Florida Department of
TRANSPORTATION

Cracking of Reinforced and Prestressed Precast Concrete Deck Panels on Florida-I Beam Bridges: A Crack Disposition Study

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Executive Summary

A new bridge system was designed by the Florida Department of Transportation (FDOT) with precast concrete elements including intermediate bent caps, prestressed girders (45" Florida-I beams), non-prestressed deck panels, and prestressed deck panels. A bridge replacement project on US Highway 90 (SR 10), consisting of four bridges, was chosen to implement the new system. The two eastbound bridges have reinforced (non-prestressed) precast deck panels, whereas the two westbound bridges have prestressed precast deck panels. This research project commenced in 2013 and was funded by a Federal Highway Administration (FHWA) Innovative Bridge Research and Deployment (IBRD) grant administered by FDOT, with the goal of documenting construction as well as performance of the bridge for the first two years in service.

The objectives of that research were to evaluate the use of the new precast components, to verify that FDOT's developmental specifications will ensure quality control for future projects, and to help improve the specifications for future use. To achieve these goals, information on the bridges was collected both during and after construction, including data from crack monitoring the precast panels, which is the basis this study. Cracks in the panels were measured every three months for two years after the bridges were placed in service, and crack maps are included in the final research project report.

This study further investigates deck cracking on the four US 90 Bridges, applying the crack disposition methodology from the 2018 FDOT Standard Specifications for Road and Bridge Construction. Practically all the cracks observed in the panels were transverse to the panels, or longitudinal to the bridge, and all bridge deck panels exhibited crack growth during the observed time in service. Overall, the prestressed precast panels performed better than the non-prestressed precast concrete panels by having fewer cracks. Almost all the panels performed well with less than 3% of the cracks needing investigation or treatment.

Introduction

The focus of this study was on cracking of precast concrete decks on a new bridge system designed by the Florida Department of Transportation (FDOT). The new bridge system employs full-width and full-depth precast deck panels that connected with reinforcement to precast prestressed concrete Florida-I beams. Four bridges were studied in this project, two of which provide access over Hurricane Creek and two which provide access over Little River. The eastbound bridges have reinforced precast concrete deck panels while the westbound bridges have prestressed precast concrete deck panels. Figures 1 and 2 present the layout of the span and panels, while Figures 3 and 4 present the plan views from the design drawings. Each of the Hurricane Creek bridges is simply supported and has a single span with a total of 13 deck panels. The bridges over Little River are also simply supported and have four spans each. Span 1 has 12 panels while the other three spans have 13 deck panels each. The names of the four bridges are: Hurricane Creek Eastbound, HCEB (NON-PRESTRESSED); Hurricane Creek Westbound, HCWB (PRESTRESSED); Little River Eastbound, LREB (NON-PRESTRESSED); and Little River Westbound, LRWB (PRESTRESSED). Further details of the bridge including geometric, reinforcing, connection, and construction details are provided in Roddenberry et al. (2019).

Cracks generally form in concrete whenever stresses are greater than the concrete tensile strength. Engineers categorize cracks based on orientation or load dependence. The decision to repair cracks and the choice of repair type depend on a few factors such as the size of the cracks, location of the cracks, and cause of the cracks. The FDOT Standard Specifications for Road and Bridge Construction provide a method for classifying cracks in concrete as isolated, occasional, moderate, or severe. Based on the classification and crack size, a repair strategy is recommended.

Cracks in the bridge deck panels were measured every three months for two years after being placed in service. Construction of the eastbound bridges was completed in February 2015, and the bridges were opened to traffic in March 2015. The westbound bridges were completed in November 2015 and opened to traffic in February 2016. The first crack mapping was performed in June 2016, and the eighth and final mapping was performed in April 2018. Crack maps were developed by manually sketching the cracks on a letter-sized sheet of paper and indicating crack widths and crack lengths. Recorded cracks were those which could be seen visually with the assistance of water spray. Widths were measured using a crack comparator. All crack maps used for this study are available in report 4 of Roddenberry et al. (2019).

Almost 1500 cracks were identified on the bridge decks in 2016. Using FDOT crack disposition analyses, most cracks were determined to need no treatment, ten cracks needed epoxy injection or methacrylate, and 22 needed additional investigation. Crack disposition has proven to be an effective way of evaluating cracks in concrete bridge decks by helping engineers determine analytically whether a crack needs treatment or not. This report contains a detailed exposition of the methodology, the analysis involved, and the results obtained from the analysis.

