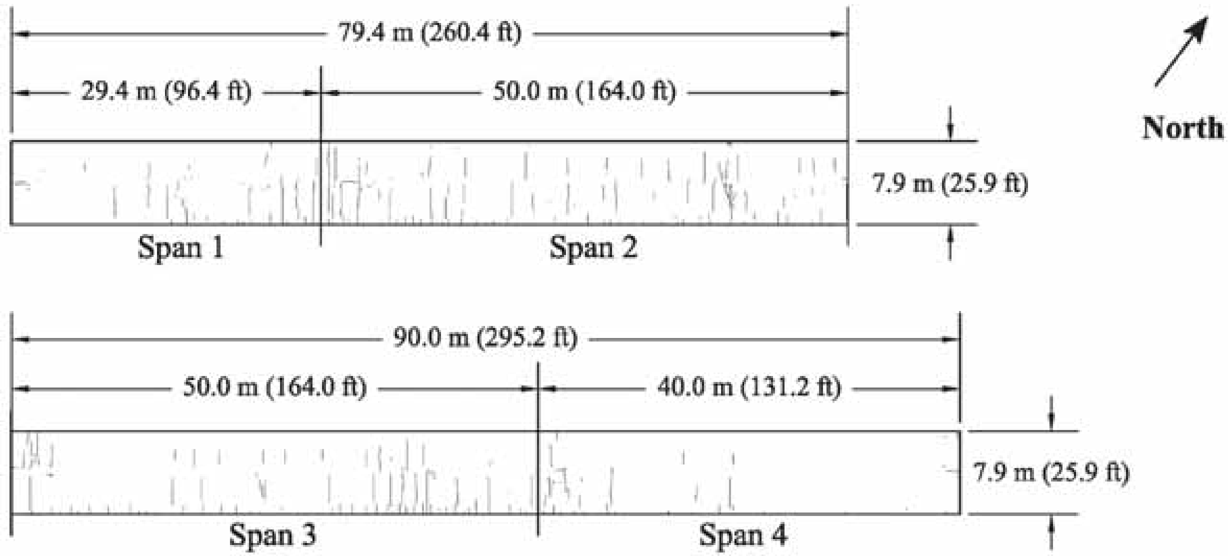
Bridge deck LC-HPC-5 was placed on 11/14/2007. To date, LC-HPC-5 has been surveyed eight times. The results for Surveys 7 and 8 are included in this report. Survey 7 was completed at 79.4 months; the results are shown in Figure 21. Survey 8 was completed at 91.8 months; the results are shown in Figure 22. A crack density of 0.229 m/m^2 was observed in Survey 7 (Figure 21). This value indicates a nearly 70% increase in crack density compared to Survey 6 reported by Bohaty et al. (2013), which was 0.140 m/m^2. A crack density of 0.247 m/m^2 was observed in Survey 8 (Figure 22). The majority of the cracks marked are medium-length transverse cracks. Also, some cracks have propagated longitudinally from both bridge ends near the abutments. It can be noted that most of the cracking has occurred on the southern side of the bridge. This may be related to the bridge being superelevated and the soaker hoses being placed at the centerline of the bridge at the time of construction, resulting a lack of water for curing at the more elevated side of the deck.

It was noted during the surveys that surface voids were present on the deck, likely due to incomplete finishing. These voids were noted in the construction report for LC-HPC-5 as being present immediately after bullfloating. Figure 23 shows a photo sample of the deck taken during Survey 8 illustrating these voids.

Control-5

In 2012, the Control-5 bridge deck of was overlaid due to high crack density. Survey 3 was the last performed for Control-3, which was reported by Bohaty et al. (2013). A crack density of 0.738 m/m^2 was observed in Survey 3.

Figure 24 compares the crack densities of LC-HPC-5 and Control-5 over time. LC-HPC-5 has exhibited much better performance than Control 5 deck.

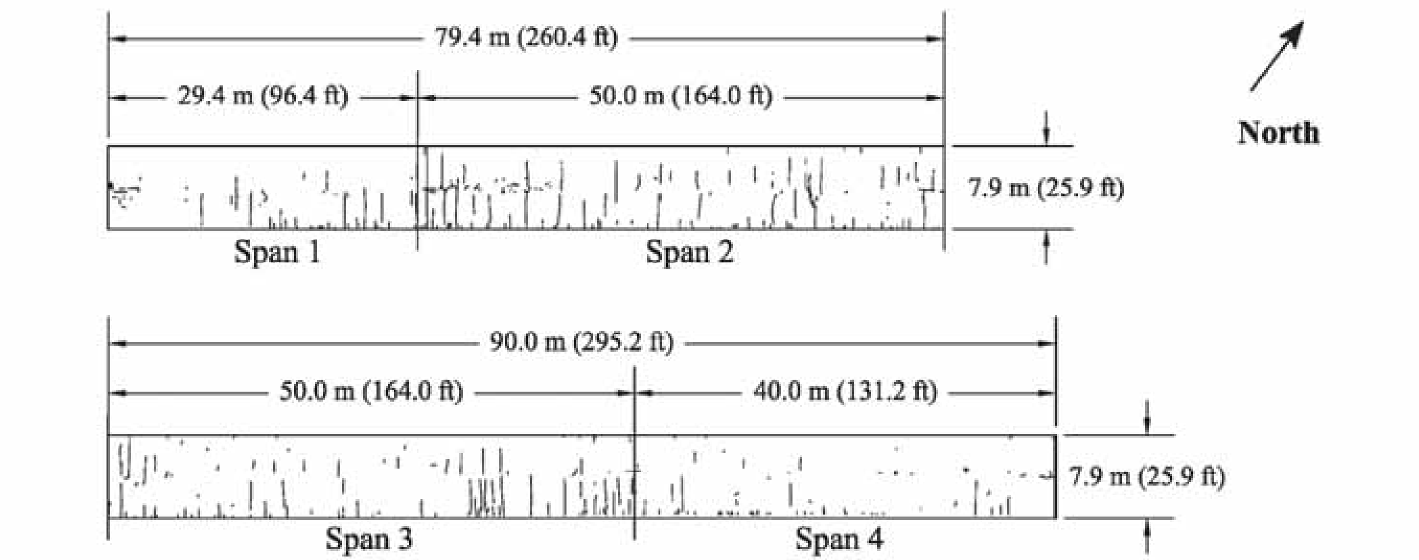


Bridge Number: 46-340 Unit 1 (KU #5)
Bridge Location: Flyover Ramp US-69 to I-435 W
Construction Date: 11/14/2007
Crack survey Date: 6/25/2014

Bridge Length: 169.4 m (555.7 ft)
Bridge Width: 7.9 m (25.9 ft)
Skew: 0°
Number of Spans: 4
Span 1: 29.4 m (96.4 ft)
Span 2: 50.0 m (164.0 ft)
Span 3: 50.0 m (164.0 ft)
Span 4: 40.0 m (131.2 ft)
Number of Placements: 1

Bridge Age: 79.4 months
Crack density: 0.229 m/m^2
Span 1: 0.195 m/m^2
Span 2: 0.321 m/m^2
Span 3: 0.257 m/m^2
Span 4: 0.106 m/m^2

Figure 21: LC-HPC-5 (Survey 7)



Bridge Number: 46-340 Unit 1 (KU #5)
Bridge Location: Flyover Ramp US-69 to I-435 W
Construction Date: 11/14/2007
Crack survey Date: 7/9/2015

Bridge Length: 169.4 m (555.7 ft)
Bridge Width: 7.9 m (25.9 ft)
Skew: 0°
Number of Spans: 4
Span 1: 29.4 m (96.4 ft)
Span 2: 50.0 m (164.0 ft)
Span 3: 50.0 m (164.0 ft)
Span 4: 40.0 m (131.2 ft)
Number of Placements: 1

Bridge Age: 91.8 months
Crack density: 0.247 m/m^2
Span 1: 0.192 m/m^2
Span 2: 0.351 m/m^2
Span 3: 0.293 m/m^2
Span 4: 0.102 m/m^2

Figure 22: LC-HPC-5 (Survey 8)

Figure 23: Surface Voids in LC-HPC-5 Bridge Deck

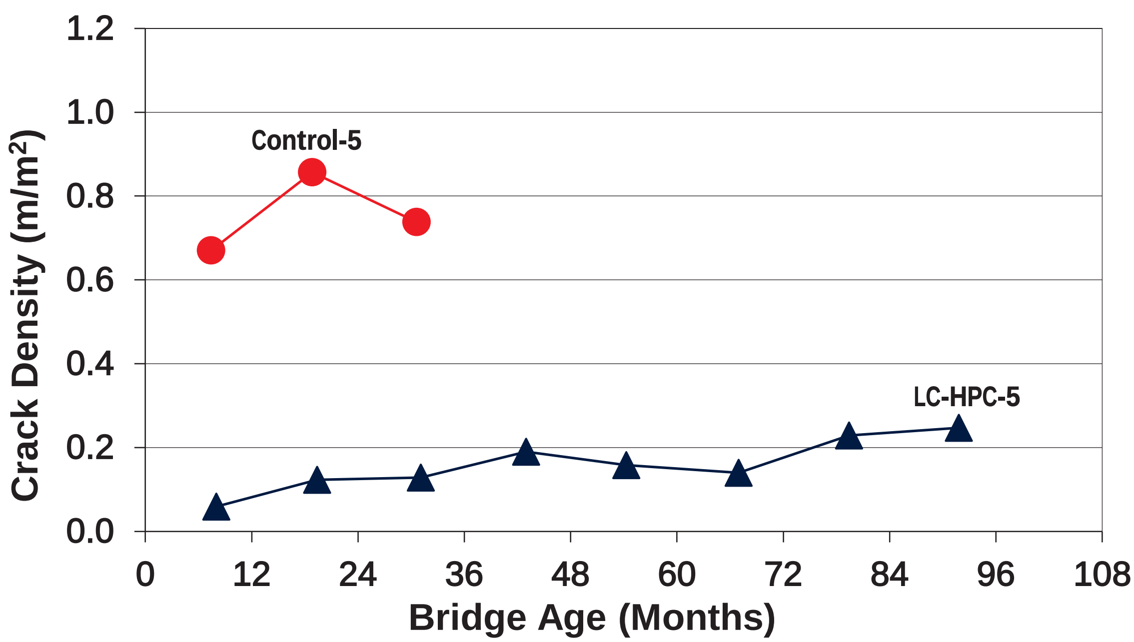


Figure 24: LC-HPC-5 and Control-5 Crack Densities Versus Deck Age

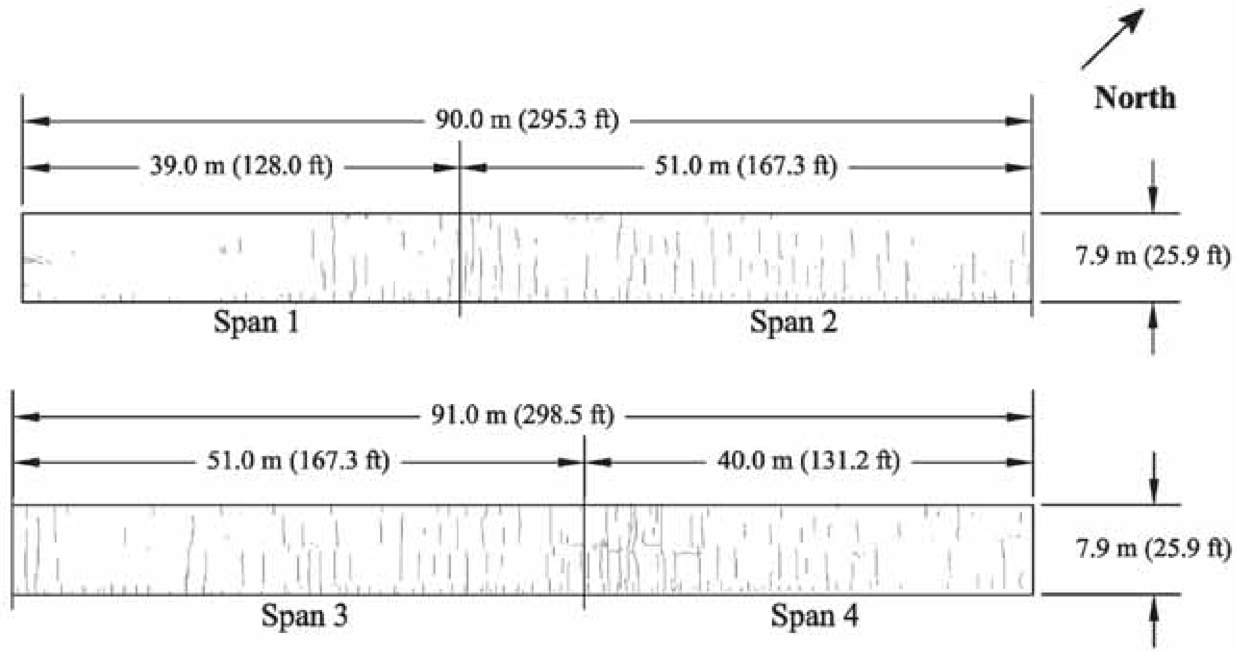
LC-HPC-6

Bridge deck LC-HPC-6 was constructed on 11/3/2007, and has been surveyed eight times. The results of Surveys 7 and 8 are included in this report. Survey 7 was performed at a deck age of 79.7 months; the crack map appears in Figure 25. Survey 8 was performed at a deck age of 92.2 months; the crack map appears in Figure 26. An overall crack density of 0.356 m/m^2 was observed in Survey 7 (Figure 25). This value represents an increase in crack density when compared to Survey 6, 0.303 m/m^2, reported by Bohaty et al. (2013). An overall crack density of 0.386 m/m^2 was observed in Survey 8 (Figure 26). Similar to LC-HPC-5, surface voids where observed during construction and during the surveys. Most of the cracks are transverse.

Control-6

Bridge deck Control-6 was placed on 10/20/2008 and has been surveyed seven times. The results for Surveys 6 and 7 are included in this report. Survey 6 was completed at 68.2 months; the crack map is shown in Figure 27. Survey 7 was completed at 81.9 months; the crack map is shown in Figure 28. A crack density of 0.646 m/m^2 was observed in Survey 6 (Figure 27), which is considerably higher than Survey 5 at 0.461 m/m^2 (Bohaty et al. 2013). A crack density of 0.628 m/m^2 was observed in Survey 7 (Figure 28), slightly lower than Survey 6. The majority of the cracks are transverse and run across the full width of the deck. The cracks are closer to each other over the piers than at other locations. Cracks propagate longitudinally adjacent the abutments. Some longitudinal cracks are present in the middle of the deck.

Figure 29 compares the crack densities between LC-HPC-6 and Control-6 over time. LC-HPC-6 deck has performed better than the Control-6 deck over the lifetime of the decks.

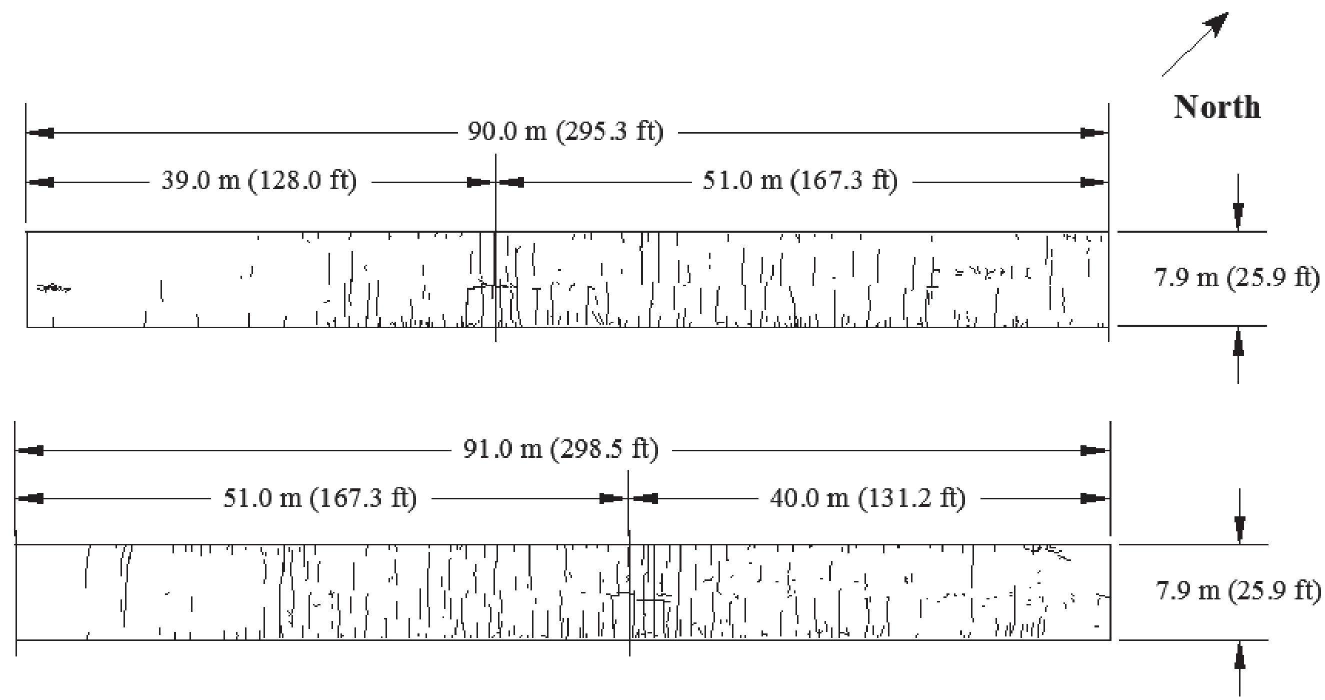


Bridge Number: 46-340 Unit 2 (KU #6)
Bridge Location: SB US-69 to WB I-435
Construction Date: 11/3/2007
Crack survey Date: 6/25/2014

Bridge Length: 181.0 m (593.8 ft)
Bridge Width: 7.9 m (25.9 ft)
Skew: 0°
Number of Spans: 4
Span 1: 39.0 m (128.0 ft)
Span 2: 51.0 m (167.3 ft)
Span 3: 51.0 m (167.3 ft)
Span 4: 40.0 m (131.2 ft)
Number of Placements: 1

Bridge Age: 79.7 months
Crack density: 0.356 m/m^2
Span 1: 0.182 m/m^2
Span 2: 0.396 m/m^2
Span 3: 0.389 m/m^2
Span 4: 0.439 m/m^2

Figure 25: LC-HPC-6 (Survey 7)

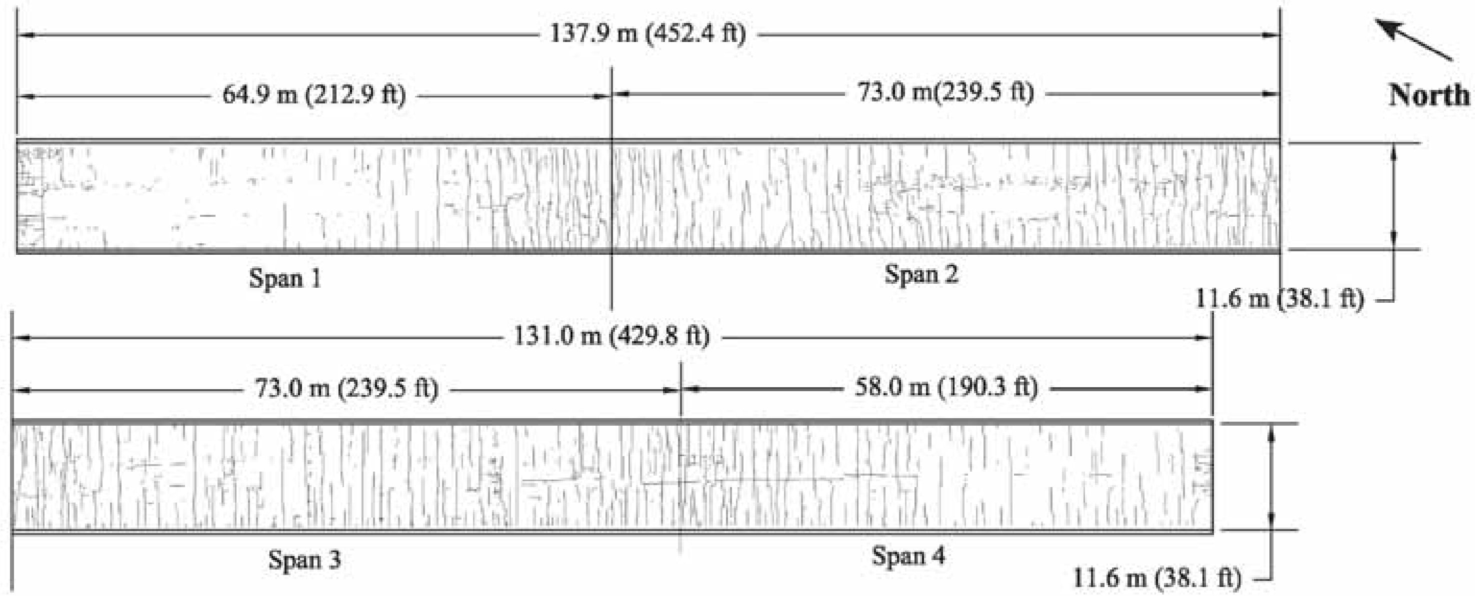


Bridge Number: 46-340 Unit 2 (KU #6)
Bridge Location: SB US-69 to WB I-435
Construction Date: 11/3/2007
Crack survey Date: 7/9/2015

Bridge Length: 181.0 m (593.8 ft)
Bridge Width: 7.9 m (25.9 ft)
Skew: 0°
Number of Spans: 4
Span 1: 39.0 m (128.0 ft)
Span 2: 51.0 m (167.3 ft)
Span 3: 51.0 m (167.3 ft)
Span 4: 40.0 m (131.2 ft)
Number of Placements: 1

Bridge Age: 92.2 months
Crack density: 0.386 m/m^2
Span 1: 0.192 m/m^2
Span 2: 0.439 m/m^2
Span 3: 0.374 m/m^2
Span 4: 0.439 m/m^2

Figure 26: LC-HPC-6 (Survey 8)



Bridge Number: 46-341 Unit 4 (Control #6)
Bridge Location: Flyover Ramp S-69 to I-435 E, Overland Park, KS
Construction Date: 10/20/2008
Crack survey Date: 6/27/2014

Bridge Length: 268.9 m (882.2 ft)
Bridge Width: 11.6 m (38.1 ft)
Skew: 0°
Number of Spans: 4
- **Span 1:** 64.9 m (212.9 ft)
- **Span 2:** 73.0 m (239.5 ft)
- **Span 3:** 73.0 m (239.5 ft)
- **Span 4:** 58.0 m (190.3 ft)

Number of Placements: 1

Bridge Age: 68.2 months
Crack density: 0.646 m/m^2
- **Span 1:** 0.374 m/m^2
- **Span 2:** 0.786 m/m^2
- **Span 3:** 0.760 m/m^2
- **Span 4:** 0.632 m/m^2

Figure 27: Control-6 (Survey 6)