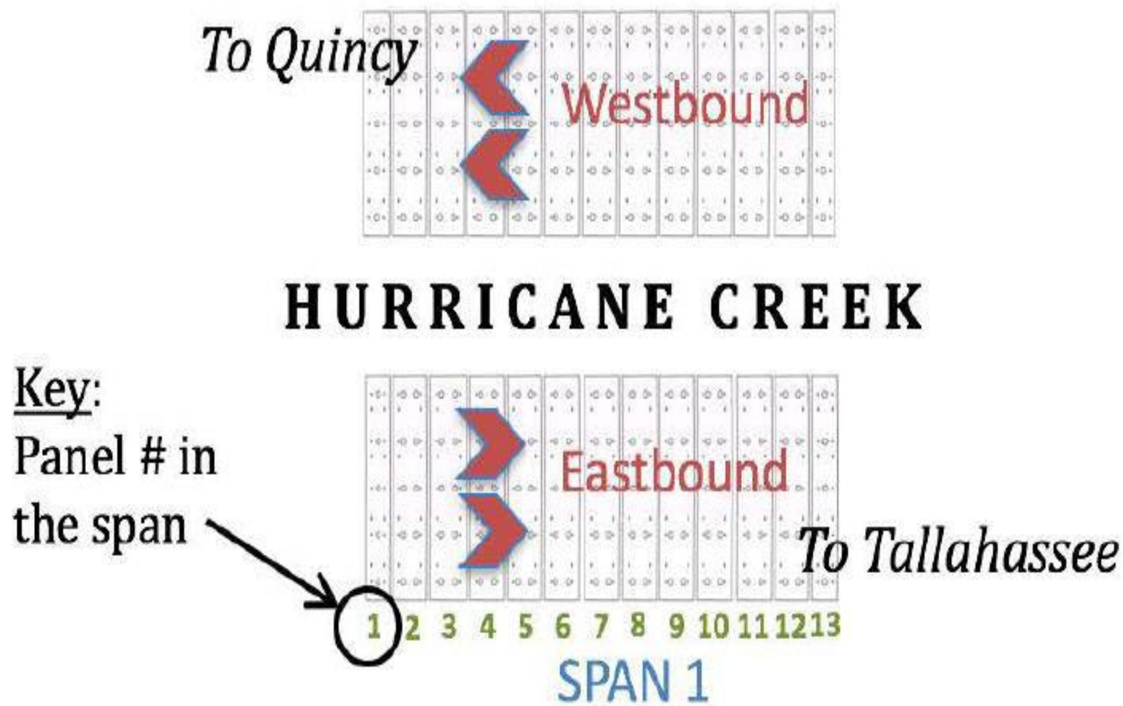


Figure 1: Layout of the span and panels of the bridges over Hurricane Creek (Roddenberry, et al., 2019)

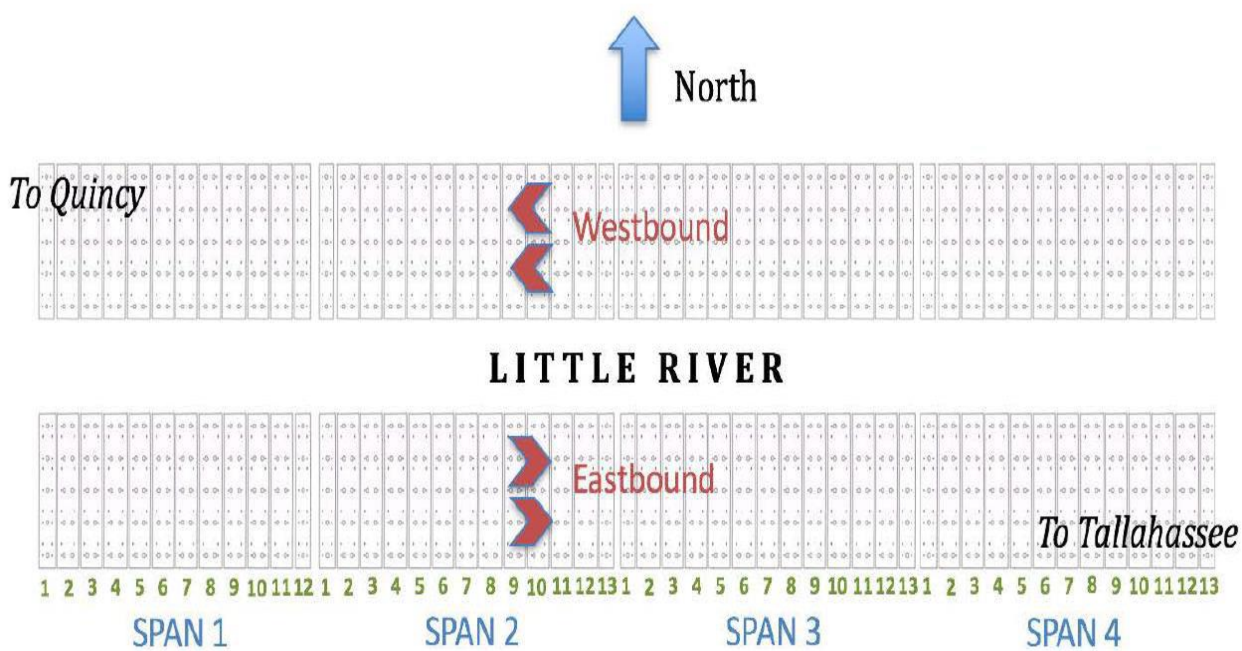


Figure 2: Layout of the span and panels of the bridges over Little River (Roddenberry, et al., 2019)

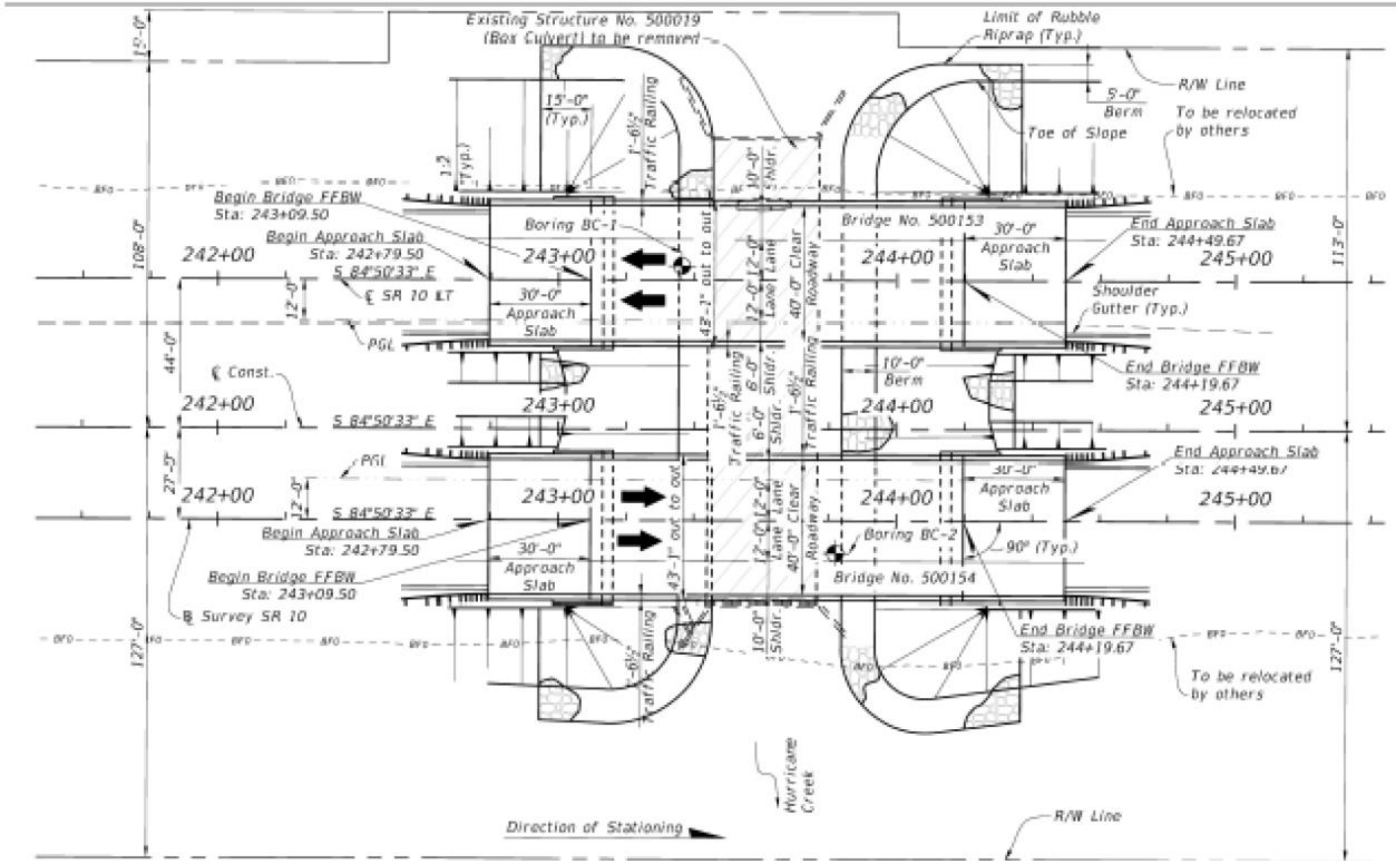


Figure 3: Plan view of the bridges over Hurricane Creek

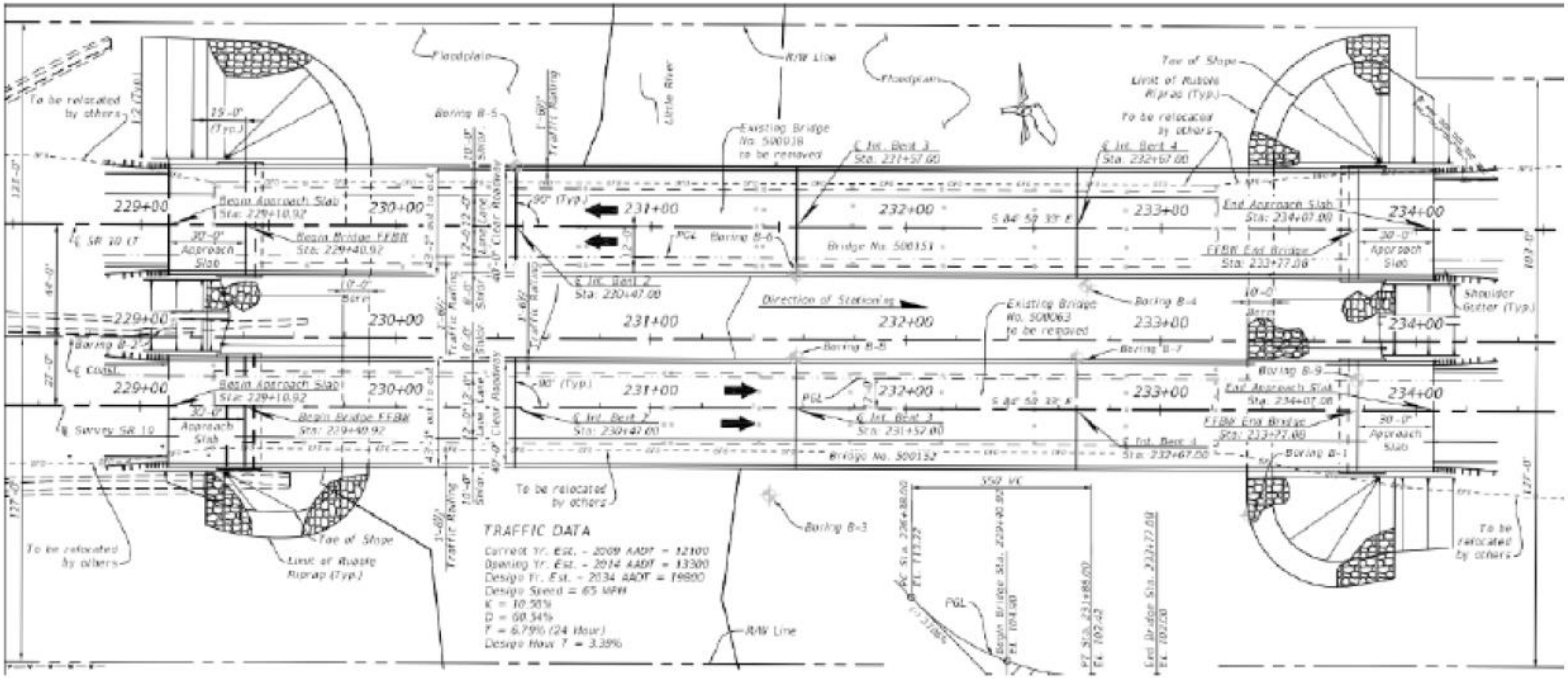


Figure 4: Plan view of the bridges over Little River

Literature Review

In this section, available literature on concepts such as effects of cracks, types of cracks, cracking in reinforced concrete bridge decks, control of crack width, allowable crack width and spacing, and crack repairs is summarized. According to Schmitt and Darwin (1995), cracks can occur early in the life of a bridge, even before it is opened to traffic. At the early age of concrete, its strength is increasing but can be low, and shrinkage stresses can cause cracking in the concrete because of the low strength.

Much of the stresses inducing the formation of cracks in concrete can be traced to a change in volume or damaging chemical interactions or reactions going on within the concrete. The Transportation Research Board (TRB) Basic Research and Emerging Technologies Related to Concrete Committee (2006) notes that volume instability results in response to moisture, chemical, and thermal effects. Cracks can be indicative of the use of improper construction materials, higher structural stiffness, drying environmental conditions, poor construction practices, or, as most often reported, a combination of several such factors (Balakumaran et al., 2018).

Effects of Cracks

Balakumaran et al. (2018) notes that cracking affects concrete in several ways and the effects of cracking can range from an aesthetically unpleasing appearance, which may provoke adverse criticism, to costly maintenance issues. Krauss and Rogalla (1996) explain that cracking reduces the time for corrosion to be initiated in a reinforced concrete structure and that substructures can be damaged when cracks open, providing channels for salt-containing water or ice to flow through. Similarly, Patnaik and Baah (2015) state that harmful, corrosive chemicals gain access to the reinforcing steel buried within the concrete through the cracks and deteriorate them, and therefore, cracks, especially when visible, foster localized corrosion at the cracked areas in the concrete structure.

TRB (2006) agree with Patnaik and Baah (2015) that further longitudinal surface cracking, delamination, spalling, reduction of the cross-sectional area of the reinforcement and de-bonding happen, ultimately resulting in a loss of the strength capacity and structure's stiffness. Patnaik and Baah further note that the moment and shear capacity of concrete structures can be affected by that kind of damage. They also reported that cracking may also affect the bending stiffness of reinforced concrete members thus leading to deflection that may exceed allowable limits or be uncomfortable.

Types of Cracks

Classification of cracking varies from one author to the other. One method, shown in Figure 5, classifies cracks based on orientation and load dependence.