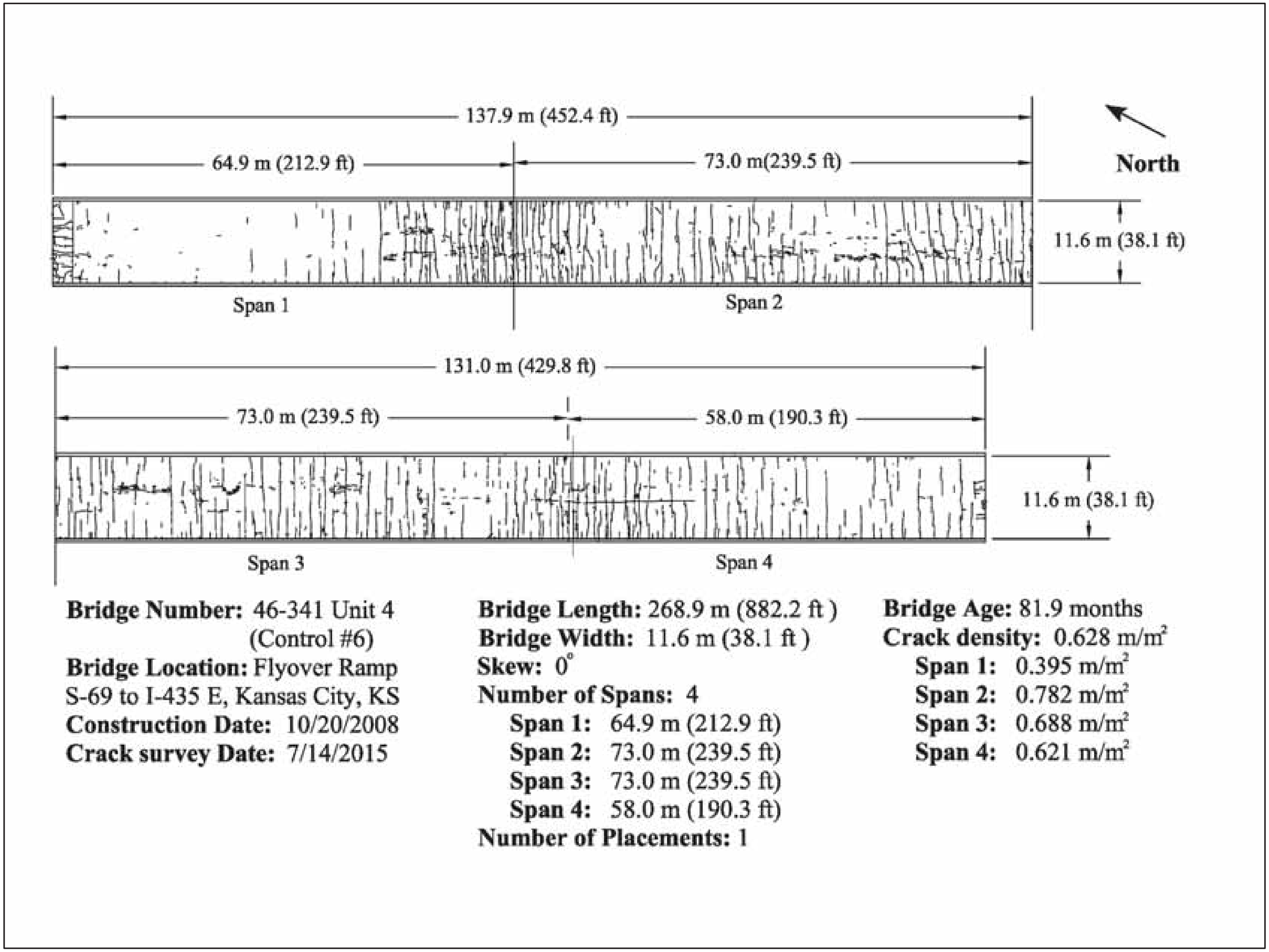


Figure 28: Control-6 (Survey 7)

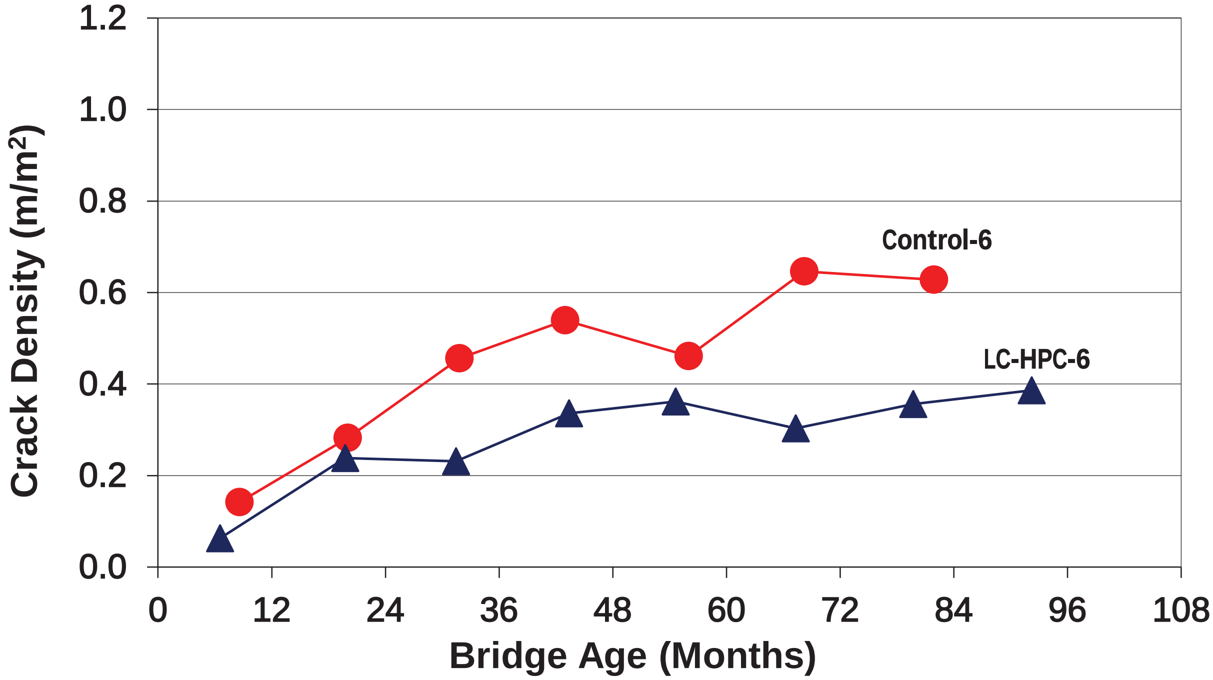


Figure 29: LC-HPC-6 and Control-6 Crack Densities Versus Deck Age

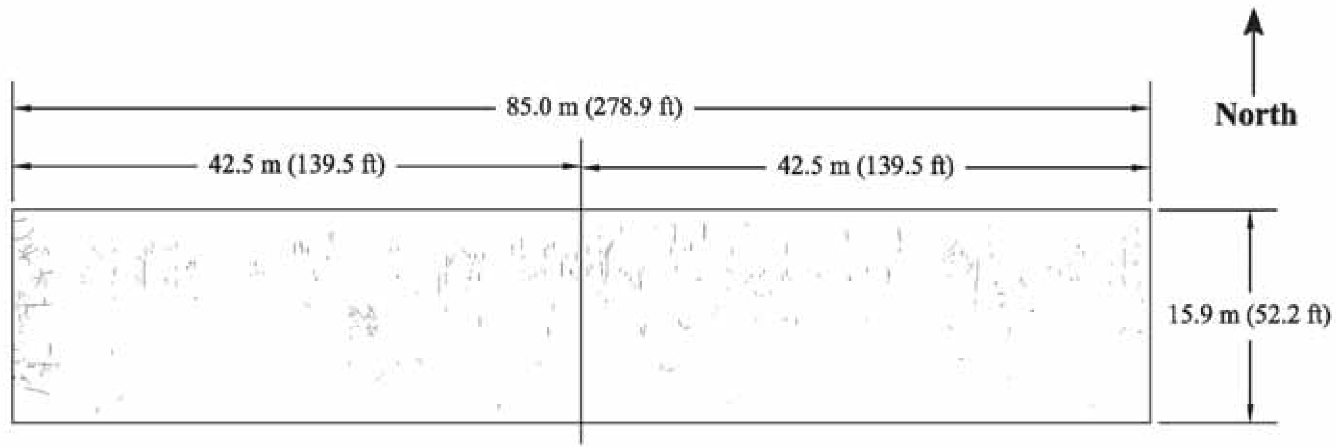
LC-HPC-7

Bridge deck LC-HPC-7 was constructed on 6/24/2006, and the deck has been surveyed nine times. The results of Surveys 8 and 9 of LC-HPC-7 are presented in this report. Survey 8 was completed at a deck age of 95.7 months; the crack map is shown in Figure 30. Survey 9 was completed at a deck age of 106.9 months; the crack map for this survey is shown in Figure 31. A crack density of 0.087 m/m^2 was observed in Survey 8 (Figure 30). This value is greater than the crack density reported by Bohaty et al. (2013) for Survey 7, 0.074 m/m^2. In Survey 9, however, a crack density of only 0.036 m/m^2 was observed (Figure 31). The measured crack density might have dropped due to dirt present on some portions of the bridge deck at the time of Survey 9. As shown in Figures 31 and 32, most of the cracks are relatively short and are distributed over the whole area of the bridge. There are some cracks near the west abutment that have propagated perpendicular to the abutment of the bridge. This deck has consistently exhibited the lowest crack density in this study.

Control-7

Control-7 was constructed in two placements. Placement 1 was cast on 3/29/2006 and Placement 2 was cast on 9/15/2006. This deck has been surveyed seven times, and the crack survey results of Survey 7 are included in this report. Survey 7 was performed at a deck age of 98.5 months for Placement 1 and 93.0 months for Placement 2; the crack map for this survey is shown in Figure 32. In Survey 7, crack densities of 1.165 m/m^2 for Placement 1 and 1.15 m/m^2 for Placement 2 were observed. These values are higher than the crack densities last reported by Bohaty et al. (2013), 1.022 m/m^2 for Placement 1 and 0.638 m/m^2 for Placement 2. Due to high cracking of Control-7, Survey 7 is considered the last survey of this bridge deck. The majority of the cracks present in Placement 1 are transverse. Relatively long longitudinal cracks cross the transverse cracks. Above the pier, cracks are much closer to each other compared to other areas of the deck. Placement 2 has a longitudinal crack running next to the construction joint. In both placements, cracks propagate longitudinally near the abutments.

Figure 33 compares the crack densities over time for LC-HPC 7 and Control-7 over time. It can be concluded that LC-HPC-7 has maintained a much lower crack density than Control 7. Noticeably, Control-7 experienced a significant jump in crack density after the second year.

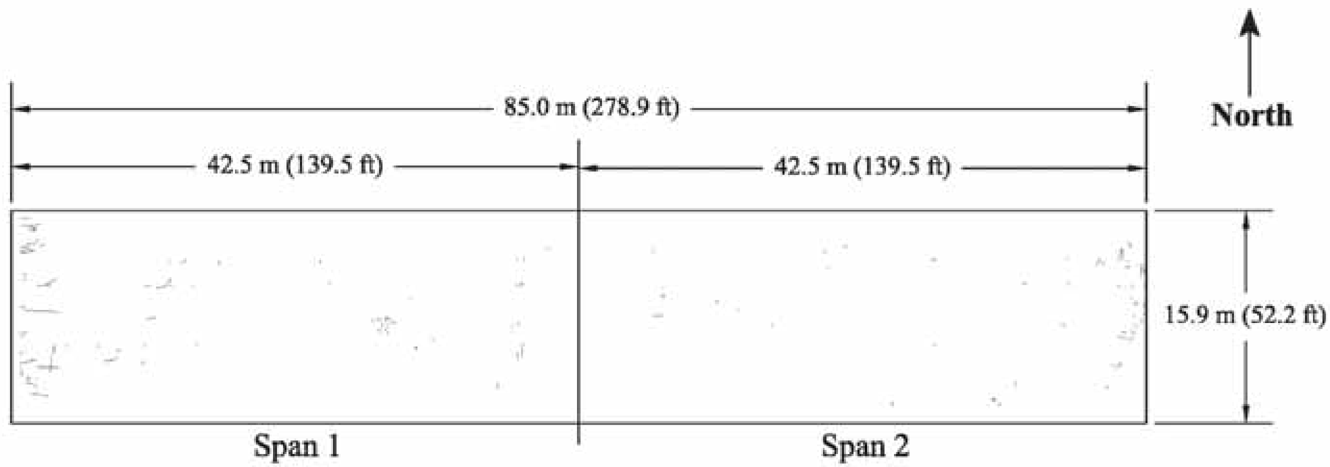


Bridge Number: 43-33 (KU #7)
Bridge Location: Co. Rd. 150 over US-75
Construction Date: 6/24/2006
Crack survey Date: 6/13/2014

Bridge Length: 85.0 m (278.9 ft)
Bridge Width: 15.9 m (52.2 ft)
Skew: 0^{o}
Number of Spans: 2
Span 1 (West): 42.5 m (139.5 ft)
Span 2 (East): 42.5 m (139.5 ft)
Number of Placements: 1

Bridge Age: 95.7 months
Crack density: 0.087 m/m^2
Span 1: 0.106 m/m^2
Span 2: 0.067 m/m^2

Figure 30: LC-HPC-7 (Survey 8)

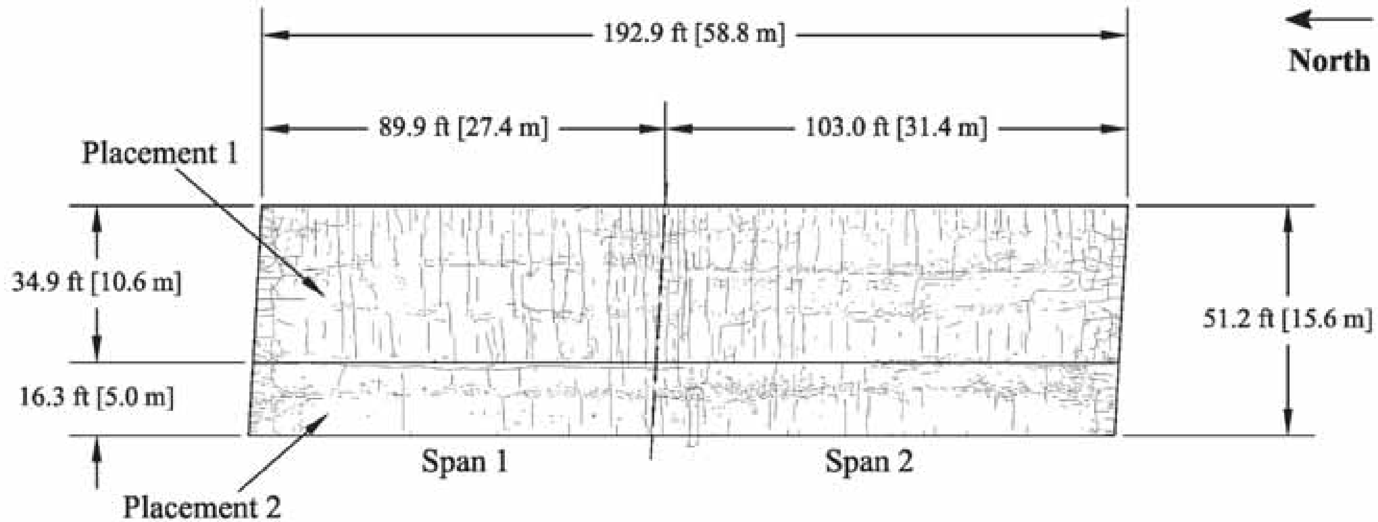


Bridge Number: 43-33 (KU #7)
Bridge Location: Co. Rd. 150 over US-75
Construction Date: 6/24/2006
Crack survey Date: 5/21/2015

Bridge Length: 85.0 m (278.9 ft)
Bridge Width: 15.9 m (52.2 ft)
Skew: 0°
Number of Spans: 2
Span 1 (West): 42.5 m (139.5 ft)
Span 2 (East): 42.5 m (139.5 ft)
Number of Placements: 1

Bridge Age: 106.9 months
Crack density: 0.036 m/m^2
Span 1: 0.053 m/m^2
Span 2: 0.022 m/m^2

Figure 31: LC-HPC-7 (Survey 9)



Bridge Number: 46-334(Control #7)
Bridge Location: NB Antioch over I-435
Construction Date:
Placement 1 (East): 3/29/2006
Placement 2 (West): 9/15/2006
Crack survey Date: 6/12/2014

Bridge Length: 58.8 m (192.9 ft)
Bridge Width: 15.6 m (51.2 ft)
Skew: -3.3°
Number of Spans: 2
Span 1 (North): 27.4 m (89.9 ft)
Span 2 (South): 31.4 m (103.0 ft)
Number of Placements: 2

Bridge Age:
Placement 1: 98.5 months
Placement 2: 93 months
Crack density: 1.160 m/m^2
Span 1: 1.068 m/m^2
Span 2: 1.240 m/m^2
Placement 1: 1.165 m/m^2
Placement 2: 1.150 m/m^2

Figure 32: Control-7 (Survey 7)

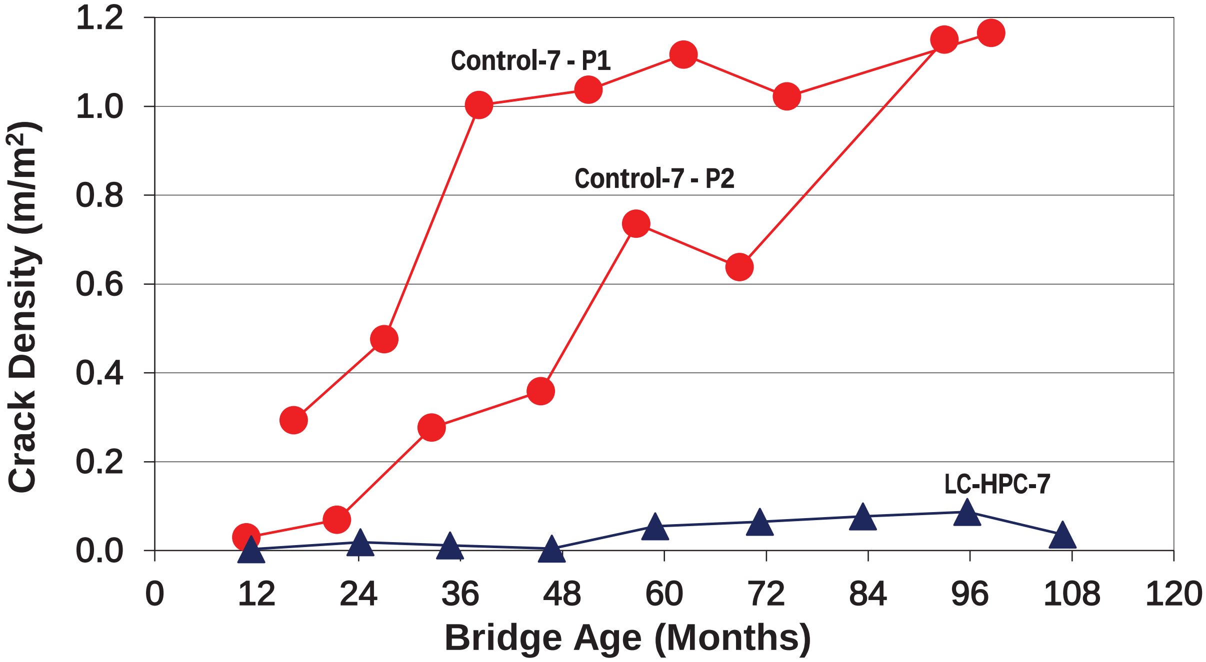
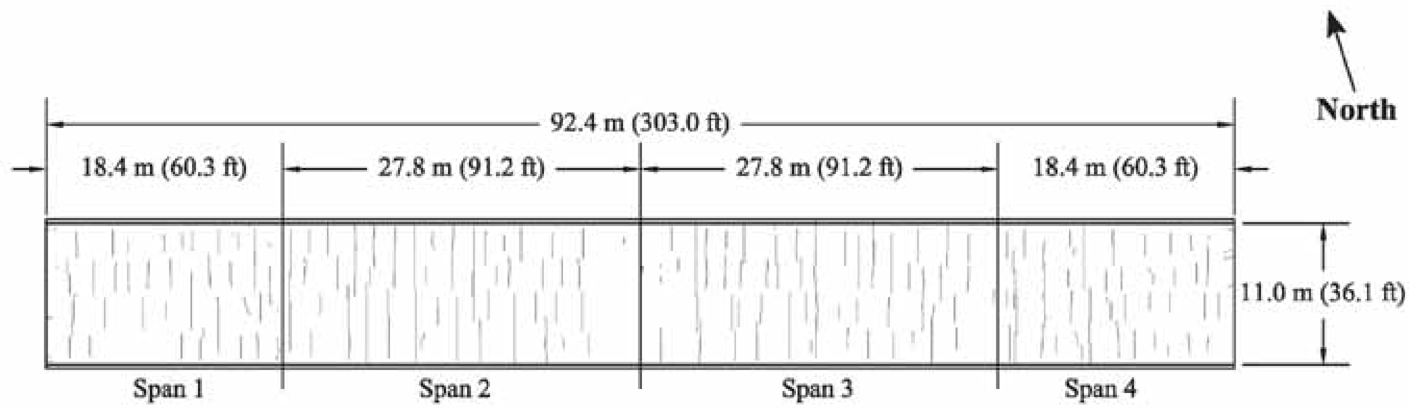


Figure 33: LC-HPC-7 and Control-7 Crack Densities Versus Deck Age

LC-HPC-8

Bridge deck LC-HPC-8 is supported by on precast-prestressed girders and was constructed on 10/3/2007. LC-HPC-8 has been surveyed seven times, and the results of Surveys 6 and 7 are presented in this report. Survey 6 was completed at a deck age of 81.6 months; the crack map appears in Figure 34. Survey 7 was performed at a deck age of 92.0 months; the crack map appears in Figure 35. A crack density of 0.425 m/m^2 was observed in Survey 6 (Figure 34). In Survey 7, a crack density of 0.462 m/m^2 was observed (Figure 35). Both values exceed the crack densities that were observed in previous surveys. Figures 34 and 35 show that almost all of the cracks are transverse. Additionally, cracks are minor above the center pier, suggesting that cracking may be a result from increased girder camber. Small longitudinal cracks are present near the abutments.

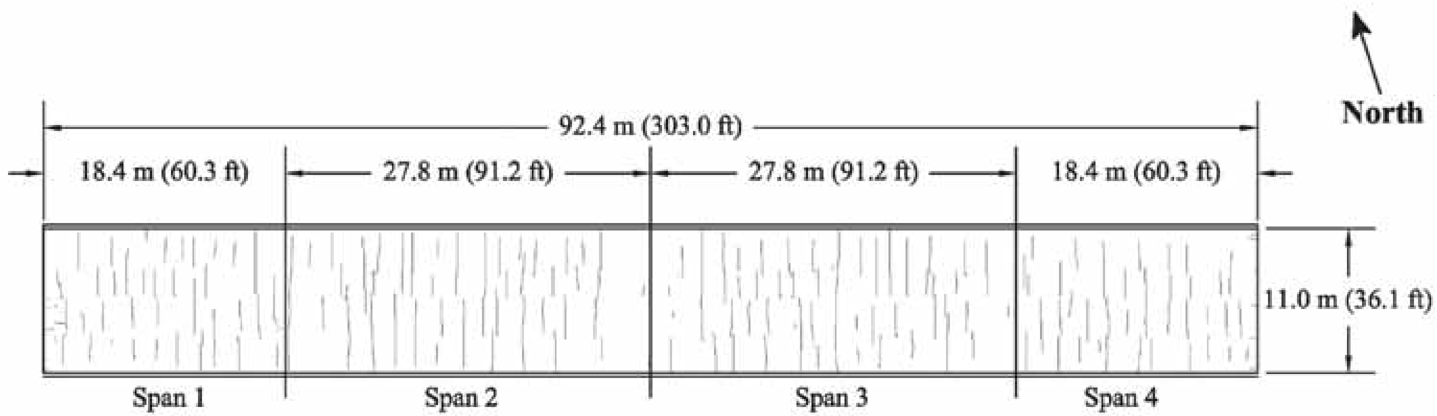


Bridge Number: 54-53 (KU 8)
Bridge Location: E 1350 Rd over US-69
Construction Date: 10/3/2007
Crack survey Date: 7/21/2014

Bridge Length: 92.4 m (303.0 ft)
Bridge Width: 11.0 m (36.1 ft)
Skew: 0^{o}
Number of Spans: 4
Span 1 (West): 18.4 m (60.3 ft)
Span 2 (West): 27.8 m (91.2 ft)
Span 3 (East): 27.8 m (91.2 ft)
Span 4 (East): 18.4 m (60.3 ft)
Number of Placements: 1

Bridge Age: 81.6 months
Crack density: 0.425 m/m^2
Span 1 (West): 0.276 m/m^2
Span 2 (West): 0.335 m/m^2
Span 3 (East): 0.471 m/m^2
Span 4 (East): 0.321 m/m^2

Figure 34: LC-HPC-8 (Survey 6)



Bridge Number: 54-53 (KU 8)
Bridge Location: E 1350 Rd over US-69
Construction Date: 10/3/2007
Crack survey Date: 6/10/2015

Bridge Length: 92.4 m (303.0 ft)
Bridge Width: 11.0 m (36.1 ft)
Skew: 0^{o}
Number of Spans: 4
Span 1 (West): 18.4 m (60.3 ft)
Span 2 (West): 27.8 m (91.2 ft)
Span 3 (East): 27.8 m (91.2 ft)
Span 4 (East): 18.4 m (60.3 ft)
Number of Placements: 1

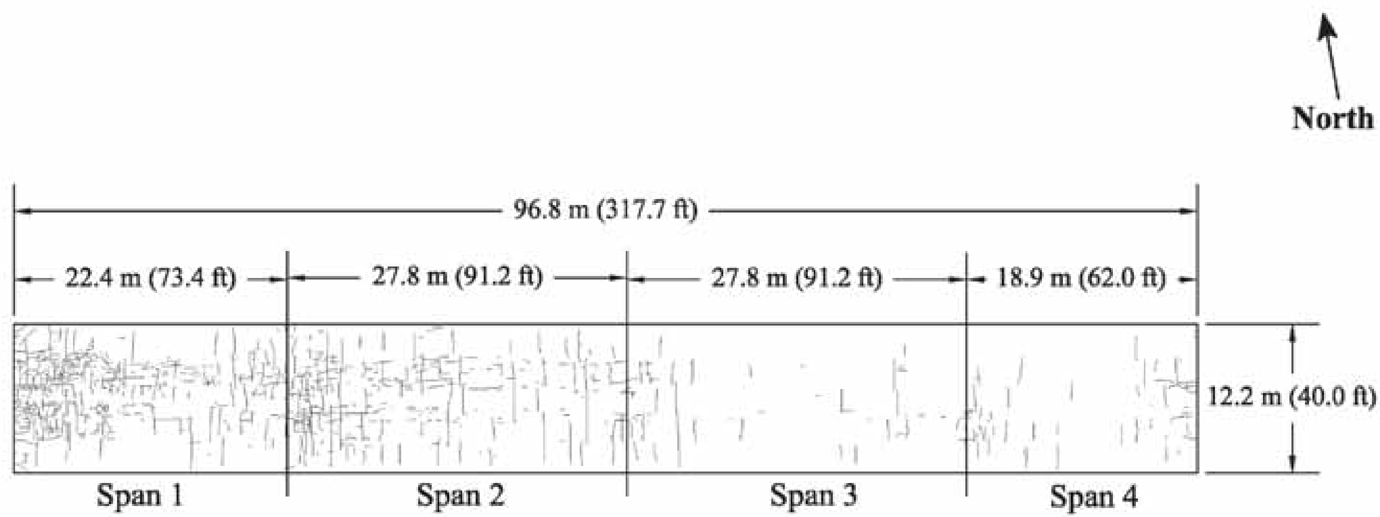
Bridge Age: 92 months
Crack density: 0.462 m/m^2
Span 1 (West): 0.496 m/m^2
Span 2 (West): 0.442 m/m^2
Span 3 (East): 0.456 m/m^2
Span 4 (East): 0.473 m/m^2

Figure 35: LC-HPC-8 (Survey 7)

Control-8/10

Bridge deck Control-8/10 serves as the control for both LC-HPC-8 and LC-HPC-10. It is a monolithic deck supported by precast-prestressed girders. Control-8/10 was constructed on 4/16/2007 and has been surveyed eight times. This report includes the results for Surveys 7 and 8. Survey 7 was completed at a deck age of 87.2 months; the crack map is shown in Figure 36. Survey 8 was completed at a deck age of 98.1 months; the crack map is shown in Figure 37. A crack density of 0.566 m/m^2 was observed in Survey 7 (Figure 36). Survey 7 shows a similar crack density to that recorded Survey 6 by Bohaty et al. (2013), which was 0.581 m/m^2. In Survey 8, a crack density of 0.680 m/m^2 was observed (Figure 37). Span 1 of the bridge has a higher crack density than the other spans, with a significant portion of these cracks due to map cracking. Also, there are moderately-sized transverse cracks distributed over the whole area of the bridge, but there are fewer in Spans 3 and 4 than in Spans 1 and 2.

Figure 38 compares the crack densities for LC-HPC-8 and Control-8/10 over time. LC-HPC-8 showed higher cracking than Control-8/10 during the early ages of the deck, but has exhibited lower densities since the third survey.



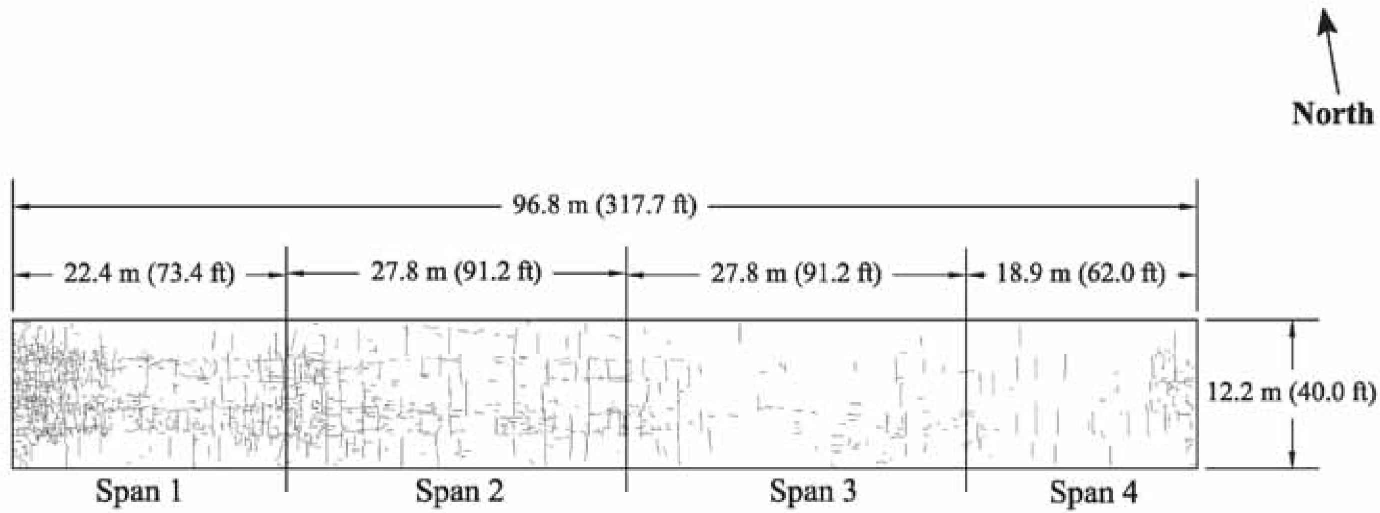
Bridge Number: 54-59 (KU #8-#10 Control)
Bridge Location: K-52 over US-69
Construction Date: 4/16/2007
Crack survey Date: 7/23/2014

Bridge Length: 96.8 m (317.7 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: 0°
Number of Spans: 4
- **Span 1:** 22.4 m (73.4 ft)
- **Span 2:** 27.8 m (91.2 ft)
- **Span 3:** 27.8 m (91.2 ft)
- **Span 4:** 18.9 m (62.0 ft)

Number of Placements: 1

Bridge Age: 87.2 months
Crack density: 0.566 m/m^2
- **Span 1:** 1.121 m/m^2
- **Span 2:** 0.734 m/m^2
- **Span 3:** 0.173 m/m^2
- **Span 4:** 0.247 m/m^2

Figure 36: Control-8/10 (Survey 7)



Bridge Number: 54-59 (KU #8-#10 Control)
Bridge Location: K-52 over US-69
Construction Date: 4/16/2007
Crack survey Date: 6/19/2015

Bridge Length: 96.8 m (317.7 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: 0°
Number of Spans: 4
- **Span 1:** 22.4 m (73.4 ft)
- **Span 2:** 27.8 m (91.2 ft)
- **Span 3:** 27.8 m (91.2 ft)
- **Span 4:** 18.9 m (62.0 ft)

Number of Placements: 1

Bridge Age: 98.1 months
Crack density: 0.680 m/m^2
- **Span 1:** 1.465 m/m^2
- **Span 2:** 0.788 m/m^2
- **Span 3:** 0.239 m/m^2
- **Span 4:** 0.327 m/m^2

Figure 37: Control-8/10 (Survey 8)

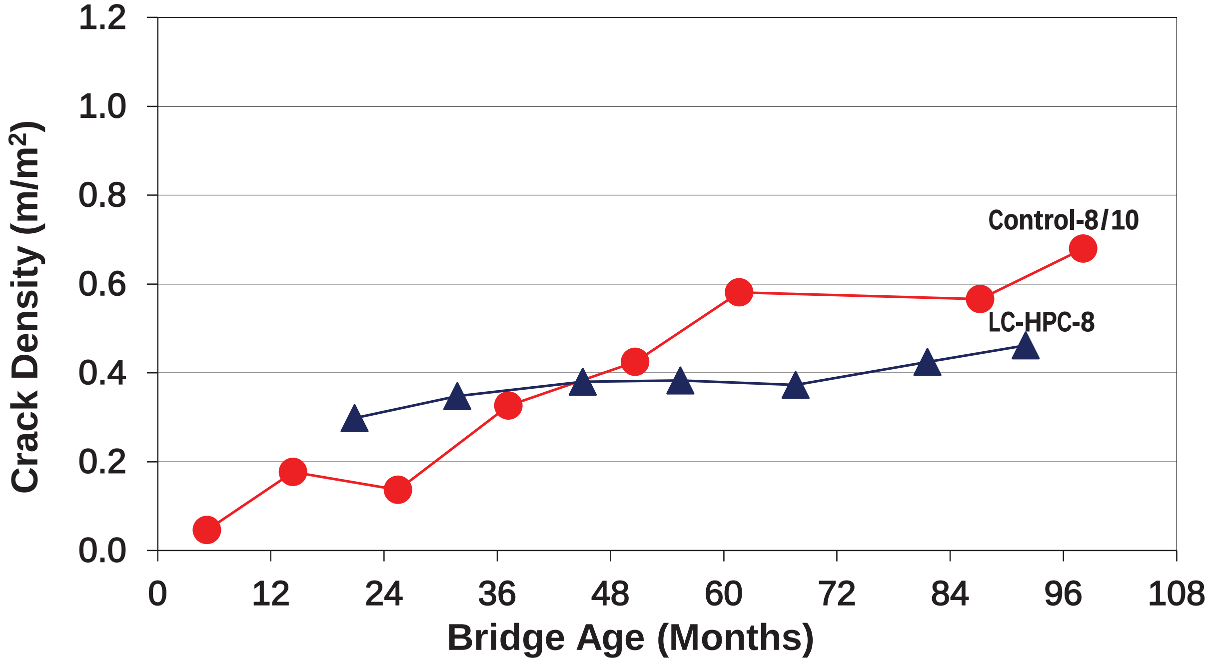
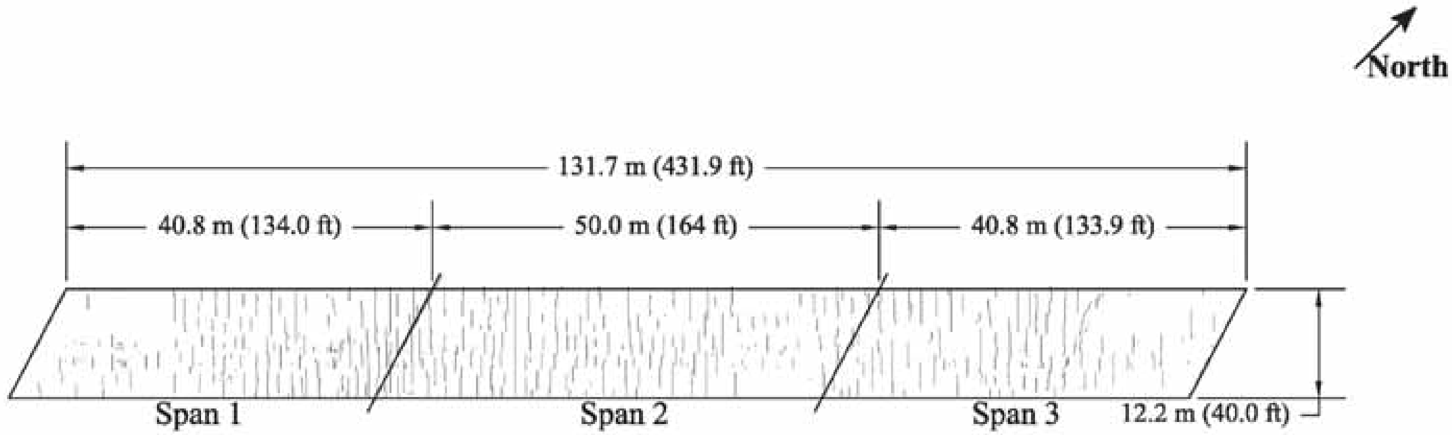


Figure 38: LC-HPC-8 and Control-8/10 Crack Densities Versus Deck Age

LC-HPC-9

Bridge deck LC-HPC-9 was constructed on 4/15/2009, and has been surveyed six times. This report includes the results of Surveys 5 and 6. Survey 5 was performed at a deck age of 62.0 months; the crack map is shown in Figure 39. Survey 6 was performed at a deck age of 73.6 months; the crack map is shown in Figure 40. In Survey 5, a crack density of 0.454 m/m^2 was observed (Figure 39). This value is significantly greater than that reported for Survey 4 by Bohaty et al. (2013), 0.299 m/m^2. A crack density of 0.430 m/m^2 was observed in Survey 6 (Figure 40), slightly lower than Survey 5. The cracks are uniformly distributed over much of the deck with the exception of the end spans, which exhibit a lower crack density.

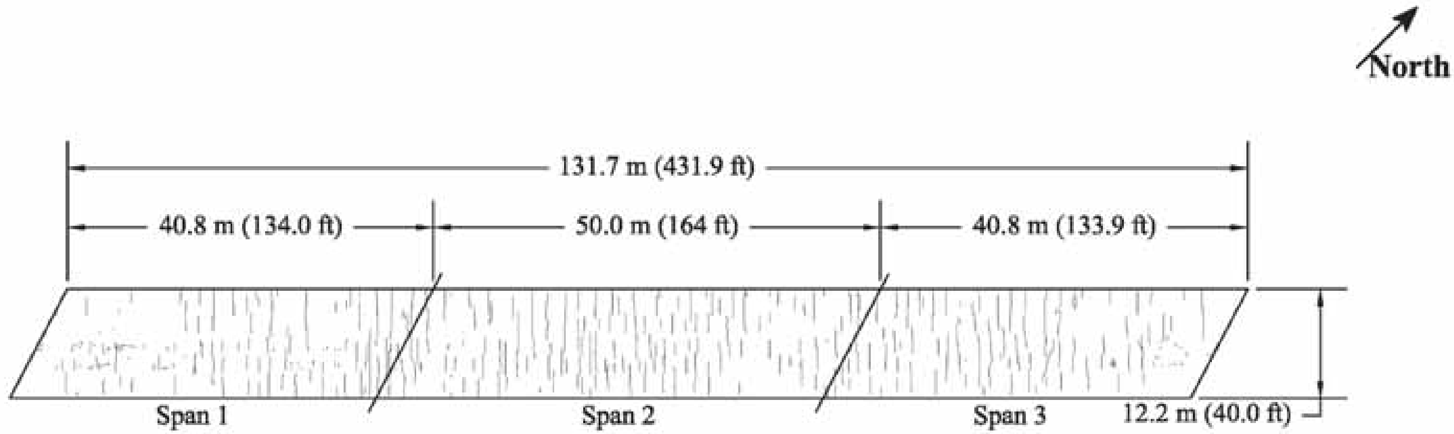


Bridge Number: 54-57 (KU 9)
Bridge Location: NB US-69 over Marair Des Cygnes Rv
Construction Date: 4/15/2009
Crack survey Date: 8/6/2014

Bridge Length: 131.7 m (431.9 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: -27.7°
Number of Spans: 3
Span 1 (South): 40.8 m (134.0 ft)
Span 2 (Middle): 50.0 m (164.0 ft)
Span 3 (North): 40.8 m (133.9 ft)
Number of Placements: 1

Bridge Age: 62 months
Crack density: 0.454 m/m^2
Span 1 (South): 0.453 m/m^2
Span 2 (Middle): 0.503 m/m^2
Span 3 (North): 0.401 m/m^2

Figure 39: LC-HPC-9 (Survey 5)



Bridge Number: 54-57 (KU 9)
Bridge Location: NB US-69 over Marair Des Cygnes Rv
Construction Date: 4/15/2009
Crack survey Date: 6/2/2015

Bridge Length: 131.7 m (431.9 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: -27.7°
Number of Spans: 3
Span 1 (South): 40.8 m (134.0 ft)
Span 2 (Middle): 50.0 m (164.0 ft)
Span 3 (North): 40.8 m (133.9 ft)
Number of Placements: 1

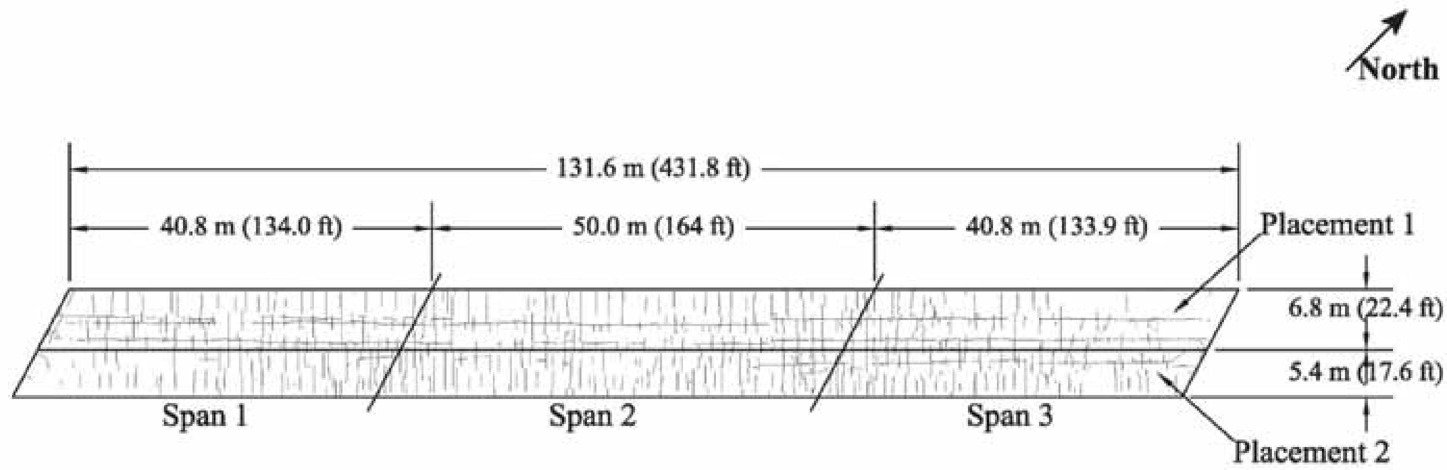
Bridge Age: 73.6 months
Crack density: 0.430 m/m^2
Span 1 (South): 0.386 m/m^2
Span 2 (Middle): 0.485 m/m^2
Span 3 (North): 0.431 m/m^2

Figure 40: LC-HPC-9 (Survey 6)

Control-9

Bridge deck Control-9 was constructed in two placements. Placement 1 was constructed on 5/21/2008 and Placement 2 was constructed on 5/29/2008. To date, Control-9 deck has been surveyed six times. The results of Surveys 5 and 6 are included in this report. Survey 5 was completed at deck 74.1 and 73.8 months; the crack map is shown in Figure 41. Survey 6 was performed at deck age of 84.4 and 84.1 months; the crack map is shown in Figure 42. In Survey 5, crack densities of 0.732 and 0.755 m/m^2 were observed for Placements 1 and 2, respectively. Both of these values are higher than Survey 4, which recorded crack densities of 0.561 and 0.635 m/m^2 for Placements 1 and 2, respectively (Bohaty et al. 2013). In Survey 6, crack densities of 0.722 and 0.845 m/m^2 were observed for Placements 1 and 2, respectively. For Survey 6, Placement 1 exhibited a slight decrease in crack density compared to Survey 5, while the crack density for Placement 2 increased compared to the previous survey. As shown in Figures 41 and 42, the majority of the cracks are transverse, parallel to the top layer of reinforcement. In Placement 1, there are two longitudinal cracks that run almost over the entire length of the deck. In Placement 2 some relatively short cracks run longitudinally. Some cracks are present near the abutments, where they have propagated longitudinally.

Figure 43 compares the crack densities for LC-HPC-9 and Control-9 over time. LC-HPC-9 has a significantly lower crack density than either placement of Control-9.



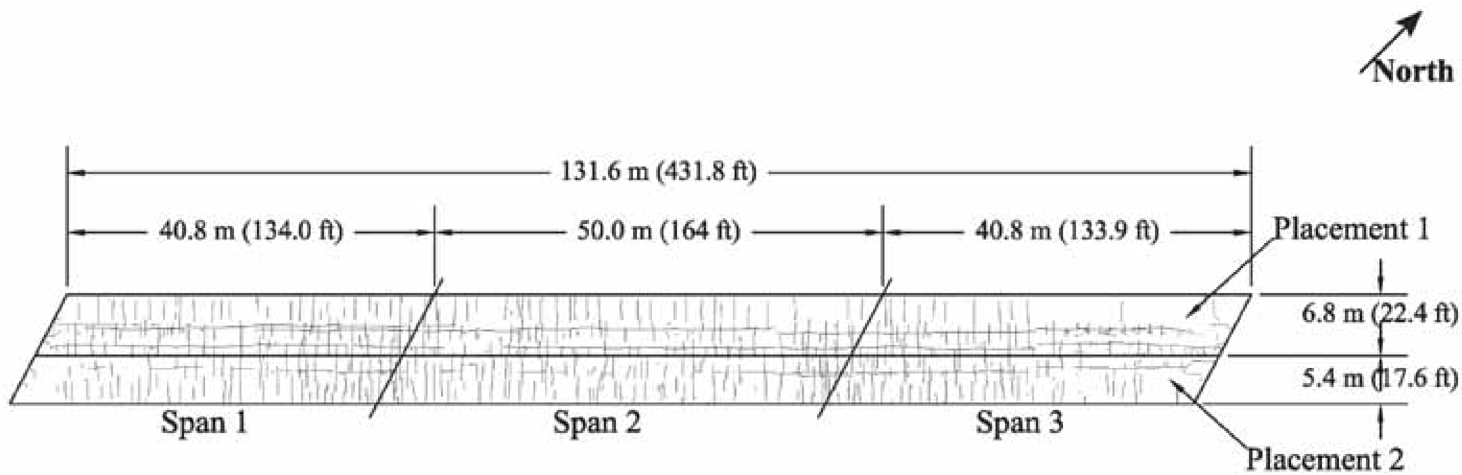
Bridge Number: 54-58 (Control #9)
Bridge Location: NB US-69 over Marair Des Cygnes Rv
Construction Date:
Placement 1 (West): 5/21/2008
Placement 2 (East): 5/29/2008

Crack survey Date: 7/24/2014

Bridge Length: 131.6 m (431.8 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: -27.2°
Number of Spans: 3
Span 1 (South): 40.8 m (134.0 ft)
Span 2 (Middle): 50.0 m (164.0 ft)
Span 3 (North): 40.8 m (133.8 ft)
Number of Placements: 2
Placement1(West): 6.8 m (22.4 ft)
Placement2 (East): 5.4 m (17.6 ft)

Bridge Age:
Placement 1: 74.1 months
Placement 2: 73.8 months
Crack density: 0.733 m/m²
Placement 1: 0.732 m/m²
Placement 2: 0.755 m/m²
Span 1 (South): 0.707 m/m²
Span 2 (Middle): 0.769 m/m²
Span 3 (North): 0.715 m/m²

Figure 41: Control-9 (Survey 5)



Bridge Number: 54-58 (Control #9)
Bridge Location: NB US-69 over Marair Des Cygnes Rv
Construction Date:
Placement 1 (West): 5/21/2008
Placement 2 (East): 5/29/2008

Crack survey Date: 6/1/2015

Bridge Length: 131.6 m (431.8 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: -27.2°
Number of Spans: 3
Span 1 (South): 40.8 m (134.0 ft)
Span 2 (Middle): 50.0 m (164.0 ft)
Span 3 (North): 40.8 m (133.8 ft)
Number of Placements: 2
Placement1(West): 6.8 m (22.4 ft)
Placement2 (East): 5.4 m (17.6 ft)

Bridge Age:
Placement 1: 84.4 months
Placement 2: 84.1 months
Crack density: 0.779 m/m²
Placement 1: 0.722 m/m²
Placement 2: 0.845 m/m²
Span 1 (South): 0.840 m/m²
Span 2 (Middle): 0.819 m/m²
Span 3 (North): 0.728 m/m²

Figure 42: Control-9 (Survey 6)