The orientation of cracks on a bridge will vary depending on the type of stress responsible for their formation. Patnaik and Baah (2015) point out that tensile stresses due to bending are known to mostly produce cracks that propagate from the edge of the beam or slab parallel to the supports and perpendicular to the face of the beam or slab. They explain that based on orientation, bridge deck cracks can be classified as follows: Longitudinal, Transverse, Diagonal, Pattern or Map.

Curtis and White (2007) explain that longitudinal cracks are known to form on top of the longitudinal reinforcement of the bridge deck and run parallel to the direction of traffic. They discovered that as the beams rotate about their own axes, there are differential movements along the beams which are believed to be responsible for the longitudinal cracking. Earlier, Schmitt and Darwin (1995) found that longitudinal cracks can develop by differential soil settlement or restraints to transverse concrete shrinkage, and longitudinal cracking occurs primarily in solid and hollow-slab bridges. They explained that cracks usually form above the top longitudinal steel in solid-slab bridges and above void tubes in hollow-slab bridges. Shrinkage of the concrete and the buoyancy of the void tubes also contribute.

Vargas (2012) explains that transverse cracks develop in concrete bridge decks when the tensile strength of the concrete is less than the longitudinal tensile stresses in the deck and that these tensile stresses are produced by changes in temperature, concrete shrinkage, and from bending resulting from self-weight and traffic loads. He further explains that most transverse bridge deck cracks are caused by the combination of shrinkage and thermal stresses and that transverse cracks are known to develop rapidly with compressive strengths higher than 6000 psi. Krauss and Rogalla (1996) and Frosch et al. (2003) find these cracks are usually full-depth cracks, aligned above the transverse reinforcing (Figure 6), that the surface crack widths typically range from 0.002 in. (0.05 mm) to 0.025 in. (0.65 mm), and the cracks are spaced usually 3 to 10 ft (1 to 3 m) apart.

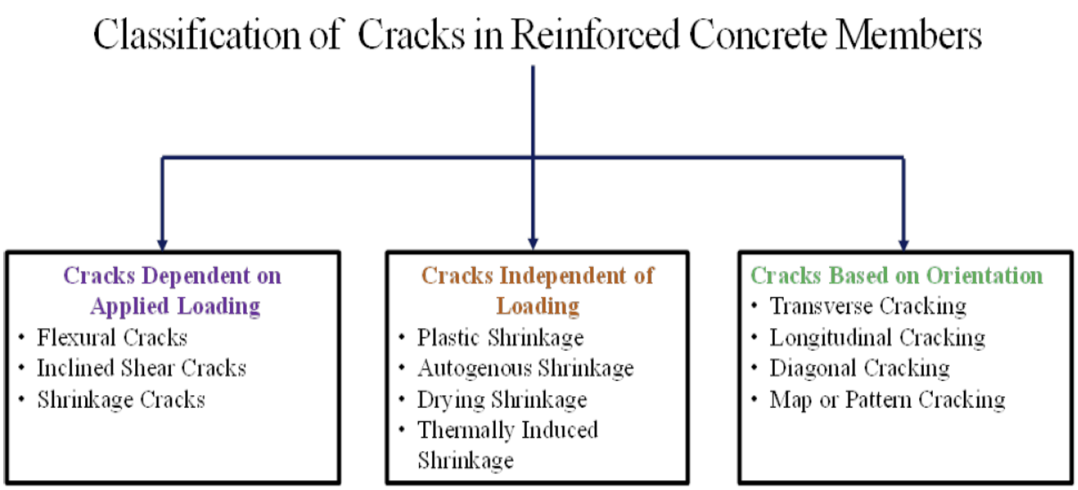
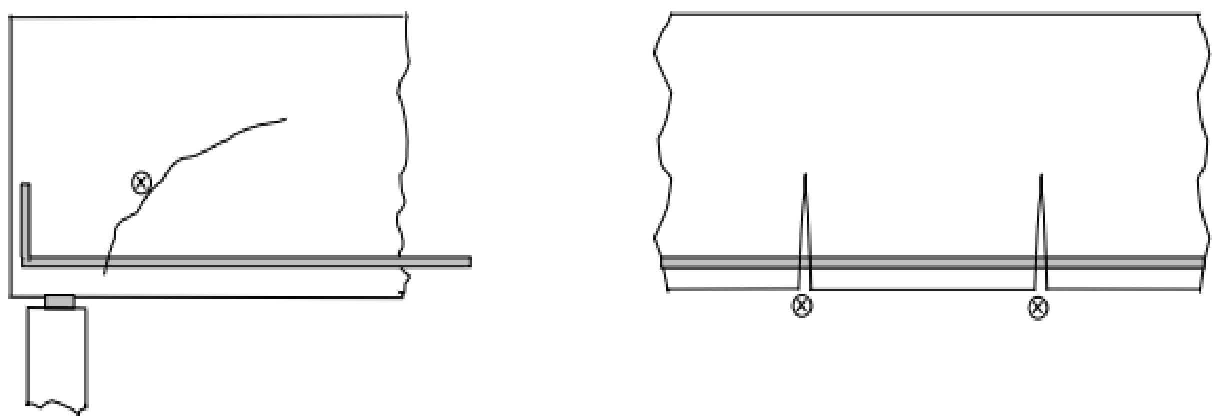