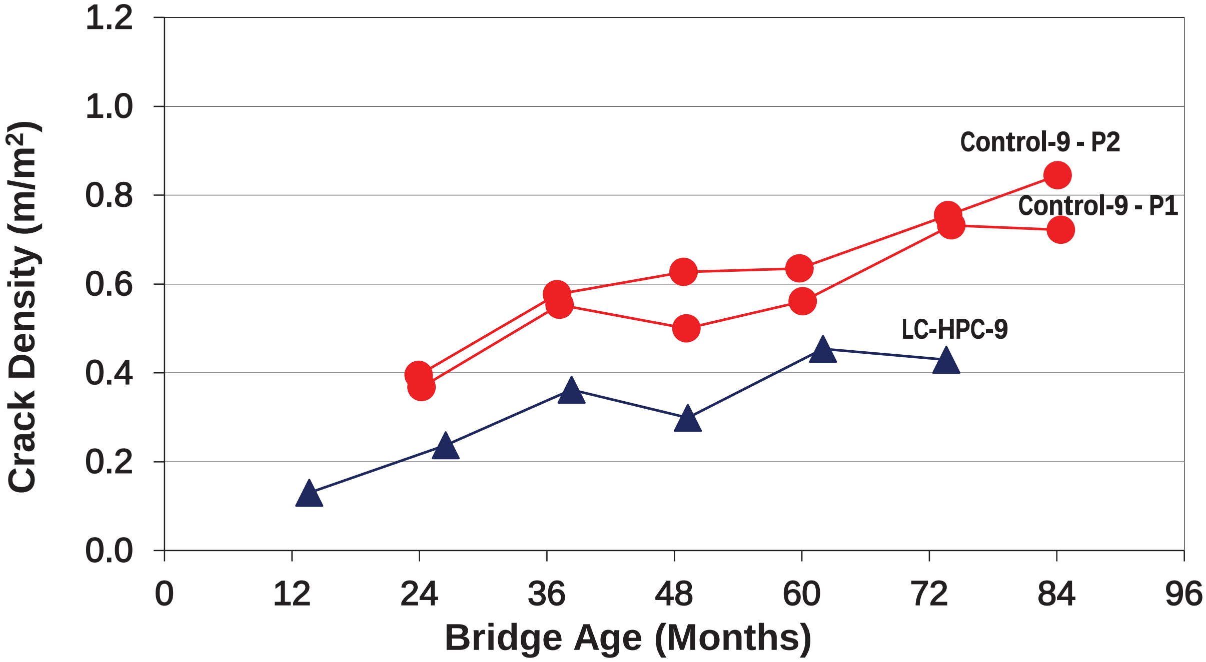
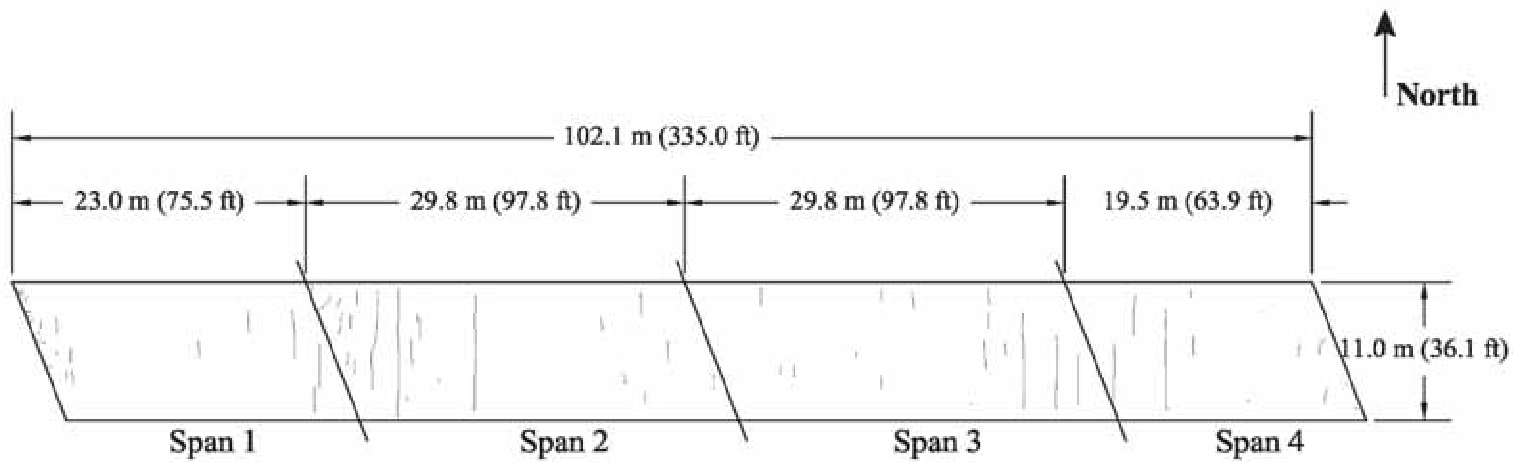


Figure 43: LC-HPC-9 and Control-9 Crack Densities Versus Deck Age

LC-HPC-10

Bridge deck LC-HPC-10 is supported by precast-prestressed girders and was constructed on 05/17/2007. LC-HPC-10 deck has been surveyed eight times. The results of Surveys 7 and 8 of LC-HPC-10 are included in this report. Survey 7 was performed at a deck age of 86.2 months; the crack map is displayed in Figure 44. Survey 8 was performed at a deck age of 96.8 months; the crack map is displayed in Figure 45. A crack density of 0.117 m/m^2 was observed in Survey 7 (Figure 44). The crack density for the survey completed in 2013, 0.125 m/m^2, as reported by Bohaty et al. (2013), is higher than recorded in Survey 7. In Survey 8, a crack density of 0.125 m/m^2 was observed (Figure 45). The first survey of this deck, exhibiting a higher crack density when compared to Control-8/10, was considered as an outlier in previous reports. However, the crack density dropped for the next two surveys, perhaps because of force transferred to the deck from the precast-prestressed girders. Therefore, it cannot be considered as an outlier and must be included in the study to provide a full understanding of the deck behavior. Most of the cracks that are present on LC-HPC-10 are transverse. Table 6 lists the new survey numbers for LC-HPC-10 since it now includes the first survey.

Figure 46 compares the crack densities of LC-HPC-10 and Control-8/10 over time. LC-HPC-10 has exhibited much less cracking than Control-8/10 most of the time since the decks were constructed.

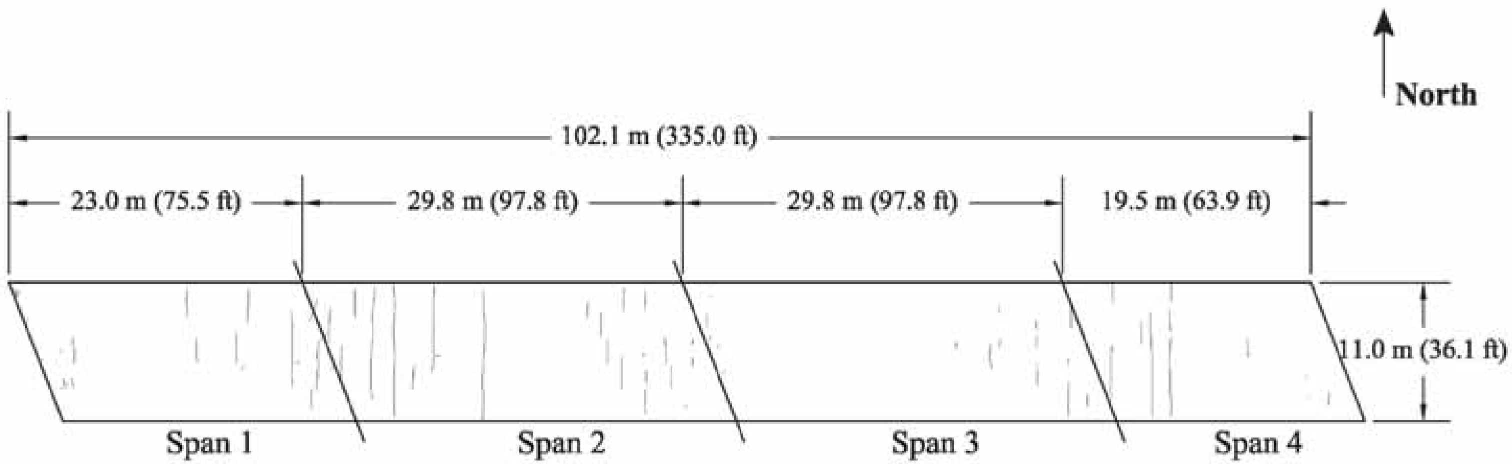


Bridge Number: 54-60 (KU 10)
Bridge Location: E1800Rd over US-69
Construction Date: 5/17/2007
Crack survey Date: 7/22/2014

Bridge Length: 102.1 m (335.0 ft)
Bridge Width: 11.0 m (36.1 ft)
Skew: 21.3°
Number of Spans: 4
Span 1 (West): 23.0 m (75.5 ft)
Span 2 (West): 29.8 m (97.8 ft)
Span 3 (East): 29.8 m (97.8 ft)
Span 4 (East) : 19.5 m (63.9 ft)
Number of Placements: 1

Bridge Age: 86.2 months
Crack density: 0.117 m/m^2
Span 1 (West): 0.105 m/m^2
Span 2 (West): 0.153 m/m^2
Span 3 (East): 0.095 m/m^2
Span 4 (East): 0.109 m/m^2

Figure 44: LC-HPC-10 (Survey 7)



Bridge Number: 54-60 (KU 10)
Bridge Location: E1800Rd over US-69
Construction Date: 5/17/2007
Crack survey Date: 6/11/2015

Bridge Length: 102.1 m (335.0 ft)
Bridge Width: 11.0 m (36.1 ft)
Skew: 21.3°
Number of Spans: 4
Span 1 (West): 23.0 m (75.5 ft)
Span 2 (West): 29.8 m (97.8 ft)
Span 3 (East): 29.8 m (97.8 ft)
Span 4 (East) : 19.5 m (63.9 ft)
Number of Placements: 1

Bridge Age: 96.8 months
Crack density: 0.125 m/m²
Span 1 (West): 0.119 m/m²
Span 2 (West): 0.205 m/m²
Span 3 (East): 0.042 m/m²
Span 4 (East): 0.138 m/m²

Figure 45: LC-HPC-10 (Survey 8)

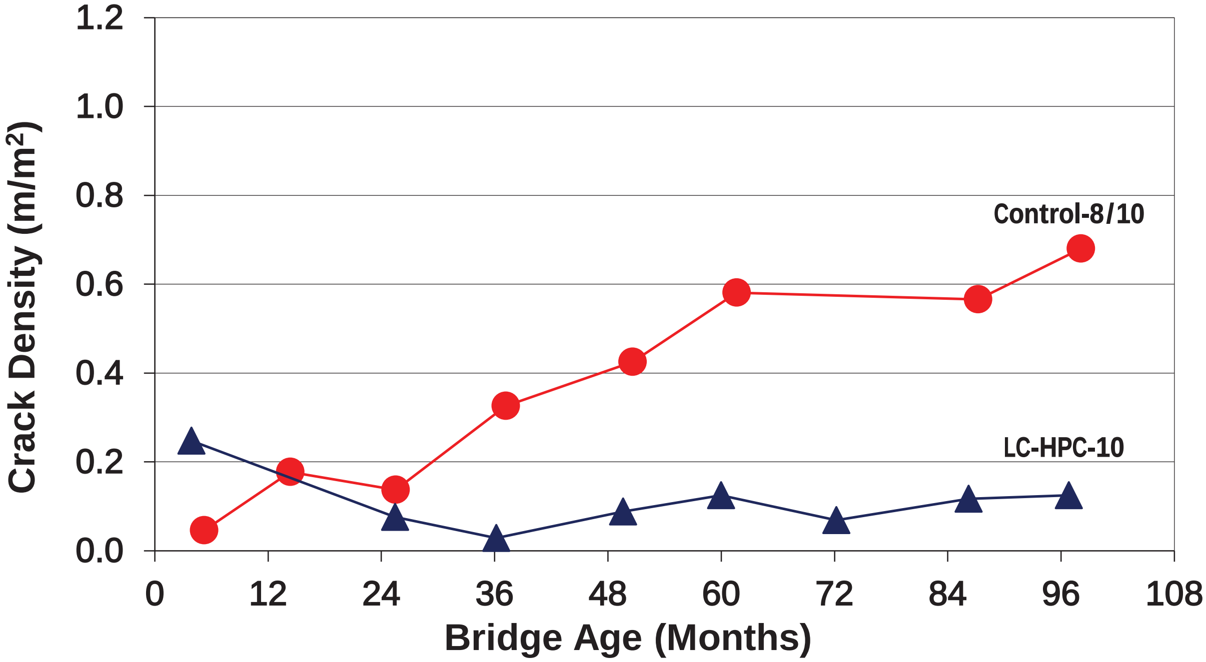


Figure 46: LC-HPC-10 and Control-8/10 Crack Densities Versus Deck Age

Table 6: New Survey Numbering for LC-HPC-10 for First Six Surveys

Date of Survey	Old Survey Number	New Survey Number
9/22/2007	Outlier	Survey 1
6/29/2009	Survey 1	Survey 2
5/22/2010	Survey 2	Survey 3
7/5/2011	Survey 3	Survey 4
5/15/2012	Survey 4	Survey 5
5/22/2013	Survey 5	Survey 6

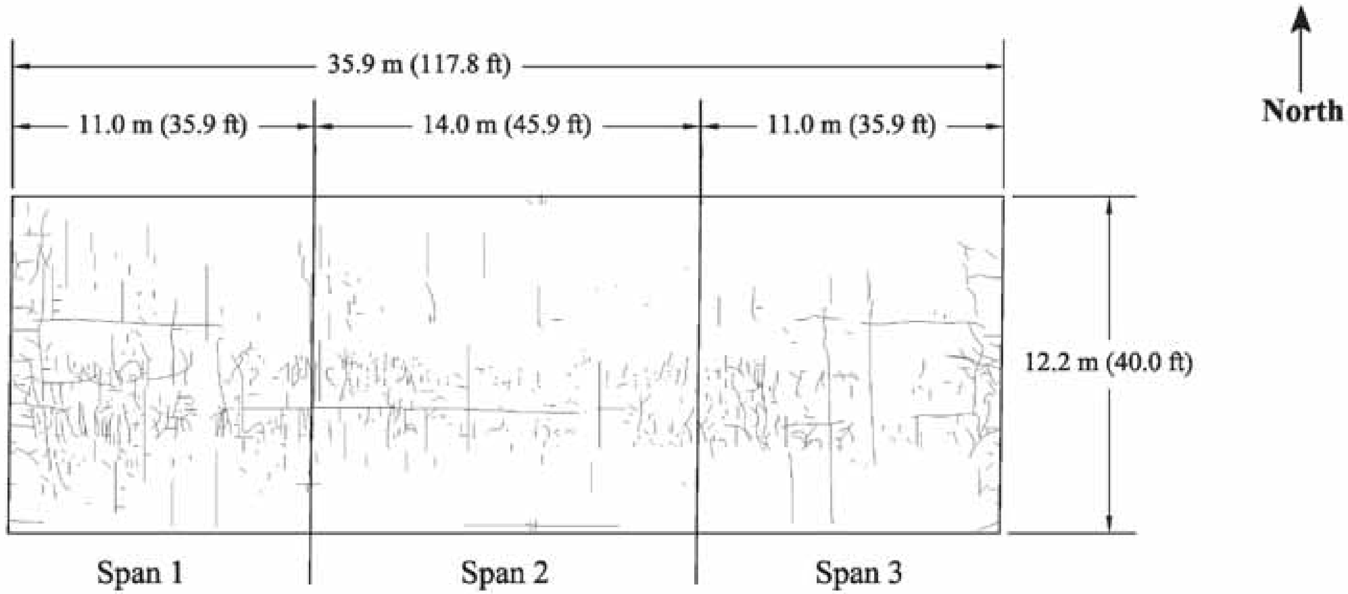
LC-HPC-11

Bridge deck LC-HPC-11 was constructed on 6/9/2007, and has been surveyed six times. This report includes the results of Survey 6. Survey 6 was completed at a deck age of 84.8 months; the crack map for this survey is shown in Figure 47. In Survey 6, a crack density of 0.842 m/m^2 was observed (Figure 47). The crack density almost doubled since the previous survey (Survey 5), reported by Bohaty et al. (2013), when the crack density was 0.420 m/m^2. Due to high cracking, Survey 6 is considered to be the last survey of LC-HPC-11. The majority of the cracks are short cracks distributed over the middle portion of the deck. Also, there are some transverse and longitudinal cracks present in different areas of the deck. The west span (Span 1) exhibits the highest crack density.

Control-11

Bridge deck Control-11 was placed on 3/28/2006 and has been surveyed 8 times. The results of Survey 8 are included in this report. Survey 8 was completed at a deck age of 98.0 months; the crack map is shown in Figure 49. In Survey 8, a crack density of 0.922 m/m^2 was observed (Figure 48). This value is considerably higher than recorded during Survey 7, 0.657 m/m^2 (Bohaty et al. 2013). Survey 8 is considered to be the final crack survey of Control-11 because of high cracking of the bridge deck. Most of the cracks are transverse and spaced uniformly. A longitudinal crack runs the full length of the deck. Cracks have propagated perpendicular to the abutments.

Figure 49 compares crack densities for LC-HPC-11 and Control-11 over time. Although both bridge decks show high crack densities, LC-HPC-11 has exhibited lower crack densities most of the time since the decks were constructed.

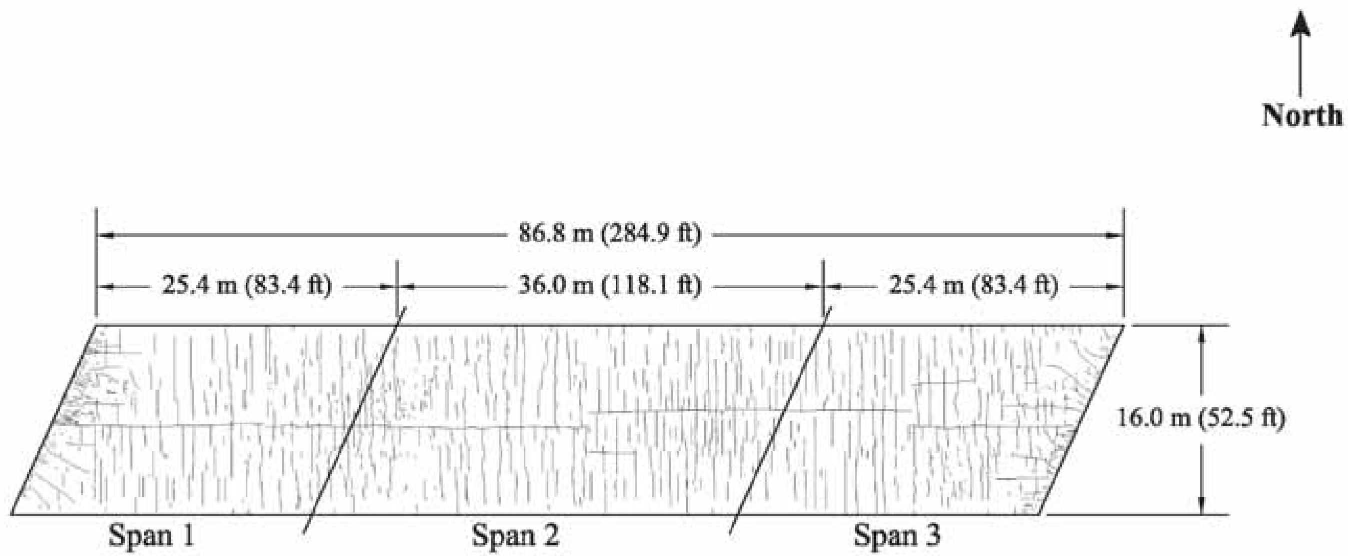


Bridge Number: 78-119 (KU #11)
Bridge Location: EB US-50 over K &ORR, Hutchinson, KS
Construction Date: 6/9/2007
Crack Survey Date:7/3/2014

Bridge Length: 35.9 m (117.8 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: -0.7°
Number of Spans: 3
Span 1: 11.0 m (35.9 ft)
Span 2: 14.0 m (45.9 ft)
Span 3: 11.0 m (35.9 ft)
Number of Placements: 1

Bridge Age: 84.8 months
Crack Density: 0.842 m/m^2
Span 1: 1.305 m/m^2
Span 2: 0.511 m/m^2
Span 3: 0.803 m/m^2

Figure 47: LC-HPC-11 (Survey 6)



Bridge Number: 56-155 (KU #11 Control)
Bridge Location: US-50 over BNSF Railroad, Emporia, KS
Construction Date: 3/28/2006
Crack Survey Date: 5/27/2014

Bridge Length: 86.8 m (284.9 ft)
Bridge Width: 16.0 m (52.5 ft)
Skew: -24.3°
Number of Spans: 3
- **Span 1:** 25.4 m (83.4 ft)
- **Span 2:** 36.0 m (118.1 ft)
- **Span 3:** 25.4 m (83.4 ft)

Number of Placements: 1

Bridge Age: 98 months
Crack Density: 0.680 m/m^2
- **Span 1:** 0.494 m/m^2
- **Span 2:** 0.659 m/m^2
- **Span 3:** 0.681 m/m^2

Figure 49: Control-11 (Survey 8)

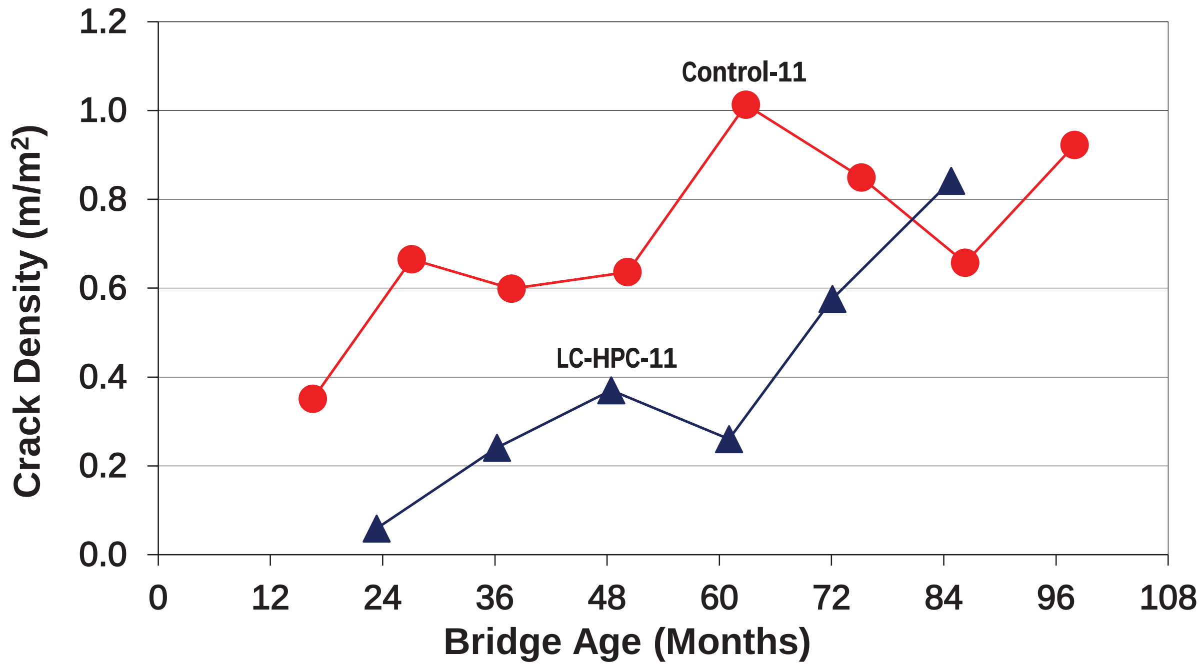


Figure 49: LC-HPC-11 and Control-11 Crack Densities Versus Deck Age

LC-HPC-12

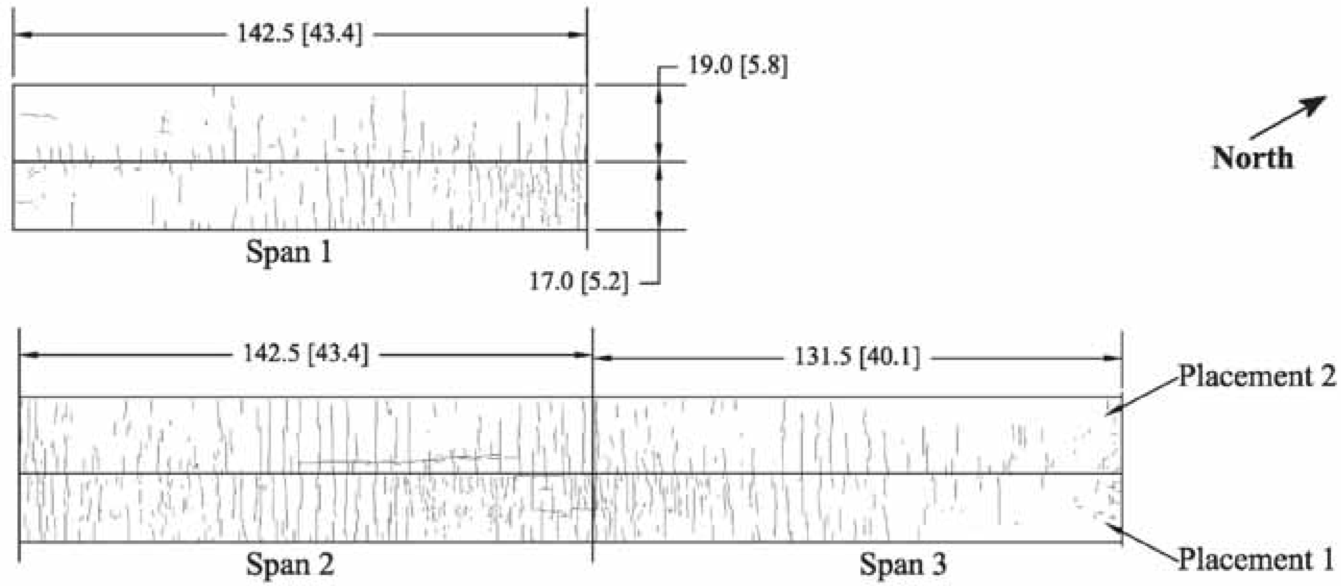
Bridge deck LC-HPC-12 was constructed in two placements; Placement 1 was constructed on 4/4/2008, and Placement 2 was constructed on 3/18/2009. Six surveys have been performed on this bridge deck. The results of Survey 6 of LC-HPC-12 are included in this report. Survey 6 was completed at deck ages of 76.3 and 64.9 months for Placements 1 and 2, respectively; the crack map is displayed in Figure 50. In Survey 6, crack densities of 0.657 m/m^2 overall, and 0.789 and 0.540 m/m^2 for Placements 1 and 2, respectively, were measured (Figure 50). These values are considerably higher than recorded during Survey 5, 0.431, 0.478, and 0.381 m/m^2 (Bohaty et al. 2013). Because of the high crack density, Survey 6 is the last crack survey of LC-HPC-12 bridge deck. Most of the cracks are transverse and run through the full width of the deck. Shorter cracks are also present and propagate from the construction joint between the two placements. Cracks are closer to each other above the piers than in other areas of the deck. During the construction of

Placement 2, heavy equipment was placed on Placement 1 (McLeod et al. 2009, Yuan et al. 2011, Pendergrass and Darwin 2014). This resulted in torsional stresses applied to Placement 1 and may explain the fact that Placement 1 has higher crack density compared to Placement 2. In addition, because loads were applied during construction, the portion of the deck being cast was subjected to relatively large torsional deflections.

Control-12

Like LC-HPC-12, Control-12 was constructed in two placements; Placement 1 was cast on 4/1/2008 and Placement 2 was cast on 4/14/2009. LC-HPC-12 and Control-12 are one bridge spanning over the Neosho River, and Control-12 is the southern portion of this bridge. This deck has been surveyed six times, and the results of Survey 6 are included in this report. Survey 6 was performed at 76.4 and 64.0 months for Placements 1 and 2, respectively; the crack map is displayed in Figure 51. In Survey 6, crack densities of 1.152 m/m^2 overall, and 1.141 and 1.163 m/m^2 for Placements 1 and 2 were observed (Figure 51). These values are higher than recorded for Survey 5, 0.858, 0.838, and 0.880 m/m^2 (Bohaty et al. 2013). Survey 6 marks the last survey of this deck due to its high densities. The majority of the cracks are long transverse cracks. They are very closely spaced compared to the transverse cracks present on LC-HPC-12. Some longitudinal cracks are also present. The middle span exhibits the greatest amount of cracking.

Figure 52 compares the crack densities for LC-HPC-12 and Control-12 over time. Although cracking has been high in LC-HPC-12, its performance has consistently exceeded that of Control-12.

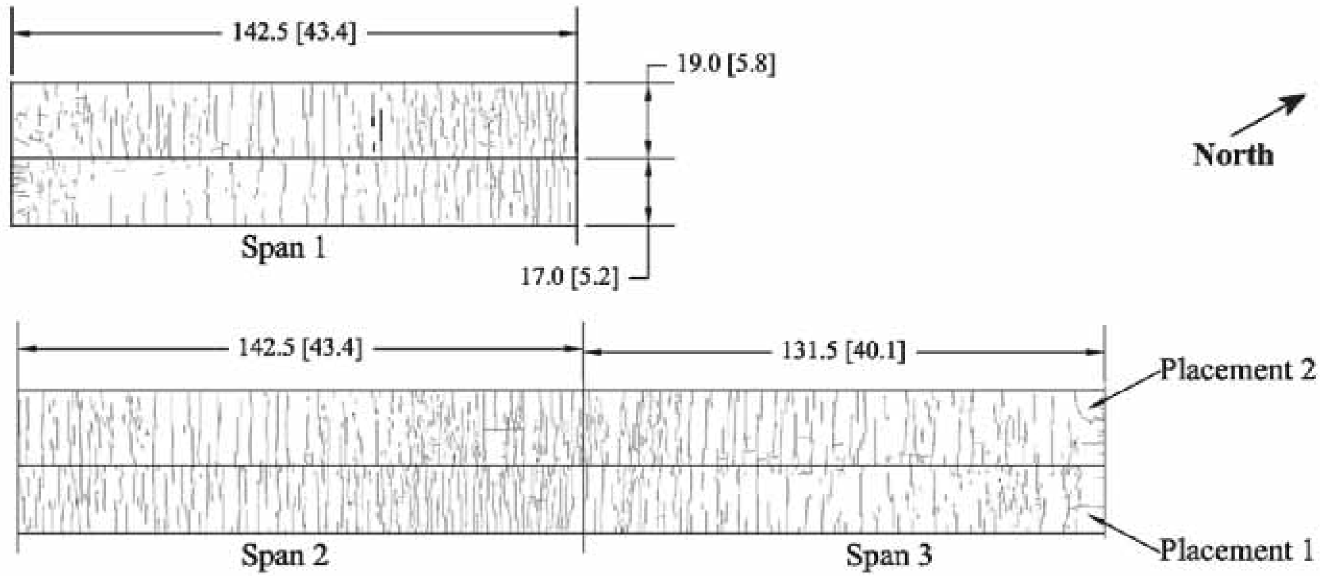


Bridge Number: 56-057 (KU 12)
Bridge Location: K-130 over Neosho Rv Unit 2
Construction Date:
Placement 1(East): 4/4/2008
Placement 2(West): 3/18/2009
Crack Survey Date: 8/13/2014

Bridge Length: 416.5' (126.95m)
Bridge Width: 36' (10.97m)
Skew: 0°
Number of Spans: 3
Span 1 (West): 142.5' (43.43m)
Span 2 (Mid): 142.5' (43.43m)
Span 3 (East): 131.5' (40.08m)
Number of Placements: 2

Bridge Age:
Placement 1: 76.3 months
Placement 2: 64.9 months
Crack Density: 0.657 m/m²
Placement 1: 0.789 m/m²
Placement 2: 0.540 m/m²
Span 1: 0.475 m/m²
Span 2: 0.929 m/m²
Span 3: 0.556 m/m

Figure 50: LC-HPC-12 (Survey 6)



Bridge Number: 56-057 (Control 12)
Bridge Location: K-130 over Neosho Rv Unit 1
Construction Date:
Placement 1 (East): 4/1/2008
Placement 2 (West): 4/14/2009
Crack Survey Date: 8/13/2014

Bridge Length: 416.5' (126.95m)
Bridge Width: 36' (10.97m)
Skew: 0^{o}
Number of Spans: 3
Span 1 (West): 142.5' (43.43m)
Span 2 (Mid): 142.5' (43.43m)
Span 3 (East): 131.5' (40.08m)
Number of Placements: 2

Bridge Age:
Placement 1: 76.4 months
Placement 2: 64 months
Crack Density: 1.152 m/m^2
Placement 1: 1.141 m/m^2
Placement 2: 1.163 m/m^2
Span 1: 0.967 m/m^2
Span 2: 1.420 m/m^2
Span 3: 1.063 m/m^2

Figure 51: Control-12 (Survey 6)

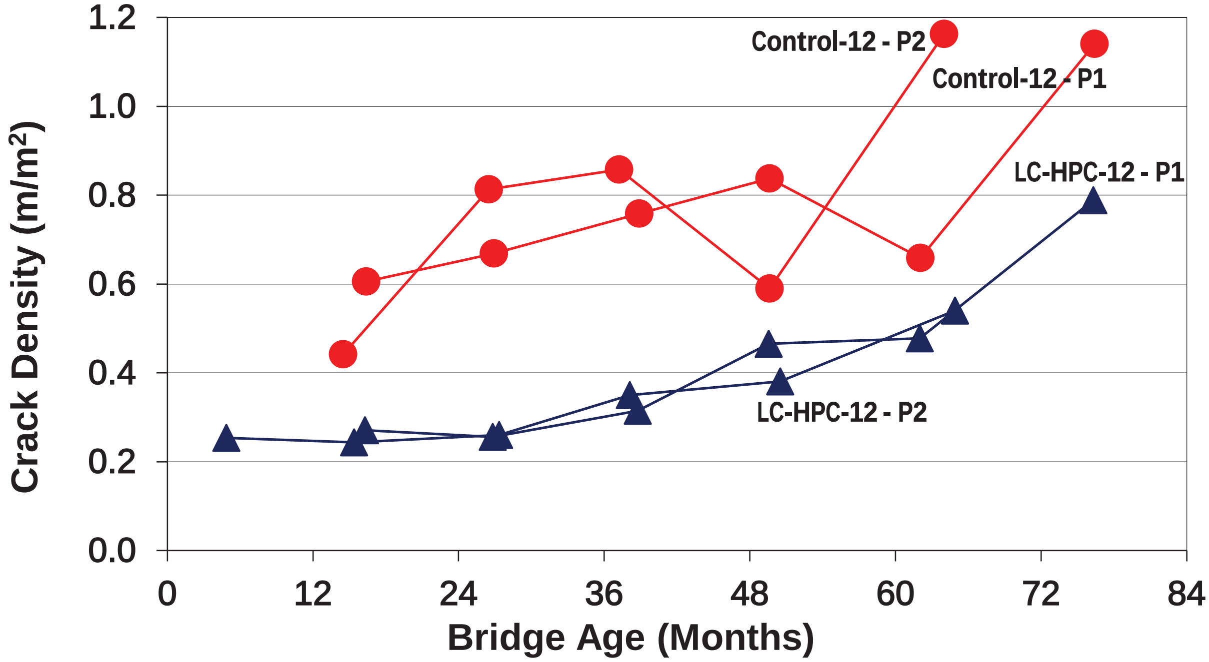
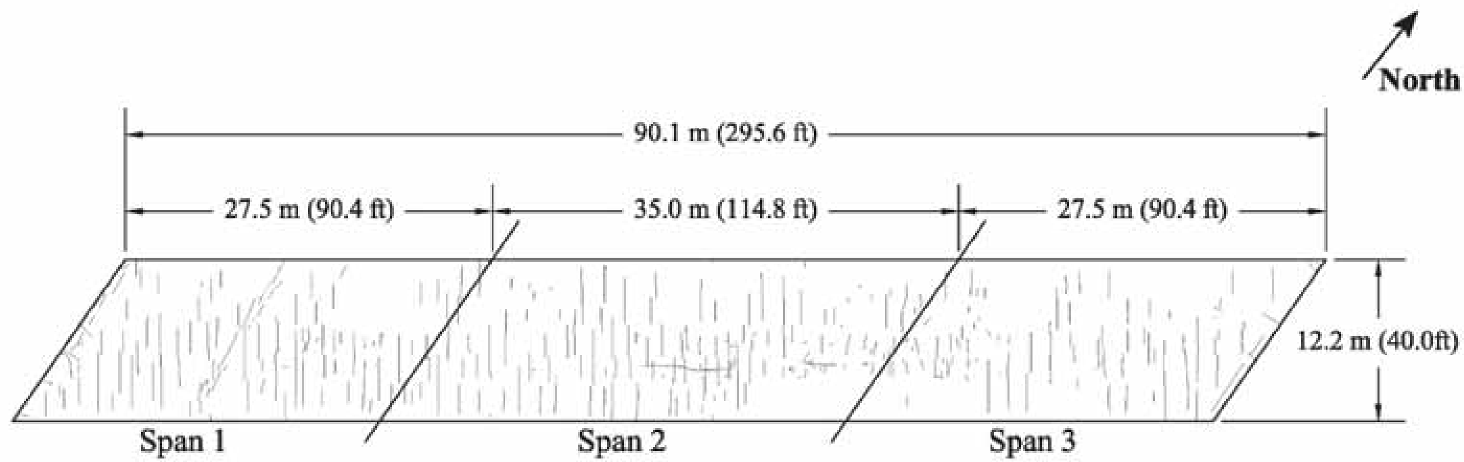


Figure 52: LC-HPC-12 and Control-12 Crack Densities Versus Deck Age

LC-HPC-13

Bridge deck LC-HPC-13 was constructed on 4/29/2008 and has been surveyed seven times. The results of Surveys 6 and 7 of LC-HPC-13 are included in this report. Survey 6 was completed at a deck age of 75.2 months; the crack map is shown in Figure 53. Survey 7 was completed at a deck age of 85.9 months; the crack map is shown in Figure 54. A crack density of 0.471 m/m^2 was observed in Survey 6 (Figure 53). This value is lower than recorded during Survey 5 at 0.576 m/m^2 (Bohaty et al. 2013). Based on surveys before and since, it appears that Survey 5 is an outlier. In Survey 7, a crack density of 0.486 m/m^2 was observed (Figure 54). Moderate sized cracks were marked during both surveys. Short cracks are present above the eastern pier.



Bridge Number: 54-66 (KU 13)
Bridge Location: NB US-69 over BNSF RR, Linn County, KS
Construction Date: 4/29/2008
Crack survey Date: 8/4/2014

Bridge Length: 90.1 m (295.6 ft)
Bridge Width: 12.2 m (40.0 ft)
Skew: -34.8
Number of Spans: 3
Span 1 (West): 27.5 m (90.4 ft)
Span 2 (Middle): 35.0 m (114.8 ft)
Span 3 (East): 27.5 m (90.4 ft)
Number of Placements: 1

Bridge Age: 75.2 months
Crack density: 0.471 m/m^2
Span 1 (West): 0.544 m/m^2
Span 2 (middle): 0.491 m/m^2
Span 3 (East): 0.373 m/m^2

Figure 53: LC-HPC-13 (Survey 6)

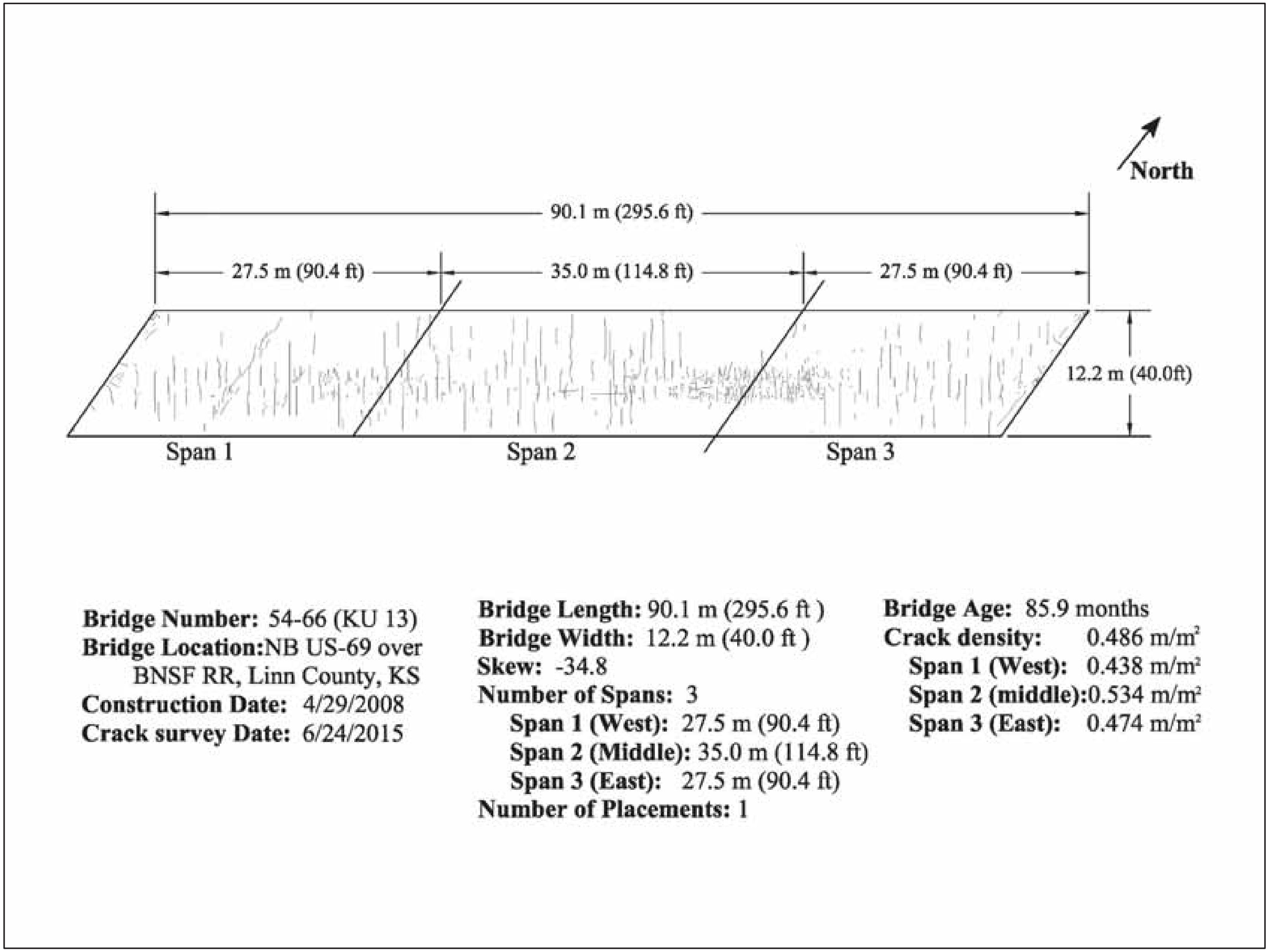


Figure 54: LC-HPC-13 (Survey 7)

Control-13

Bridge deck Control-13 was placed on 7/25/2008 and has been surveyed seven times. The results of Surveys 6 and 7 are included in this report. Survey 6 was completed at a deck age of 72.5 months; the crack map is shown in Figure 55. Survey 7 was completed at a deck age of 84.1 months; the crack map is shown in Figure 56. In Survey 6, a crack density of 0.711 m/m^2 was observed (Figure 55). Survey 6 has a lower crack density than Survey 5, 0.807 m/m^2 (Bohaty et al. 2013). In Survey 7, a crack density of 0.718 m/m^2 was observed (Figure 56), which is slightly higher than Survey 6. Similar to LC-HPC-13, Survey 5 can be consider as an outlier. As shown in Figures 55 and 56, it can be seen that there are moderate-length transverse cracks distributed over the whole area of the bridge. Map cracking is present at some locations on the deck. Short cracks have propagated perpendicular to both abutments.

Figure 57 compares the crack densities for LC-HPC-13 and Control-13 over time. LC-HPC-13 has consistently exhibited less cracking density than Control-13 over the life of the decks.

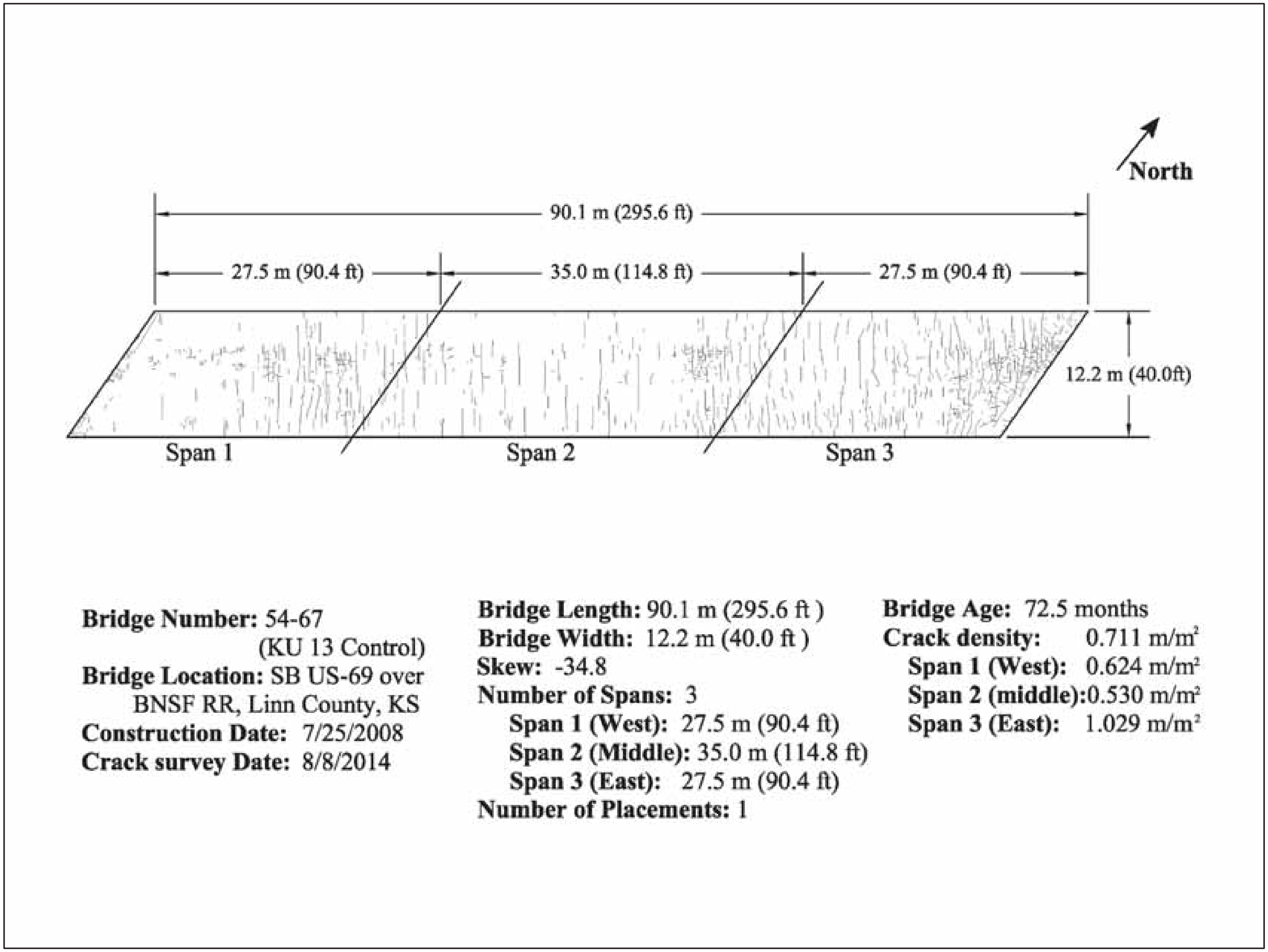


Figure 55: Control-13 (Survey 6)

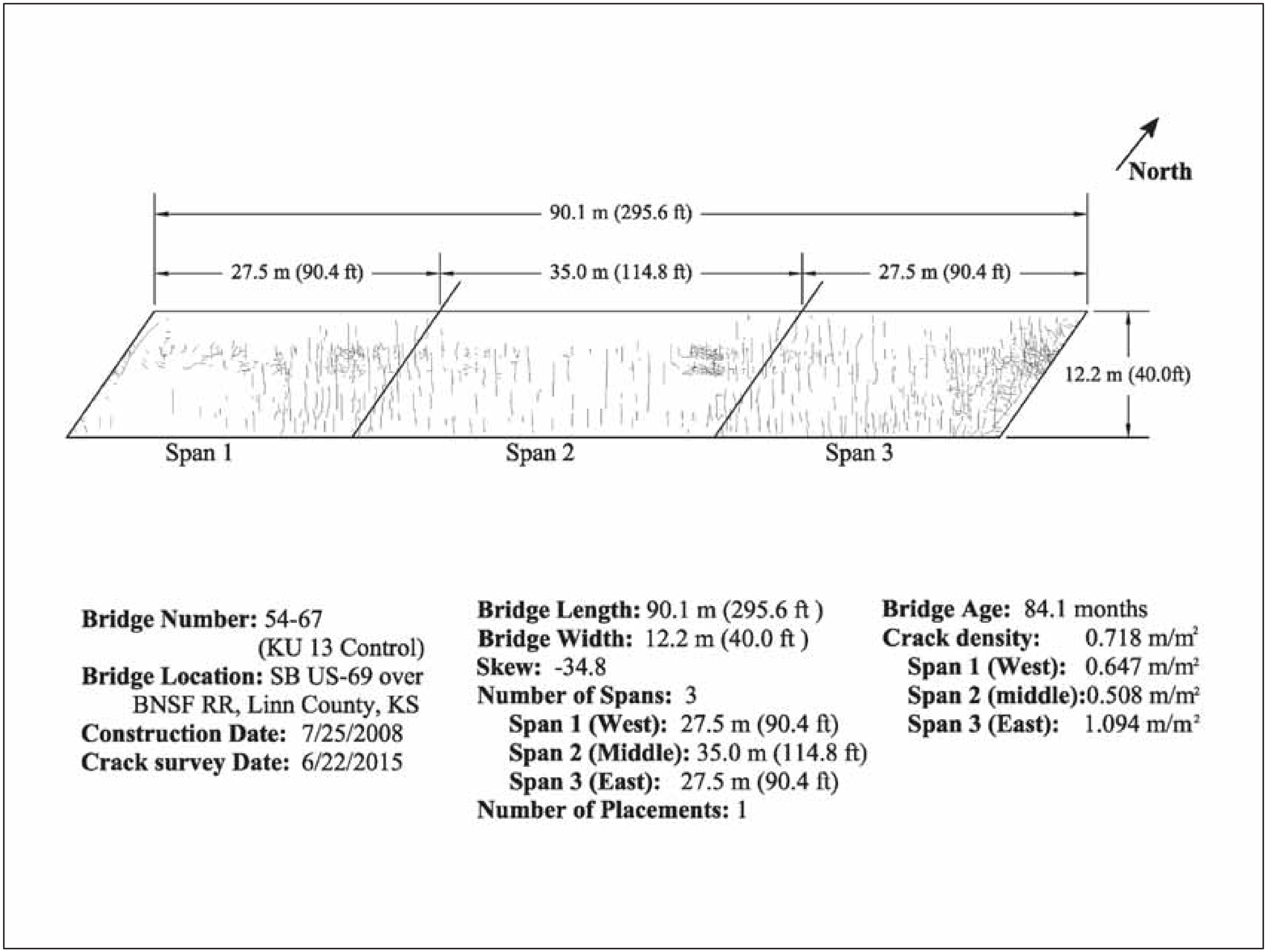


Figure 56: Control-13 (Survey 7)