Figure 5: Classification of cracks (Patnaik & Baah, 2015)

Figure 6: Transverse cracking (Frosch et al., 2003)

Diagonal, pattern, or map cracks have orientations and layouts which are not as regular as longitudinal and transverse cracks. As the name suggests, diagonal cracks are at an angle to the direction of traffic. The likely explanation for this type of cracking, as Schmitt and Darwin (1995) pointed out, is the resistance of the structure to deformation, caused by either external loads or concrete shrinkage. It has been suggested that pattern or map cracks have little effect on the durability of bridge decks in the long term. These types of cracks have a random orientation and are believed to be indicative of restraints in the concrete's inner layers showing on the surface.

Patnaik and Baah (2015) state that there are two main types of cracks caused by externally applied loads, namely: flexural cracks and inclined shear cracks (Figure 7). They further state that when the tensile strength of concrete is less than the stress in the tension face of the concrete, flexural cracks begin to occur. Flexural cracks develop in members that are subjected to bending moments, such as beams and slabs. Shear cracks begin to occur when the applied shear stress exceeds the resisting shear capacity of concrete.



a) inclined shear cracks *b) flexural cracks*

Figure 7: Cracks dependent on loading (Piyasena, 2003)

Shrinkage and temperature changes are the main causes of cracks formed independent of applied loading. The age of concrete plays a significant role in the type of cracks formed. "Cracks that develop in concrete before hardening are primarily due to settlement, construction movements, and excessive evaporation of water, and they are called plastic cracks" (TRB, 2006). The common types of cracking in plastic concrete are plastic shrinkage cracking and subsidence cracking. TRB further explained that thermal cracking and drying shrinkage cracking are believed to be the main types of cracking in hardened concrete. One of the factors that affect the rate and magnitude of drying shrinkage in concrete is the size of the specimen (Krauss & Rogalla, 1996). As seen in Figure 8, the specimen size drastically affects the rate and magnitude of the drying shrinkage in the first 100 days. Restrained drying shrinkage is another cause of cracking (Figure 9).

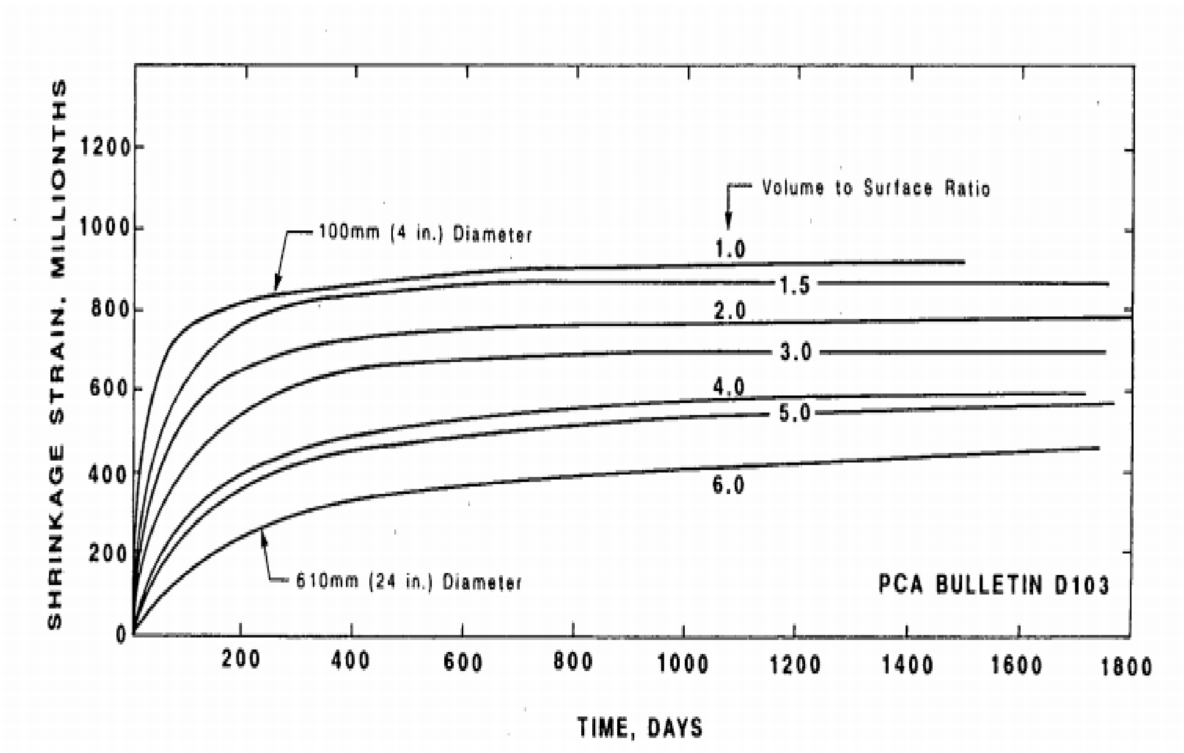


Figure 8: Shrinkage vs. surface-to-volume ratio (Krauss and Rogalla, 1996)