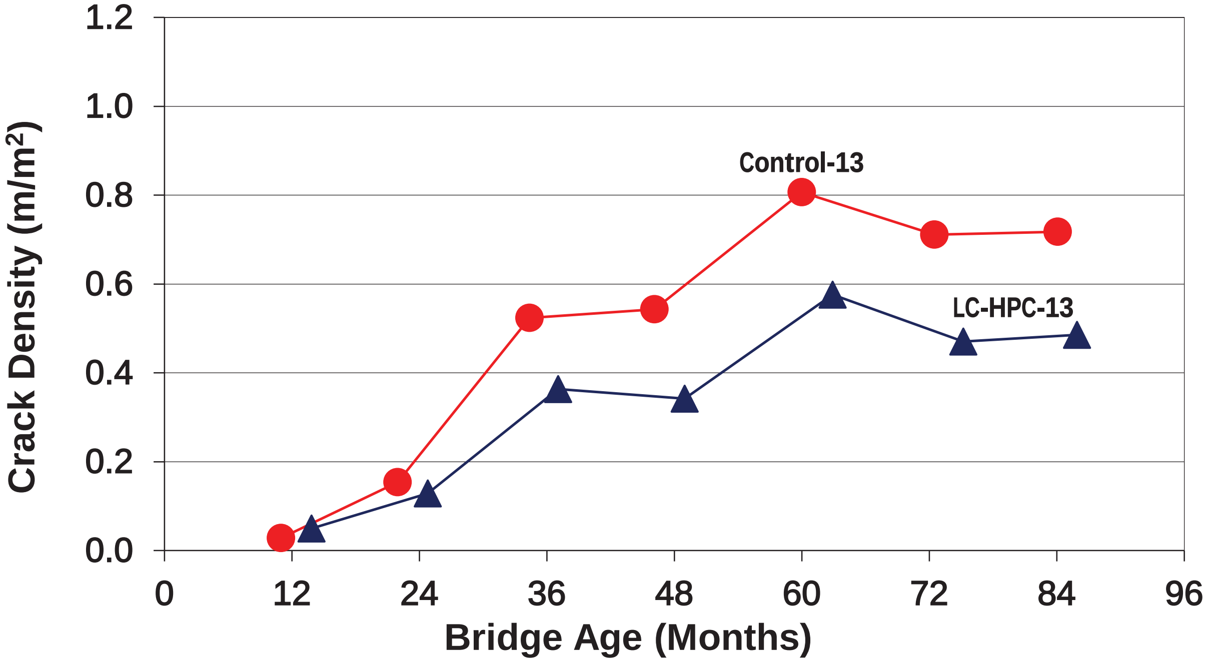


Figure 57: LC-HPC-13 and Control-13 Crack Densities Versus Deck Age

OP-14

Bridge deck OP-14 was constructed in three separate placements; Placements 1, 2, and 3 were cast on 12/19/2007, 5/2/2008, and 5/21/2008, respectively. OP-14 has been surveyed four times. Survey 4 is considered to be the last for OP-14 due to excessive deck cracking. Survey 4 recorded a crack density of 1.083, 1.331, and 1.387 m/m^2 for Placements 1, 2, and 3, respectively (Bohaty et al. 2013). Placements 2 and 3 of this deck recorded the highest crack densities among any of the decks included in this study (LC-HPC and control decks). Figure 58 compares the crack densities for OP-14 over time (Bohaty et al. 2013). OP-14 was bid as an LC-HPC bridge deck. However, the contractor did not follow important aspects of the LC-HPC specifications, and the owner, the City of Overland Park, did not enforce the specifications (McLeod et al. 2009).

Placement 1 of OP-14 was constructed on two separate dates because the concrete pump clogged after placing the first 30 ft (9 m) of the deck. This portion of the deck was demolished before the second construction attempt. For some concrete batches during the second attempt, the measured slump was much higher than the maximum slump specified for LC-HPC decks. Inadequate consolidation was observed during the construction: the gang vibrators were removed too quickly leaving visible holes at the deck surface. Excessive bullfloating was used on the deck surface, which resulted in excessive cement paste to the surface. The specified ten-minute time between finishing and placing burlap was exceeded throughout the deck construction. Also, water was used as finishing aid. Placements 2 and 3 of OP-14 had the same construction issues as Placement 1, resulting in high deck cracking. During the construction of Placement 2, concrete trucks were delayed and the contractor removed concrete from a previously placed wingwall and used it to complete a portion of the deck. During the construction of Placement 3, the deck reinforcement was not fully supported, resulting in reinforcement vibration. This issue may have increased the potential for settlement cracking (Lindquist et al. 2008, Gruman et al. 2009, and McLeod et al. 2009).

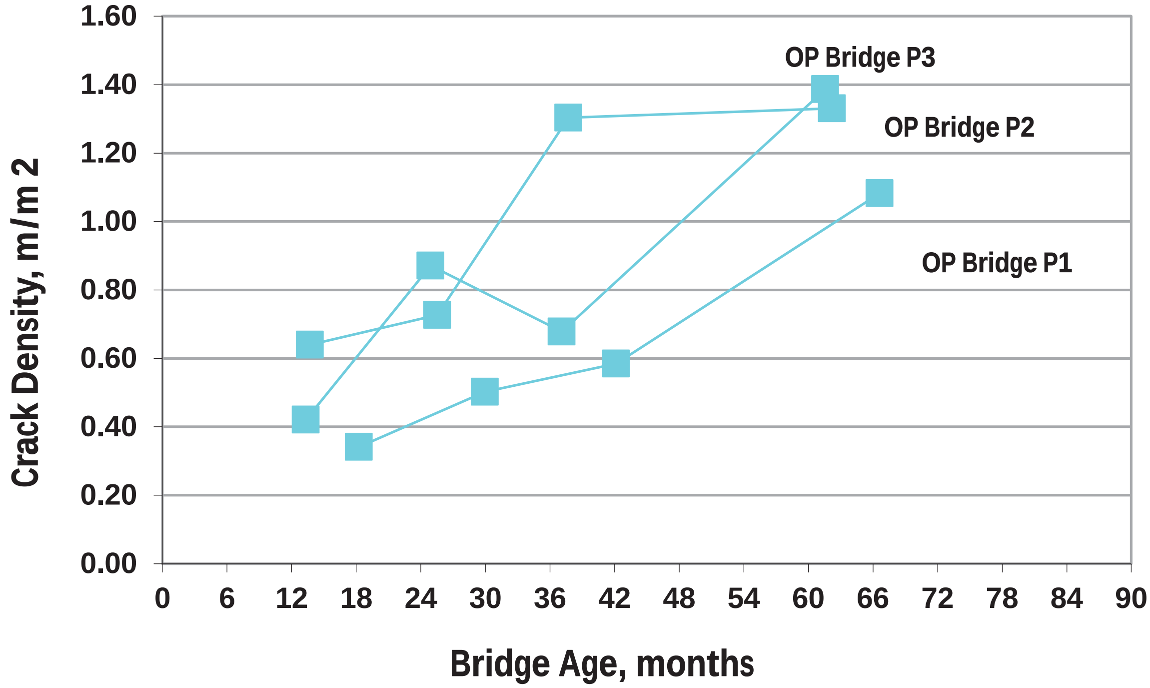
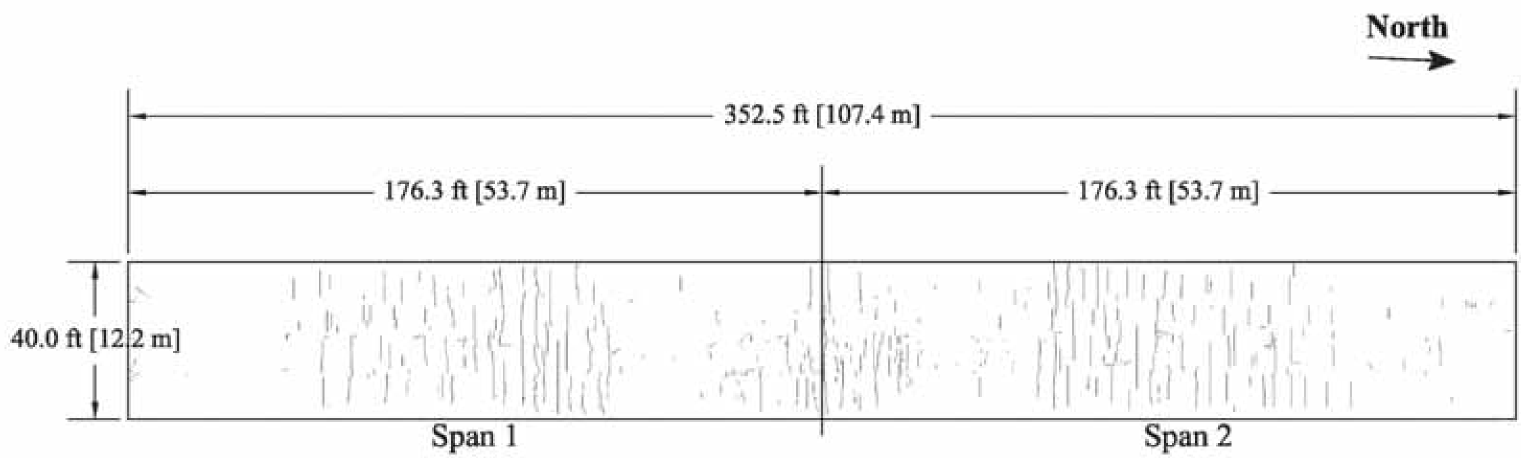


Figure 58: OP-14 Crack Densities Versus Deck Age (Bohaty et al. 2013)

LC-HPC-15

Bridge deck LC-HPC-15 was constructed on 11/10/2010. This deck does not have a control deck for comparison. LC-HPC-15 has been surveyed four times and this report includes the results of Surveys 3 and 4. Survey 3 was performed at a deck age of 43.0 months; the crack map is shown in Figure 59. Survey 4 was performed at a deck age of 56.2 months; the crack map is shown in Figure 60. A crack density of 0.316 m/m^2 was observed in Survey 3 (Figure 58), a significant increase in crack density from Survey 2, 0.161 m/m^2 (Bohaty et al. 2013). In Survey 4, a crack density of 0.299 m/m^2 was observed (Figure 59), slightly lower than in Survey 3. As shown in Figures 59 and 60, the majority of the cracks in LC-HPC-15 are transverse, and appear to run parallel to the top reinforcement layer. A few short cracks appear near the abutments. Figure 61 displays the crack density versus deck age for LC-HPC-15.

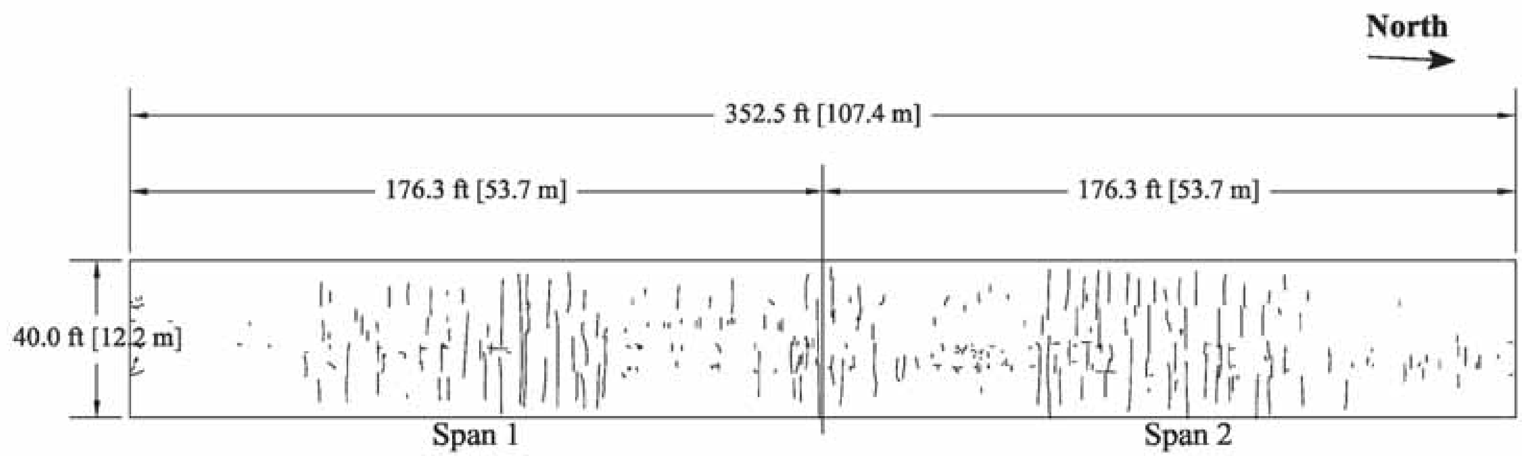


Bridge Number: 46-351 (KU 15)
Bridge Location: NB K-7 over Johnson Dr./55th St.
Construction Date: 11-10-10
Crack Survey Date: 6-9-2014

Bridge Length: 352.5 ft (118.2 m)
Bridge Width: 40.0 ft(12.2 m)
Skew: 0°
Number of Spans: 3
Span 1: 176.25 ft (36.7 m)
Span 2: 176.25 ft (44.8 m)
Number of Placements: 1

Bridge Age: 43 months
Crack Density: 0.317 m/m²
Span 1: 0.290 m/m²
Span 2: 0.344 m/m²

Figure 59: LC-HPC-15 (Survey 3)



Bridge Number: 46-351 (KU 15)
Bridge Location: NB K-7 over Johnson Dr./55th St.
Construction Date: 11-10-10
Crack Survey Date: 6-23-2015

Bridge Length: 352.5 ft (118.2 m)
Bridge Width: 40.0 ft(12.2 m)
Skew: 0°
Number of Spans: 3
Span 1: 176.25 ft (36.7 m)
Span 2: 176.25 ft (44.8 m)
Number of Placements: 1

Bridge Age: 56.2 months
Crack Density: 0.299 m/m²
Span 1: 0.288 m/m²
Span 2: 0.311 m/m²

Figure 60: LC-HPC-15 (Survey 4)

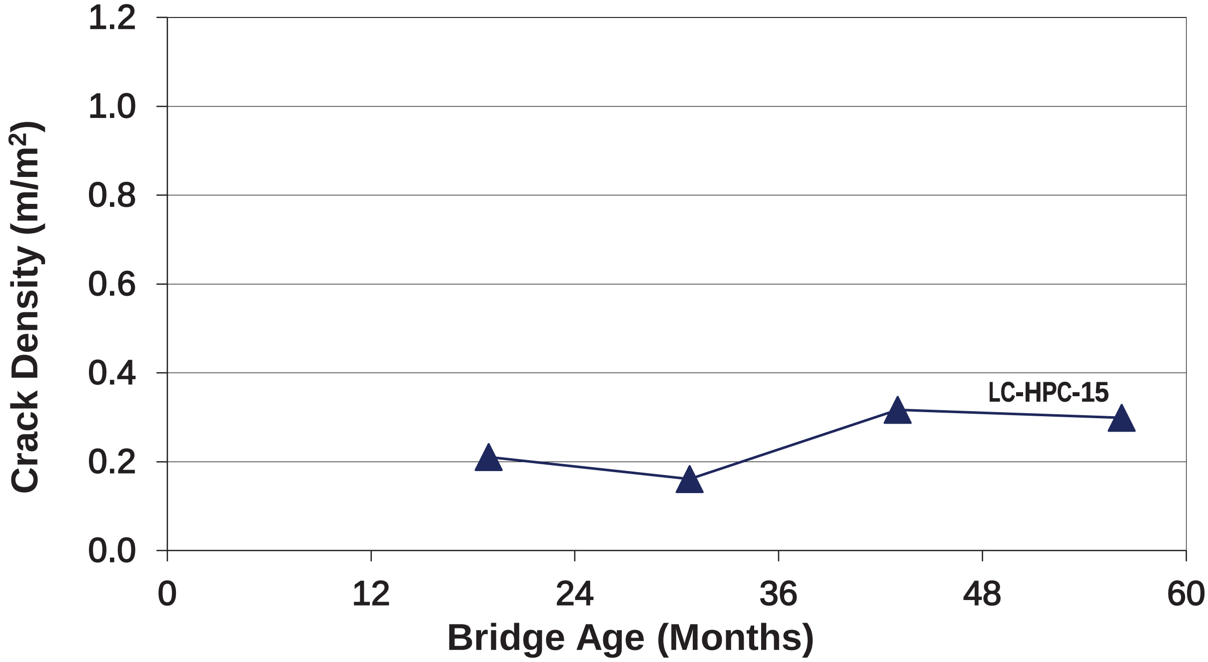
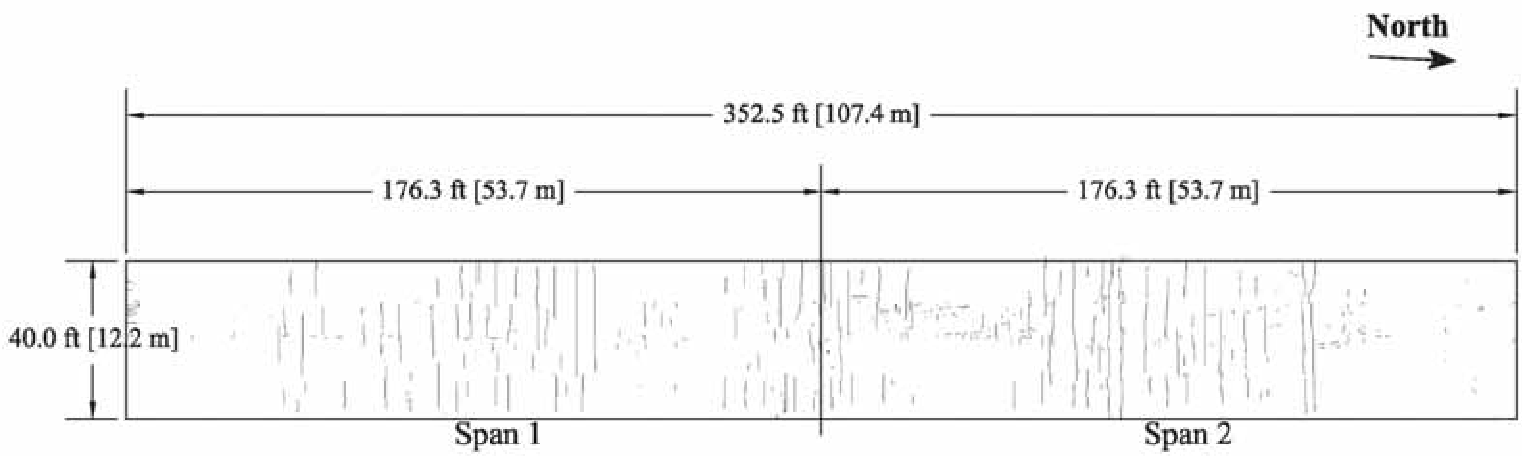


Figure 61: LC-HPC-15 Crack Densities Versus Deck Age

LC-HPC-16

Bridge deck LC-HPC-16 was constructed on 6/11/2014. This bridge does not have a control deck for comparison. This deck has been surveyed five times. The results of Surveys 4 and 5 of LC-HPC-16 are discussed in this report. Survey 4 was completed at a deck age of 43.5 months; the crack map is displayed in Figure 62. Survey 5 was completed at a deck age of 55.0 months; the crack map is displayed in Figure 63. A crack density of 0.311 m/m^2 was observed in Survey 4 (Figure 62) compared to a crack density of Survey 3, 0.211 m/m^2 (Bohaty et al. 2013). In Survey 5, a crack density of 0.397 m/m^2 was observed (Figure 63). Most of the cracks are transverse (Figures 62 and 63). Map cracking is also present on some portions of the deck. Near the abutments, some cracks have propagated longitudinally. Figure 64 shows the crack density as a function of age for LC-HPC-16.

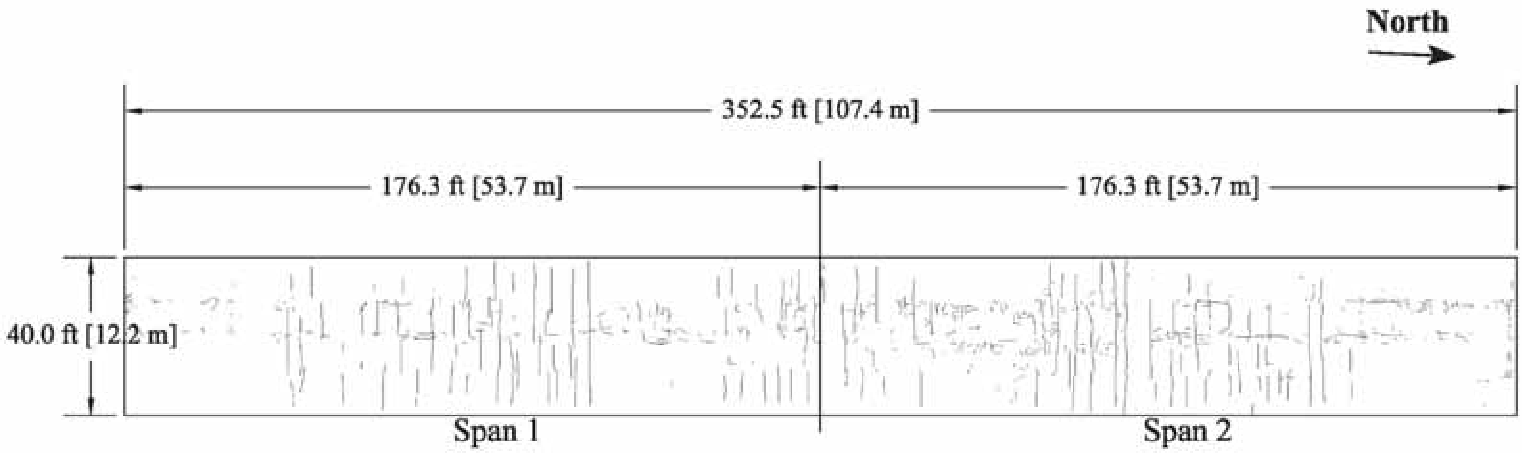


Bridge Number: 46-352 (KU 16)
Bridge Location: SB K-7 over Johnson Dr./55th St.
Construction Date: 10-28-2010
Crack Survey Date: 6-11-2014

Bridge Length: 352.5 ft (107.4 m)
Bridge Width: 40.0 ft(12.2 m)
Skew: 0°
Number of Spans: 2
Span 1: 176.25 ft (53.7 m)
Span 2: 176.25 ft (53.7 m)
Number of Placements: 1

Bridge Age: 43.5 months
Crack Density: 0.311 m/m²
Span 1: 0.267 m/m²
Span 2: 0.354 m/m²

Figure 62: LC-HPC-16 (Survey 4)



Bridge Number: 46-352 (KU 16)
Bridge Location: SB K-7 over Johnson Dr./55th St.
Construction Date: 10-28-2010
Crack Survey Date: 5-27-2015

Bridge Length: 352.5 ft (107.4 m)
Bridge Width: 40.0 ft(12.2 m)
Skew: 0°
Number of Spans: 2
Span 1: 176.25 ft (53.7 m)
Span 2: 176.25 ft (53.7 m)
Number of Placements: 1

Bridge Age: 55 months
Crack Density: 0.397 m/m^2
Span 1: 0.361 m/m^2
Span 2: 0.447 m/m^2

Figure 63: LC-HPC-16 (Survey 5)

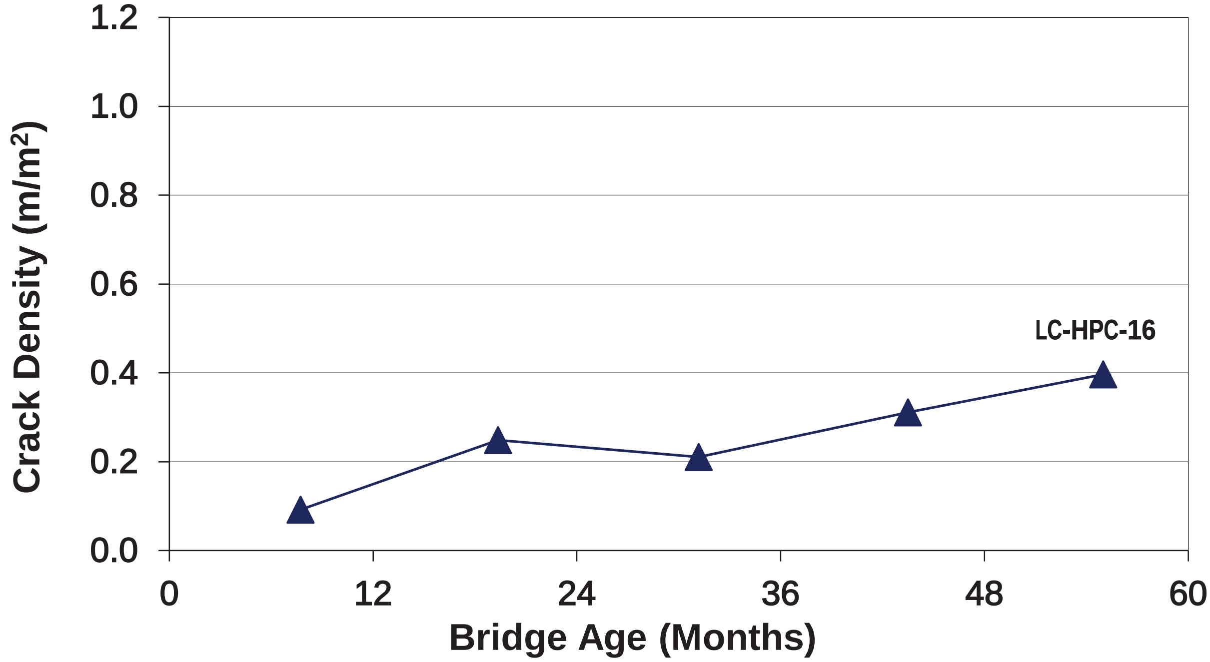
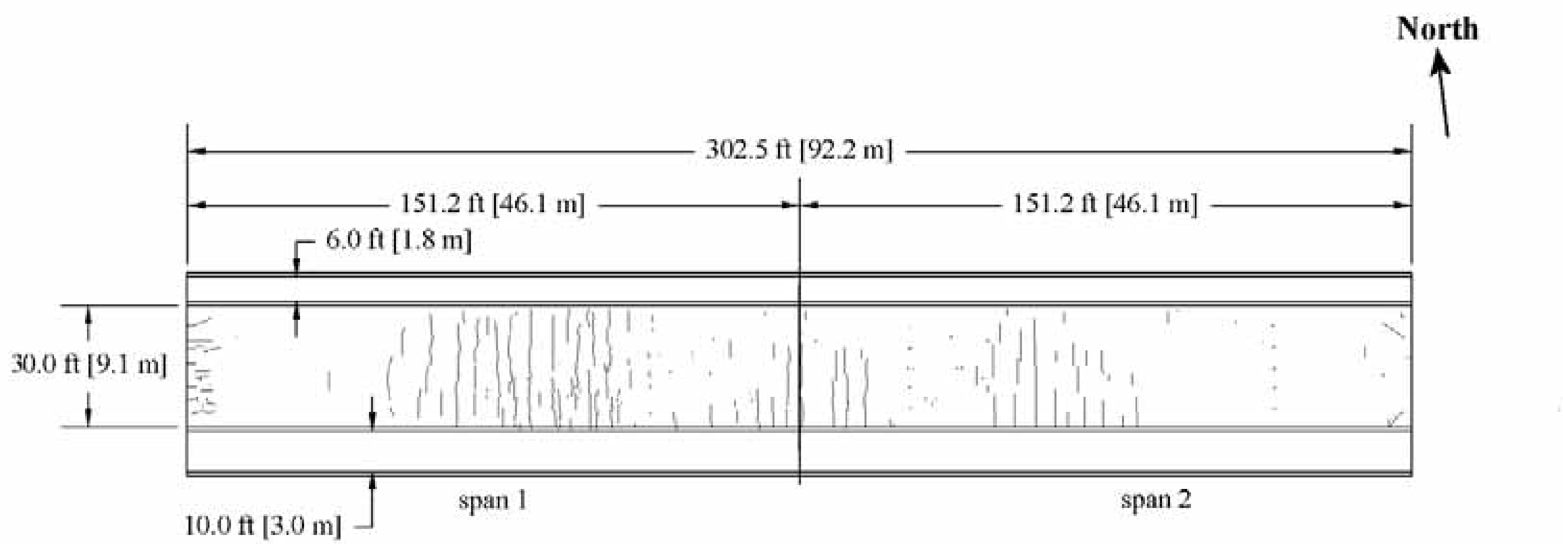


Figure 64: LC-HPC-16 Crack Densities Versus Deck Age

LC-HPC-17

Bridge deck LC-HPC-17 was placed on 9/28/2011. There is no control deck for this bridge. This deck has been surveyed four times, and the results of Surveys 3 and 4 are included in this report. Survey 3 was performed at a deck age of 32.5 months; the crack map is shown in Figure 65. Survey 4 was performed at a deck age of 45.5 months; the crack map is shown in Figure 66. In Survey 3, an overall crack density of 0.274 m/m^2 was observed (Figure 65), slightly higher than the value reported by Bohaty et al. (2013) for Survey 2, 0.240 m/m^2. An overall crack density of 0.308 m/m^2 was observed in Survey 4 (Figure 66). The surveys do not include the sidewalks. As shown in Figures 65 and 66, the majority of the cracks are transverse and located near the mid-span. There are, also, some transverse cracks above the pier. Survey 4 recorded some small areas of map cracking near the east abutment. Cracks also propagate longitudinally near the west abutment. Figure 67 shows the crack density for LC-HPC-17 over time.

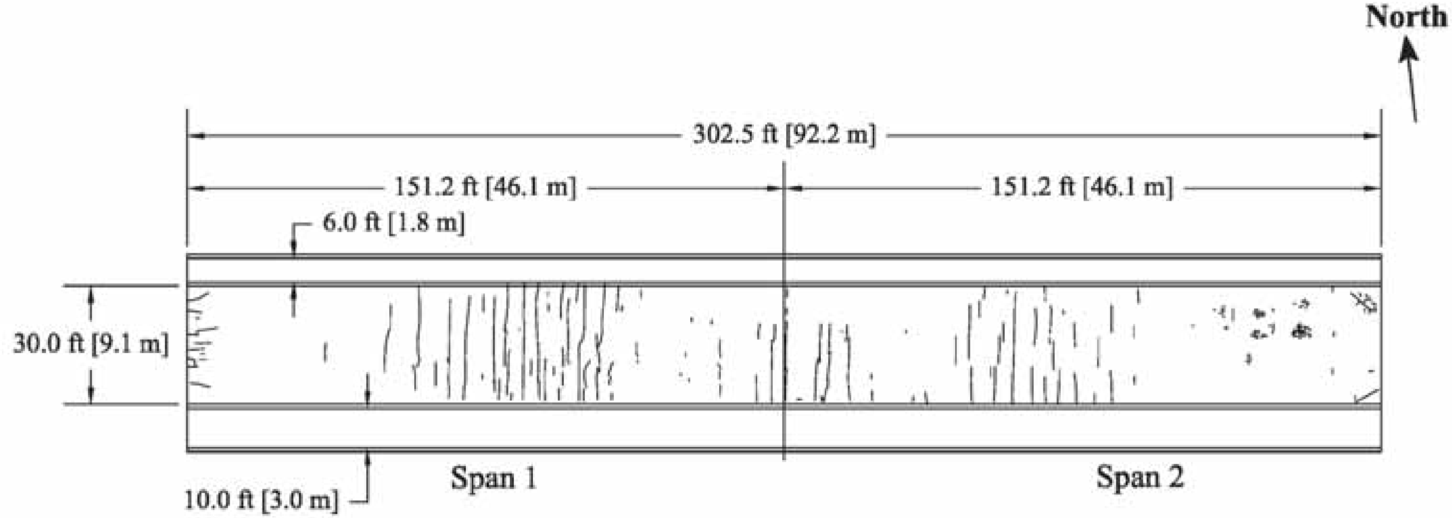


Bridge Number: 46-373 (KU 17)
Bridge Location: Clear Creek Parkway over K-7
Construction Date: 09-28-11
Crack Survey Date: 6/11/2014

Bridge Length: 302.5 ft (92.2 m)
Bridge Width: 48.0 ft(14.6 m)
Skew: 0°
Number of Spans: 2
Span 1: 151.25 ft (46.1 m)
Span 2: 151.25 ft (46.1 m)
Number of Placements: 1

Bridge Age: 32.5 months
Crack Density: 0.274 m/m^2
Span 1: 0.359 m/m^2
Span 2: 0.189 m/m^2

Figure 65: LC-HPC-17 (Survey 3)



Bridge Number: 46-373 (KU 17)
Bridge Location: Clear Creek Parkway over K-7
Construction Date: 09-28-11
Crack Survey Date: 6-25-2015

Bridge Length: 302.5 ft (92.2 m)
Bridge Width: 48.0 ft(14.6 m)
Skew: 0°
Number of Spans: 2
Span 1: 151.25 ft (46.1 m)
Span 2: 151.25 ft (46.1 m)
Number of Placements: 1

Bridge Age: 45.5 months
Crack Density: 0.308 m/m²
Span 1: 0.349 m/m²
Span 2: 0.268 m/m²

Figure 66: LC-HPC-17 (Survey 4)

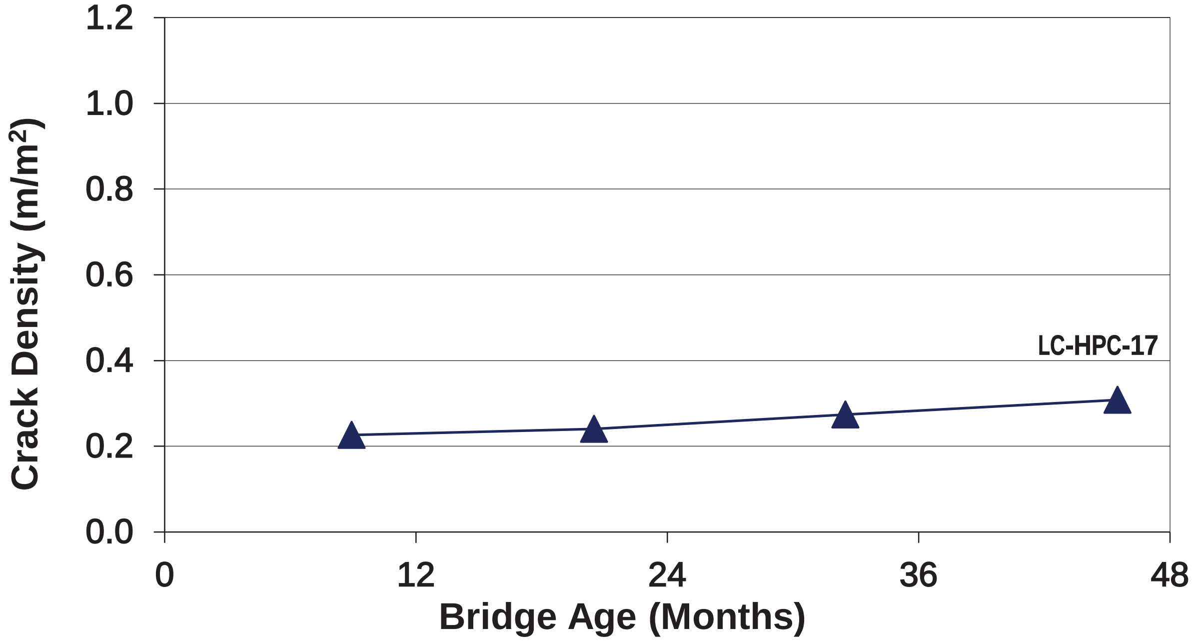


Figure 67: LC-HPC-17 Crack Densities Versus Deck Age

Paired LC-HPC Decks Versus Unpaired LC-HPC Decks

Figure 68 compares paired LC-HPC decks (LC-HPC 1 through 13) to the unpaired LC-HPC decks (LC-HPC 15, 16, and 17) over time. The crack densities for the three unpaired LC-HPC decks fall just under the upper boundary of paired 13 LC-HPC decks. LC-HPC-16 started with a crack density similar to most of the unpaired LC-HPC-decks. However, the crack density jumped in the second and subsequent surveys. The majority of paired LC-HPC decks have exhibited lower crack densities during the first 60 months since construction.

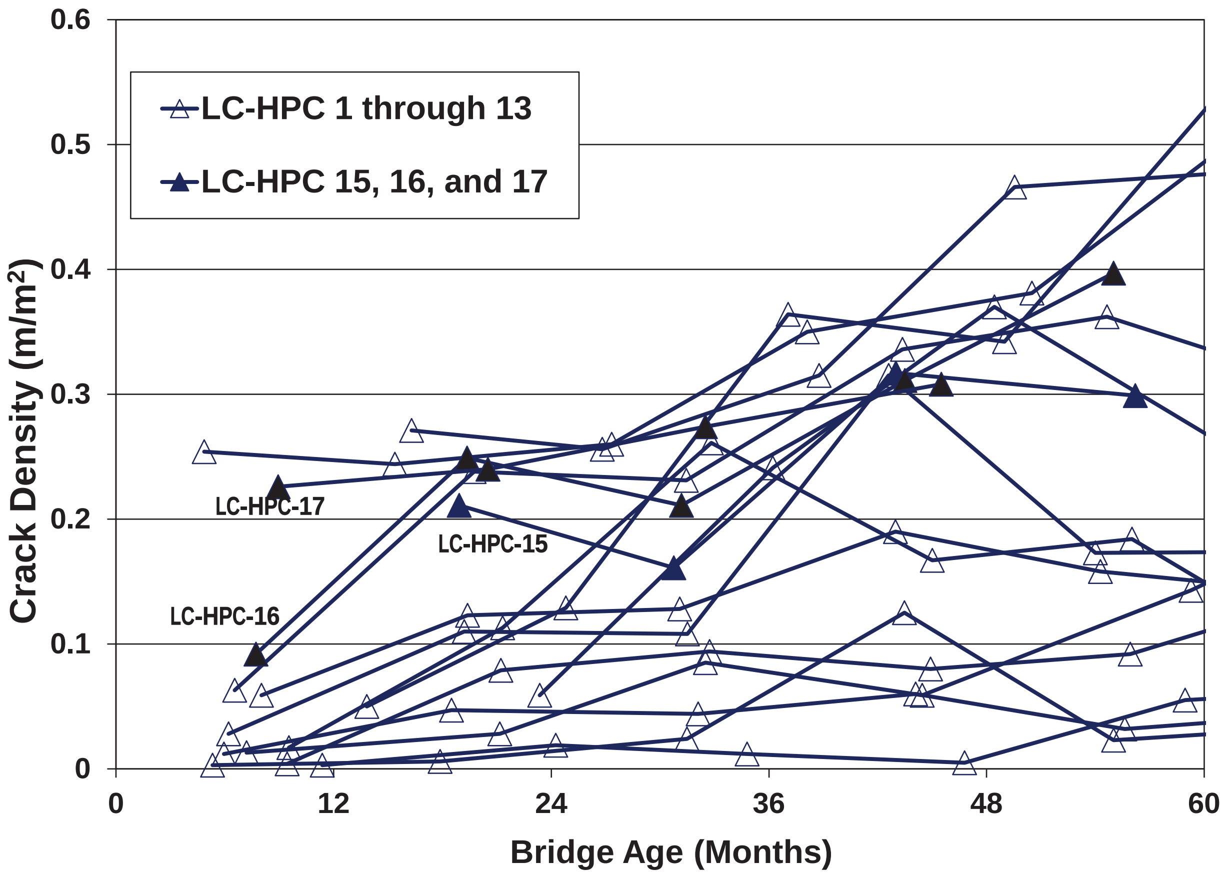


Figure 68: LC-HPC 1 through 13 and LC-HPC 15, 16, and 17 Crack Densities Versus Deck Age

Summary of Results

Tables 4 and 5 list crack survey results for bridge decks included in this study for surveys completed in 2014 and 2015. Generally, LC-HPC bridge decks exhibit less overall cracking than the control decks. LC-HPC-3, and to some extent, LC-HPC-2 are exceptions. LC-HPC-3 is showing higher overall cracking compared to its control. LC-HPC-2 is showing lower overall cracking than Control-1/2 in the 2015 survey. However, LC-HPC-2 exhibited a higher crack density than Placement 1 of Control-1/2 and a slightly lower density than Placement 2 of Control-1/2.

In general, the majority of the cracks present in the bridge decks are transverse, although some cracks propagate from the abutments, perpendicularly.

As shown in Tables 4 and 5, surveys completed in 2014 and 2015 showed that 12 of the 13 LC-HPC decks exhibited lower overall crack densities than their controls. For the 10 decks supported by steel girders, all but one LC-HPC deck exhibited better performance than the control deck. Of the decks supported by precast-prestressed girders, both LC-HPC decks performed better than the control deck.

Bridge deck OP-14 was not constructed in accordance with LC-HPC specifications, and OP-14 has exhibited excessive cracking throughout its life. Two of the three placements of OP-14 exhibit the highest crack densities among all decks included in this study (1.331 m/m^2 for Placement 2 and 1.387 m/m^2 for Placement 3).

Based on 2014 survey results, the highest recorded crack density on a LC-HPC deck was 0.842 m/m^2 (LC-HPC-11 at 84.8 months) and the highest density on a control deck was 1.152 m/m^2 (Control-12 at 64.0 and 76.4 months). Based on 2015 survey results, the highest recorded crack density on a LC-HPC deck is currently 0.487 m/m^2 (LC-HPC-3 at 91.5 months) and the highest density on a control deck is 0.779 m/m^2 (Control-9 at 84.4 and 84.1 months). Control-12 was not surveyed in 2015.

SUMMARY AND CONCLUSIONS

Low-Cracking High-Performance Concrete (LC-HPC) specifications have been developed by KDOT and the University of Kansas for the purpose of increasing the expected service life of concrete bridge decks by the reduction of cracking. Surveys of LC-HPC and control bridge decks were performed and crack densities compared to examine the benefits of implementing LC-HPC specifications. Comparisons between 13 LC-HPC and matching Control bridge decks are made based on the crack density and changes in crack density over time.

Based on the results of this study, the following conclusions can be drawn:

1. LC-HPC bridge decks exhibit less cracking than the matching control decks in the vast majority of cases.
2. For all of the surveys that are discussed in this report, only bridge deck LC-HPC-3 had a higher overall crack density than its control deck.
3. The most common crack type is transverse cracking. Cracks of this type appear to run parallel to the top layer of the deck's reinforcement.
4. Near the abutments, cracks usually propagate perpendicular to the abutments.
5. The width of cracks that were measured generally ranged from 0.006 to 0.025 in. (0.15 to 0.64 mm).
6. As shown for bridge deck OP-14, not following the LC-HPC specifications, such as by using high-slump concrete, poor consolidation, delayed curing, or over-finishing, may result in increased cracking.
7. Decks supported by precast-prestressed girders may exhibit a reduction in crack density during the early ages of the deck.

REFERENCES

ACI Committee 308, (1997). Standard Practice for Curing Concrete, ACI 308-92, American Concrete Institute, Farmington Hills, Michigan.

ASCE (2013). "2013 Report Card for America's Infrastructure" 2015 American Society of Civil Engineers. <http://www.infrastructurereportcard.org/bridges/> (June 4, 2015)

Bohaty, B., Riedel, E., and Darwin, D. (2013). "Crack Surveys of Low-Cracking High-Performance Concrete Bridge Decks in Kansas 2011-2013," SL Report 13-6, University of Kansas Center for Research, Inc., Lawrence, Kansas, December, 153 pp.

Gruman, D., Darwin, D., and Browning, J. (2009). "Crack Surveys of Low-Cracking High-Performance Concrete Bridge Decks in Kansas 2006-2008," SL Report 09-1, University of Kansas Center for Research, Inc., Lawrence, Kansas, January, 50 pp.

Kansas Department of Transportation (2007a). "Low-Cracking High-Performance Concrete - Aggregates," Standard Specifications for State Road and Bridge Construction, Topeka, KS.

Kansas Department of Transportation (2007b). "Low-Cracking High-Performance Concrete," Standard Specifications for State Road and Bridge Construction, Topeka, KS.

Kansas Department of Transportation (2007c). "Low-Cracking High-Performance Concrete - Construction," Standard Specifications for State Road and Bridge Construction, Topeka, KS.

Lindquist, W., Darwin, D., and Browning, J. (2005). "Cracking and Chloride Contents in Reinforced Concrete Bridge Decks," SM Report No. 78, University of Kansas Center for Research, Inc., Lawrence, Kansas, February, 453 pp.

Lindquist, W., Darwin, D., Browning, J., and Miller, G. G. (2006). "Effect of Cracking on Chloride Content in Concrete Bridge Decks," ACI Materials Journal, Vol. 103, No. 6, Nov.-Dec., pp. 467-473.

Lindquist, W. D., Darwin, D., and Browning, J. P., "Development and Construction of Low-Cracking High-Performance Concrete (LC-HPC) Bridge Decks: Free Shrinkage, Mixture Optimization, and Concrete Production" SM Report No. 92, University of Kansas Center for Research, Inc., Lawrence, Kansas, November 2008, 540 pp.

McLeod, H. A. K., Darwin, D., and Browning, J. (2009). "Development and Construction of Low-Cracking High-Performance Concrete (LC-HPC) Bridge Decks: Construction Methods, Specifications, and Resistance to Chloride Ion Penetration," SM Report No. 94, University of Kansas Center for Research, Inc., Lawrence, Kansas, September, 815 pp.

Pendergrass, B., Darwin, D., and Browning, J. (2011). "Crack Surveys of Low-Cracking High-Performance Concrete Bridge Decks in Kansas 2009-2010," SL Report 11-3, University of Kansas Center for Research, Inc., Lawrence, Kansas, October, 103 pp.

Pendergrass, B. and Darwin, D., "Low-Cracking High-Performance Concrete (LC-HPC) Bridge Decks: Shrinkage-Reducing Admixtures, Internal Curing, and Cracking Performance," SM Report No. 107, The University of Kansas Center for Research, Inc., Lawrence, KS, February 2014, 664 pp.

Shilstone, J. M., Sr. (1990). “Concrete Mixture Optimization,” Concrete International, Vol. 12, No. 6, June, pp. 33-39.

Yuan, J., Darwin, D., and Browning, J. (2011). “Development and Construction of Low-Cracking High-Performance Concrete Bridge Decks: Free Shrinkage Tests, Restrained Shrinkage Tests, Construction Experience, and Crack Survey Results,” SM Report No. 103, University of Kansas Center for Research, Lawrence, Kansas, 505 pp.

APPENDIX A

BRIDGE DECK SURVEY SPECIFICATION

1.0 DESCRIPTION.

This specification covers the procedures and requirements to perform bridge deck surveys of reinforced concrete bridge decks.

2.0 SURVEY REQUIREMENTS.

a. Pre-Survey Preparation.

(1) Prior to performing the crack survey, related construction documents need to be gathered to produce a scaled drawing of the bridge deck. The scale must be exactly 1 in. = 10 ft (for use with the scanning software), and the drawing only needs to include the boundaries of the deck surface.

NOTE 1 – In the event that it is not possible to produce a scaled drawing prior to arriving at the bridge deck, a hand-drawn crack map (1 in.= 10 ft) created on engineering paper using measurements taken in the field is acceptable.

(2) The scaled drawing should also include compass and traffic directions in addition to deck stationing. A scaled 5 ft by 5 ft grid is also required to aid in transferring the cracks observed on the bridge deck to the scaled drawing. The grid shall be drawn separately and attached to the underside of the crack map such that the grid can easily be seen through the crack map.

NOTE 2 – Maps created in the field on engineering paper need not include an additional grid.

(3) For curved bridges, the scaled drawing need not be curved, i.e., the curve may be approximated using straight lines.