By paying close attention to the mixture design, material placement, and curing, a significant amount of cracking can be eliminated in fresh or plastic concrete. Wan et al. (2010) noted that applying curing compounds as quickly as possible, covering the concrete, and erecting wind breakers and sunshades help prevent excessive evaporation and inhibit plastic shrinkage cracking.

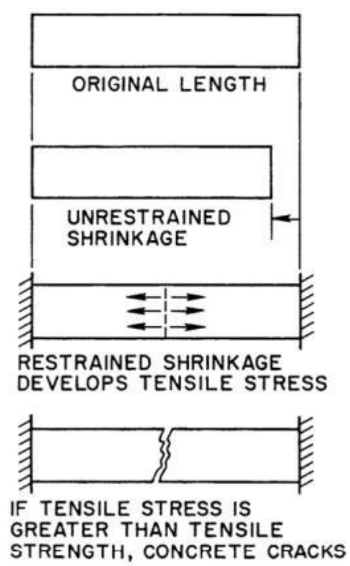


Figure 9: Cracking of concrete due to drying shrinkage (ACI, 2001)

Control of Crack Width

Low strength and low extensibility make cracking in concrete inevitable. “Reinforced concrete structures having low steel stresses under service loads undergo very limited cracking, except for the cracks that occur due to shrinkage of concrete and temperature changes” (Piyasena, 2003). Limited cracking may be achieved in slab systems, provided they are designed to achieve low steel stresses at service load (Patnaik & Baah, 2015). Vargas (2012) recommends the use of a compressive strength of 5000-6000 psi because transverse cracks are known to develop rapidly at higher compressive strengths.

Gergely and Lutz analyzed flexural crack widths on the bottom face of members and at the level of reinforcement. They found that the most important factor is the steel stress. With increase in the strain gradient, the widths of the bottom cracks were found to increase. The nearness of the compression zone reduces the width of the crack in the side for flexural members. They also found that the bar diameter is not an important factor as far as the crack width of flexural members is concerned. The major factors are the effective area of concrete, the number of bars, the cover to the side or bottom, and the steel stress (ACI , 2001).

As stated by Krauss and Rogalla (1996):

> Typical acceptable crack widths for structures subject to deicing chemicals range from near 0 to 0.2 mm (0.008 in.). Denmark, Japan, and Switzerland codes typically specify a maximum crack width of 0.2 mm (0.008 in.) on conventionally reinforced decks. Only two U.S. transportation agencies limit crack widths; one limits crack width to 0.18 mm (0.007 in.), and the other specifies less than 15.2 m (50 ft) of cracks wider than 0.5 mm (0.020 in.) per 46.5 m^2 (500 ft^2) of deck surface area.

A guide to reasonable crack width is presented in Figure 10. While Gergely and Lutz’s equations are concerned with calculating crack width, which depends on area, steel stress, and cover, ACI gives allowable crack width based on exposure condition. The equations considered to best predict the probable maximum bottom crack width and side crack are equations 1 and 2, respectively.

$$w_b = 0.091\sqrt[3]{t_b A\beta(f_s - 5) \times 10^{-3}} \tag{1}$$

$$w_s = \frac{0.091\sqrt[3]{t_b A}}{1 + {t_s}/{h_1}}(f_s - 5) \times 10^{-3} \tag{2}$$

Where:

w_b = most probable maximum crack width at the bottom of beam (in.)

w_s = most probable maximum crack width at the level of reinforcement (in.)

t_b = bottom cover to center of bar (in.)

t_s = side cover to center of bar (in.)

β = ratio of the distance between the neutral axis and tension face to the distance between the neutral axis and the reinforcing steel (about 1.20 in beams)

f_s = reinforcing steel stress (ksi)

A = area of concrete symmetric with reinforcing steel divided by number of bars (in.^{2})

h_1 = distance from neutral axis to the reinforcing steel (in.)

Because there is a need to calculate crack widths, a lot of research has been done to develop analytical methods. These methods have helped engineers evaluate the parameters that affect and more importantly control crack widths (Frosch et al., 2003). Equation 3 bases crack width on the steel stress level, effective area around a bar and cover (Frosh et al., 2003).

$$w_b = 0.115\beta f_s \sqrt[4]{A} \quad (3)$$

Where:

w_b = maximum bottom crack width (0.001 in.)