(4) Coordinate with traffic control so that at least one side (or one lane) of the bridge can be closed during the time that the crack survey is being performed.

b. Preparation of Surface.

(1) After traffic has been closed, station the bridge in the longitudinal direction at ten feet intervals. The stationing shall be done as close to the centerline as possible. For curved bridges, the stationing shall follow the curve.

(2) Prior to beginning the crack survey, mark a 5 ft by 5 ft grid using lumber crayons or chalk on the portion of the bridge closed to traffic corresponding to the grid on the scaled drawing. Measure and document any drains, repaired areas, unusual cracking, or any other items of interest.

(3) Starting with one end of the closed portion of the deck, using a lumber crayon or chalk, begin tracing cracks that can be seen while bending at the waist. After beginning to trace cracks, continue to the end of the crack, even if this includes portions of the crack that were not initially seen while bending at the waist. Cracks not attached to the crack being traced must not be marked unless they can been seen from waist height. Surveyors must return to the location where they started tracing a crack and continue the survey. Areas covered by sand or other debris need not be

surveyed. Trace the cracks using a different color crayon than was used to mark the grid and stationing.

(4) At least one person shall recheck the marked portion of the deck for any additional cracks. The goal is not to mark every crack on the deck, only those cracks that can initially be seen while bending at the waist.

NOTE 3 – An adequate supply of lumber crayons or chalk should be on hand for the survey. Crayon or chalk colors should be selected to be readily visible when used to mark the concrete.

c. Weather Limitations.

(1) Surveys are limited to days when the expected temperature during the survey will not be below 60 °F.

(2) Surveys are further limited to days that are forecasted to be at least mostly sunny for a majority of the day.

(3) Regardless of the weather conditions, the bridge deck must be completely dry before the survey can begin.

3.0 BRIDGE SURVEY.

a. Crack Surveys.

Using the grid as a guide, transfer the cracks from the deck to the scaled drawing. Areas that are not surveyed should be marked on the scaled drawing. Spalls, regions of scaling, and other areas of special interest need not be included on the scale drawings but should be noted.

b. Delamination Survey.

At any time during or after the crack survey, bridge decks shall be checked for delamination. Any areas of delamination shall be noted and drawn on a separate drawing of the bridge. This second drawing need not be to scale.

c. Under Deck Survey.

Following the crack and delamination survey, the underside of the deck shall be examined and any unusual or excessive cracking noted.

APPENDIX B

BRIDGE DECK DATA

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty et al. 2013)

Bridge Number	County and Serial Number	Portion Placed	Date of Placement	Survey # 1			Survey # 2			Survey # 3		
				Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)
LC-HPC-1	105-304	South	10/14/2005	4/13/2006	5.9	0.012	4/30/2007	18.5	0.047	6/17/2008	32.1	0.044
		North	11/2/2005	4/13/2006	5.3	0.003	4/30/2007	17.9	0.006	6/17/2008	31.5	0.024
		Entire Deck	--	4/13/2006	--	0.007	4/30/2007	--	0.027	6/17/2008	--	0.034
LC-HPC-2	105-310	Deck	9/13/2006	4/20/2007	7.2	0.014	6/18/2008	21.2	0.029	5/29/2009	32.5	0.085
Control-1/2	105-311	South	10/10/2005	4/13/2006	6.1	0.000	4/30/2007	18.6	0.151	6/17/2008	32.2	0.114
		North	10/28/2005	4/13/2006	5.5	0.000	4/30/2007	18.0	0.044	6/17/2008	31.6	0.091
		Entire Deck	--	4/13/2006	--	0.000	4/30/2007	--	0.089	6/17/2008	--	0.099
LC-HPC-3	46-338	Deck	11/13/2007	5/29/2008	6.5	0.032	6/18/2009	19.2	0.110	6/28/2010	31.5	0.108
Control-3	46-337	Deck	7/17/2007	5/29/2008	10.4	0.037	6/5/2009	22.6	0.216	6/28/2010	35.4	0.232
LC-HPC-4	46-339	South	9/29/2007	7/15/2008	9.5	0.017	7/9/2009	21.3	0.113	6/24/2010	32.8	0.231
		North	10/2/2007	7/15/2008	9.4	0.004	7/9/2009	21.2	0.079	6/24/2010	32.7	0.094
Control-4	46-347	Deck	11/16/2007	6/10/2008	6.8	0.050	7/7/2009	19.7	0.366	7/5/2010	31.6	0.473
LC-HPC-5	46-340 Unit 1	Deck	11/14/2007	7/15/2008	8.0	0.059	6/26/2009	19.4	0.123	6/17/2010	31.1	0.128
Control-5	46-341 Unit 3	Deck	11/25/2008	7/9/2009	7.4	0.670	6/22/2010	18.9	0.857	6/15/2011	30.6	0.738
LC-HPC-6	46-340 Unit 2	Deck	11/3/2007	5/20/2008	6.5	0.063	6/26/2009	19.7	0.238	6/17/2010	31.4	0.231
Control-6	46-341 Unit 4	Deck	10/20/2008	7/9/2009	8.6	0.142	6/22/2010	20.0	0.282	6/14/2011	31.8	0.456
LC-HPC-7	43-33	Deck	6/24/2006	6/5/2007	11.4	0.003	7/1/2008	24.2	0.019	5/18/2009	34.8	0.012
Control-7	46-334	East	3/29/2006	8/10/2007	16.4	0.293	6/30/2008	27.1	0.476	6/4/2009	38.2	1.003
		West	9/15/2006	8/10/2007	10.8	0.030	6/30/2008	21.5	0.069	6/4/2009	32.6	0.277
LC-HPC-8	54-53	Deck	10/3/2007	6/29/2009	20.9	0.298	5/27/2010	31.8	0.348	7/5/2011	45	0.380
LC-HPC-10	54-60	Deck	5/17/2007	6/29/2009	25.4	0.076	5/22/2010	36.2	0.029	7/5/2011	49.6	0.088
Control-8/10	54-59	Deck	4/16/2007	6/26/2008	14.4	0.177	5/31/2009	25.5	0.127	5/22/2010	37.2	0.137
LC-HPC-9	54-57	Deck	4/15/2009	6/4/2010	13.6	0.130	6/30/2011	26.5	0.237	6/25/2012	38.3	0.362

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty et al. 2013)

Bridge Number	Survey # 4			Survey # 5			Survey # 6		
	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)
LC-HPC-1	6/17/2009	44.1	0.060	6/3/2010	55.6	0.032	9/1/2011	70.6	0.061
	6/17/2009	43.5	0.125	6/3/2010	55.0	0.023	9/1/2011	69.6	0.103
	6/17/2009	--	0.093	6/3/2010	--	0.027	9/1/2011	--	0.082
LC-HPC-2	5/28/2010	44.5	0.059	8/22/2011	59.3	0.144	5/18/2012	68.1	0.204
Control-1/2	6/17/2009	44.2	0.261	6/3/2010	55.8	0.132	9/1/2011	70.7	0.259
	6/17/2009	43.6	0.133	6/3/2010	55.2	0.106	9/1/2011	70.1	0.137
	6/17/2009	--	0.184	6/3/2010	--	0.115	9/1/2011	--	0.190
LC-HPC-3	6/1/2011	42.6	0.315	5/14/2012	54.0	0.173	5/21/2013	66.2	0.174
Control-3	6/7/2011	46.6	0.323	5/14/2012	57.9	0.314	5/21/2013	70.1	0.294
LC-HPC-4	6/30/2011	45.0	0.167	5/30/2012	56.0	0.184	6/13/2013	68.5	0.105
	6/30/2011	44.9	0.080	5/30/2012	55.9	0.092	6/13/2013	68.4	0.140
Control-4	6/7/2011	42.7	0.618	6/12/2012	54.9	0.669	6/20/2013	67.1	0.561
LC-HPC-5	6/14/2011	43.0	0.190	5/23/2012	54.3	0.158	6/13/2013	67.0	0.140
Control-5	-	-	-	-	-	-	-	-	-
LC-HPC-6	6/14/2011	43.3	0.336	5/23/2012	54.6	0.362	6/13/2013	67.3	0.303
Control-6	5/30/2012	43.0	0.539	6/19/2013	56.0	0.461	6/27/2014	68.2	0.646
LC-HPC-7	5/18/2010	46.8	0.005	5/23/2011	58.9	0.048	6/1/2012	71.3	0.065
Control-7	7/1/2010	51.1	1.037	6/7/2011	62.3	0.899	6/12/2012	74.5	0.910
	7/1/2010	45.5	0.359	6/7/2011	56.7	0.822	6/12/2012	68.9	0.900
LC-HPC-8	5/15/2012	55.4	0.383	5/22/2013	67.7	0.373	7/21/2014	81.6	0.425
LC-HPC-10	5/15/2012	60	0.125	5/22/2013	72.2	0.069	7/22/2014	86.2	0.117
Control-8/10	7/5/2011	50.6	0.326	6/4/2012	61.6	0.425	8/1/2013	75.5	0.581
LC-HPC-9	5/24/2013	49.3	0.299	8/6/2014	62	0.454	6/2/2015	73.6	0.43

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty et al. 2013)

Bridge Number	Survey # 7			Survey # 8			Survey # 9		
	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)
LC-HPC-1	5/16/2012	79.0	0.096	5/23/2013	91.3	0.043	5/19/2014	103.1	0.050
	5/16/2012	78.4	0.081	5/23/2013	90.6	0.040	5/19/2014	102.5	0.027
	5/16/2012	--	0.085	5/23/2013	--	0.085	5/19/2014	--	0.038
LC-HPC-2	5/24/2013	80.3	0.151	5/20/2014	92.2	0.116	5/19/2015	104.2	0.222
Control-1/2	5/16/2012	79.2	0.281	5/23/2013	91.4	0.149	5/19/2014	103.3	0.106
	5/16/2012	78.6	0.138	5/23/2013	90.8	0.126	5/19/2014	102.7	0.217
	5/16/2012	--	0.196	5/23/2013	--	0.149	5/19/2014	--	0.151
LC-HPC-3	6/24/2014	79.3	0.660	6/29/2015	91.5	0.487			
Control-3	6/24/2014	83.2	0.366	6/30/2015	96.9	0.391			
LC-HPC-4	6/27/2014	80.4	0.371	7/9/2015	93.3	0.305			
	6/27/2014	80.3	0.173	7/9/2015	93.2	0.181			
Control-4	8/5/2014	80.7	0.667	7/17/2015	92.9	0.755			
LC-HPC-5	6/25/2014	79.4	0.229	7/9/2015	91.8	0.247			
Control-5									
LC-HPC-6	6/25/2014	79.7	0.356	7/9/2015	92.2	0.386			
Control-6	7/14/2015	81.9	0.628						
LC-HPC-7	6/7/2013	83.4	0.078	6/13/2014	95.7	0.087	5/21/2015	106.9	0.036
Control-7	6/12/2014	98.5	1.068						
	6/12/2014	93	1.24						
LC-HPC-8	6/10/2015	92.0	0.462						
LC-HPC-10	6/11/2015	96.8	0.125						
Control-8/10	7/23/2014	87.2	0.566	6/19/2015	98.1	0.680			
LC-HPC-9									

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty et al. 2013)

Bridge Number	Survey # 10		
	Date of Survey	Age (months)	Crack Density (m/m^2)
LC-HPC-1	5/18/2015	115.1	0.037
	5/18/2015	114.5	0.055
	5/18/2015	--	0.045
LC-HPC-2	-	-	-
Control-1/2	5/18/2015	115.6	0.239
	5/18/2015	115.3	0.164
	5/18/2015	--	0.186
LC-HPC-3			
Control-3			
LC-HPC-4			
Control-4			
LC-HPC-5			
Control-5			
LC-HPC-6			
Control-6			
LC-HPC-7			
Control-7			
LC-HPC-8			
LC-HPC-10			
Control-8/10			
LC-HPC-9			

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty 2013)

Bridge Number	County and Serial Number	Portion Placed	Date of Placement	Survey # 1			Survey # 2		
				Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)
Control-9	54-58	West	5/21/2008	5/28/2010	24.2	0.368	6/28/2011	37.2	0.553
		East	5/29/2008	5/28/2010	24.0	0.395	6/28/2011	37	0.577
LC-HPC-11	78-119	Deck	6/9/2007	5/20/2009	23.4	0.059	6/15/2010	36.2	0.241
Control-11	56-155	Deck	3/28/2006	8/13/2007	16.5	0.351	6/30/2008	27.1	0.665
LC-HPC-12	56-57	East	4/4/2008	8/13/2009	16.3	0.271	6/29/2010	26.8	0.256
		West	3/18/2009	8/13/2009	4.9	0.254	6/29/2010	15.4	0.244
Control-12	56-57	East	4/1/2008	8/13/2009	16.4	0.606	6/29/2010	26.9	0.669
		West	4/14/2009	-	-	-	6/29/2010	14.5	0.442
LC-HPC-13	54-66	Deck	4/29/2008	6/24/2009	13.8	0.050	5/24/2010	24.8	0.129
Control-13	54-67	Deck	7/25/2008	6/24/2009	11.0	0.028	5/24/2010	21.9	0.154
LC-HPC-15	46-351	Deck	11/10/2010	6/8/2012	18.9	0.211	6/3/2013	30.8	0.161
LC-HPC-16	46-352	Deck	10/28/2010	6/20/2011	7.7	0.092	6/8/2012	19.4	0.249
LC-HPC-17	46-373	Deck	9/28/2011	6/26/2012	8.9	0.226	6/14/2013	20.5	0.240

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty et al. 2013)

Bridge Number	Survey # 3			Survey # 4			Survey # 5			Survey # 6		
	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)
Control-9	6/25/2012	49.1	0.500	5/24/2013	60.1	0.539	7/24/2014	74.1	0.732	6/1/2015	84.4	0.722
	6/25/2012	48.9	0.627	5/24/2013	59.8	0.603	7/24/2014	73.8	0.755	6/1/2015	84.1	0.845
LC-HPC-11	6/22/2011	48.4	0.370	7/10/2012	61	0.260	6/11/2013	72.1	0.576	7/3/2014	84.8	0.842
Control-11	5/21/2009	37.8	0.599	6/2/2010	50.2	0.636	6/23/2011	62.9	0.923	7/3/2012	75.2	0.849
LC-HPC-12	6/28/2011	38.8	0.315	5/21/2012	49.5	0.466	8/19/2013	64.5	0.478	8/13/2014	76.3	0.789
	6/28/2011	27.4	0.260	5/21/2012	38.1	0.350	8/19/2013	53.1	0.381	8/13/2014	64.9	0.54
Control-12	6/29/2011	38.9	0.812	5/21/2012	49.6	0.838	8/19/2013	64.6	0.838	8/13/2014	76.4	1.141
	6/29/2011	26.5	0.758	5/21/2012	37.2	0.858	8/19/2013	52.2	0.88	8/13/2014	64	1.163
LC-HPC-13	6/1/2011	37.1	0.364	5/29/2012	49	0.342	7/25/2013	62.9	0.576	8/4/2014	75.2	0.471
Control-13	6/6/2011	34.4	0.524	5/29/2012	46.1	0.543	7/25/2013	60	0.807	8/8/2014	72.5	0.711
LC-HPC-15	6/9/2014	43	0.317	6/23/2015	56.2	0.299						
LC-HPC-16	6/3/2013	31.2	0.211	6/11/2014	43.5	0.311	5/27/2015	55.0	0.397			
LC-HPC-17	6/11/2014	32.5	0.274	6/25/2015	45.5							

Table B.1 (Continued) – Crack Densities for Individual Bridge Placements (Lindquist et al. 2008, Pendergrass et al. 2011, Bohaty et al. 2013)

Bridge Number	Survey # 7			Survey # 8		
	Date of Survey	Age (months)	Crack Density (m/m^2)	Date of Survey	Age (months)	Crack Density (m/m^2)
Control-9						
LC-HPC-11						
Control-11	6/6/2013	86.3	0.657	5/27/2014	98	0.7
LC-HPC-12						
Control-12						
LC-HPC-13	6/24/2015	85.9	0.486			
Control-13	6/22/2015	84.1	0.718			
LC-HPC-15						
LC-HPC-16						
LC-HPC-17						

Table B.2 – Average Properties for the Low-Cracking High-Performance Concrete (LC-HPC) Bridge Decks (Lindquist et al. 2008, McLeod et al. 2009, Pendergrass et.al. 2011)

LC-HPC Number	Portion Placed	Date of Placement	Average Air Content	Average Slump		Average Concrete Temperature		Average Unit Weight		Average Compressive Strength†	
				(mm)	(in.)	(°C)	(°F)	(kg/m³)	(lb/ft³)	(MPa)	(psi)
1	South	10/14/2005	7.9	95	3.75	19.8	68	2251	140.5	35.9	5210
	North	11/2/2005	7.8	85	3.25	20.1	68	2238	139.7	34.4	4980
2	Deck	9/13/2006	7.7	75	3.00	19.2	67	--	--	31.7	4600
3	Deck	11/13/2007	8.7	85	3.25	14.3	58	--	--	41.3	5990
4	Deck - South	9/29/2007	8.7	50	2.00	--	--	2202	137.4	--	--
	Deck - North	10/2/2007	8.8	80	3.00	17.5	64	2210	137.9	33.1	4790
5	Deck - 0.420 *w/c*	11/14/2007	8.3	70	2.75	16.7	62	2249	140.4	44.0	6380
	Deck - 0.428 *w/c*	11/14/2007	9.0	60	2.50	16.4	62	2242	140.0	--	--
	Deck - 0.429 *w/c*	11/14/2007	9.1	90	3.50	15.2	59	2230	139.2	--	--
	Deck - 0.451 *w/c*	11/14/2007	8.7	80	3.25	15.7	60	2228	139.1	--	--
	Average Values	11/14/2007	8.7	80	3.00	15.9	61	2236	139.6	--	--
6	Deck	11/3/2007	9.5	95	3.75	15.3	60	--	--	40.3	5840
7	Deck	6/24/2006	8.0	95	3.75	21.9	71	2221	138.6	26.1	3790
8	Deck	10/3/2007	7.9	50	2.00	19.5	67	2264	141.3	32.6	4730
9	Deck	4/15/2009	6.7	90	3.50	17.9	64	2264	141.3	28.9	4190
10	Deck	5/17/2007	7.3	80	3.25	18.6	66	2212	138.1	31.6	4580
11	Deck	6/9/2007	7.8	80	3.00	15.8	60	2278	142.2	32.3	4680
12	Deck - East	4/4/2008	7.4	70	2.75	14.5	58	2259	141.0	31.5	4570
	Deck - West	3/18/2009	7.8	104	4.10	19.0	67	--	--	28.8 (0.45 *w/c*)	4180 (0.45 *w/c*)
										31.6 (0.44 *w/c*)	4580 (0.44 *w/c*)
13	Deck	4/29/2008	8.1	75	3.00	20.4	69	2266	141.5	29.5	4280
OP	Deck - Center	12/19/2007	8.7	95	3.75	18.1	65	2237	139.7	30.6	4440
	Deck - West	5/2/2008	9.8	110	4.25	17.9	64	2213	138.1	25.6	3710
	Deck - East	5/21/2008	9.9	130	5.25	18.3	65	2195	137.1	26.4	3830
15	Deck	11/10/2010	9.0	84	3.30	17.2	63	2201	137.4	30.6	4440
16	Deck	10/28/2010	6.4	97	3.80	15.0	59	2260.61954	141.1	34.8	5043
17	Deck	9/28/2011	7.5	64	2.50	22.2	72	2245	140.1	34.5	5007

†Average 28-day compressive strength for lab-cured specimens. Strengths were taken at 27 days for the first LC-HPC-1 placement and LC-HPC-11, and 31 days for LC-HPC-7

Table B.3 – Average Properties for Control Bridge Decks (Lindquist et al. 2008, McLeod et al. 2009, Pendergrass et.al. 2011)

Control Number	Portion Placed	Date of Placement	Average Air Content	Average Slump		Average Concrete Temperature		Average Unit Weight		Average Compressive Strength†	
				(mm)	(in.)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(MPa)	(psi)
1/2	Subdeck - North	9/30/2005	5.3	110	4.25	19.0	66	2318	144.7	39.1	5670
	Overlay - North	10/10/2005	5.5	125	5.00	18.0	64	2281	142.4	40.1	5810
	Subdeck - South	10/18/2005	6.5	80	3.25	24.7	76	2274	142.4	35.1	5090
	Overlay - South	10/28/2005	7.0	115	4.50	20.0	68	2254	140.7	55.6 (31 days)	8060 (31 days)
3	Subdeck	7/6/2007	5.8	170	6.75	27.1	81	2251	140.5	39.2	5690
	Overlay	7/17/2007	7.3	185	7.25	29.9	86	2249	140.4	57.6	8350
4	Subdeck	10/20/2007	7.3	195	7.75	22.8	73	2240	139.9	43.7	6340
	Overlay	11/16/2007	6.9	145	5.75	20.0	68	2239	140.0	53.0	7700
5	Subdeck - Seq. 1 & 2	11/8/2008	5.6	200	7.75	19.0	66	2278	142.2	--	--
	Subdeck - Seq. 3, 5, & 6	11/13/2008	6.8	230	9.25	20.0	68	2245	140.1	--	--
	Subdeck - Seq. 4 & 7	11/17/2008	5.5	205	8.00	17.0	63	2275	142.0	--	--
	Overlay - West	11/22/2008	7.6	150	6.00	18.0	64	2250	140.5	--	--
	Overlay - East	11/25/2008	6.6	230	9.00	17.0	63	2262	141.2	--	--
6	Subdeck - Seq. 1 & 2	9/16/2008	7.4	205	8.00	24.0	75	2238	139.7	34.1	4950
	Subdeck - Seq. 3	9/18/2008	7.3	180	7.00	21.0	70	2246	140.2	--	--
	Subdeck - Seq. 5, & 6	9/23/2008	6.4	175	6.75	31.0	88	2261	141.1	--	--
	Subdeck - Seq. 4	9/26/2008	6.6	160	6.25	30.0	86	2254	140.7	--	--
	Subdeck - Seq. 7	9/30/2008	5.5	225	8.75	26.0	79	2269	141.6	--	--
	Overlay - West	10/16/2008	7.7	175	7.00	22.0	72	2258	141.0	--	--
	Overlay - East	10/20/2008	8.1	210	8.25	22.0	72	2231	139.3	53.1	7700

†Average 28-day compressive strength for lab-cured specimens. Strengths were taken at 31 days for the second overlay placement for Control-1/2

Table B.3 (Continued) – Average Properties for Control Bridge Decks (Lindquist et al. 2008, McLeod et al. 2009, Pendergrass et.al. 2011)

Control Number	Portion Placed	Date of Placement	Average Air Content	Average Slump		Average Concrete Temperature		Average Unit Weight		Average Compressive Strength†	
				(mm)	(in.)	(°C)	(°F)	(kg/m³)	(lb/ft³)	(MPa)	(psi)
7	Subdeck - East	3/15/2006	5.9	235	9.25	26.5	80	2239	139.8	38.2	5540
	Overlay - East	3/29/2006	7.4	190	7.50	23.0	73	2239	139.8	--	--
	Subdeck - West	8/16/2006	7.3	195	7.75	21.3	70	2226	139.0	37.9	5500
	Overlay - West	9/15/2006	6.4	175	7.00	18.0	64	2252	140.6	50.8	7370
8/10	Deck	4/16/2007	7.4	130	5.00	21.2	70	2234	139.4	33.3	4830
9	Overlay - West	5/21/2008	5.6	90	3.50	24.7	77	2282	142.4	44.0	6380
	Overlay - East	5/28/2008	6.2	130	5.00	21.7	71	2262	141.2	42.6	6170
11	Subdeck - North	2/3/2006	6.8	90	3.50	22.0	72	2263	141.3	40.6	5890
	Subdeck - South	2/14/2006	7.0	135	5.25	23.0	73	2252	140.6	37.5	5440
	Overlay	3/28/2006	6.0	80	5.00	15.5	60	2277	142.1	52.7	7640
12	Subdeck - Phase 1	3/11/2008	6.9	110	4.25	21.9	72	2250	140.5	36.4	5270
	Overlay - Phase 1	4/1/2008	6.8	95	3.75	14.8	59	2254	140.7	43.0	6240
	Subdeck - Phase 2	3/13/2009	7.2	120	4.75	22.0	72	--	--	34.3	4980
	Overlay - Phase 2	4/14/2009	7.7	57	2.25	16.7	62	--	--	53.1	7710
13	Subdeck	7/11/2008	5.8	90	3.50	31.7	89	2271	141.7	--	--
	Overlay	7/25/2008	6.3	135	5.25	33.0	91	2269	141.6	57.1	8280
Alt	Deck	6/2/2005	5.9	85	3.00	--	--	2255	140.8	38.0	5510

†Average 28-day compressive strength for lab-cured specimens. Strengths were taken at 31 days for the second overlay placement for Control-1/2