β = ratio of distances to neutral axis from extreme tension fiber and from centroid of reinforcement

f_s = steel stress calculated by elastic crack section theory (ksi)

A = average effective concrete area around reinforcing bar, having same centroid as reinforcement (in.^{2})

It is important to note that the crack width equations described above are for flexural behavior and cracking on the tension face of the member. Cracking in bridge decks is essentially caused by a different mechanism.

Exposure condition	Crack width	
	in.	mm
Dry air or protective membrane	0.016	0.41
Humidity, moist air, soil	0.012	0.30
Deicing chemicals	0.007	0.18
Seawater and seawater spray, wetting and drying	0.006	0.15
Water-retaining structures†	0.004	0.10

* It should be expected that a portion of the cracks in the structure will exceed these values. With time, a significant portion can exceed these values. These are general guidelines for design to be used in conjunction with sound engineering judgement.
†Exclusing nonpressure pipes.

Figure 10: Guide to reasonable crack widths, reinforced concrete under service loads (ACI, 2001)

Crack Repairs

Before a repair method can be decided upon, it is essential that the condition of the structure be determined, as well as the causes of deterioration using inspection and investigation techniques. Adequate testing, towards accurately determining the condition of concrete immediately adjacent to the spot where repair is needed, is very important not just in providing an extended life to the repair but also in quantifying the contract for realistic cost estimates (Pearson & Patel, 2002).

Pearson and Patel (2002) also argued that the common factors which govern the selection of repair materials, their application, and the way the area should be repaired include:

- The function the repair was meant to perform. For example, resistance to chemicals, cosmetic repair, strength, avoidance of corrosion, and so on.
- The part where the repair is located, e.g. "if the repair material is to be applied to a soffit or vertical face it must be a modified cementitious mortar with superior adhesion and can be built up in thick layers without falling off".
- The time of repair, e.g. repairs during the winter will require hardening at low temperature, or special protection and curing techniques might be required.

The Virginia Department of Transportation (VDOT) (2009) specifies that cracks on bridge decks that are 0.0079 in. (0.2 mm) or narrower in width typically do not need to be filled even when at a drying age of 6 months. Cracks narrower than 0.004 in. (0.1 mm) in width at a drying age of 1 month also do not need to be filled. American Concrete Institute (1998) explains that epoxy injection might be a good treatment to bond cracks that are as small as 0.002 in. (0.05 mm) in width. Vargas (2012), however, reported that epoxy injection worked the best for cracks equal to or larger than 0.02 in. and that High Molecular Weight Methacrylate (HMWM) performed best for cracks less than 0.02 in. in width. Methacrylate is a monocarboxylic acid anion that is obtained by removal of a proton from the carboxylic acid group of methacrylic acid. It has low viscosity and volatility which allow it to easily penetrate and fill deep cracks in concrete.

Epoxy injection can be done by locating the entry ports as well as the venting ports along the cracks and sealing all the exposed surfaces or injecting the epoxy with some pressure. This method is not recommended for structural cracks and before they are employed, the cause of the cracking must first be ascertained, otherwise the cracks will occur again.

According to Lasa (2019), Florida DOT had no guidance on how to approach the treatment of different cases of cracks in concrete structures, before about 12 years ago. There was a need for a standardized methodology for every project. As a result, the Florida Department of Transportation (FDOT) assembled a task force team of people from several departments, namely: maintenance, construction, structures design, and materials. The task force reached a consensus to classify cracks according to the environment in which they are located, and that the severity of the cracks should be considered. The result of their work is shown in Figure 11, which provides recommended treatment, repair, or rejection of a concrete bridge deck based on the crack width, environment category, and cracking significance. The abbreviations in Figure 11 are described as follows:

- SA - Slightly Aggressive
- MA - Moderately Aggressive
- EA - Extremely Aggressive
- NT - No Treatment
- EI - Epoxy Injection
- M - Methacrylate.

Table 2 DISPOSITION OF CRACKED CONCRETE BRIDGE DECKS [see separate Key of Abbreviations and Footnotes for Tables 1 and 2]													
Elev. Range	Crack Width Range (inch) (2)	Cracking Significance Range per LOT (1)											
		Isolated less than 0.005%			Occasional 0.005% to<0.017%			Moderate 0.017% to<0.029%			Severe 0.029% or gtr.		
		Environment Category											
	x = crack width	SA	MA	EA	SA	MA	EA	SA	MA	EA	SA	MA	EA
Elevation: 12 feet or Less AMHW	x ≤ 0.004	NT	NT	NT	NT	NT	NT	NT	NT	NT			
	0.004< x ≤ 0.008	NT	NT	EI/M	NT	NT	EI/M	EI/M	EI/M	EI/M			
	0.008< x ≤ 0.012	NT	NT	EI/M	NT	EI/M	EI/M	EI/M	EI/M				
	0.012< x ≤ 0.016	NT	NT	EI/M	NT	EI/M							
	0.016< x ≤ 0.020	EI/M	EI/M	EI	EI								
	0.020< x ≤ 0.024	EI/M	EI	EI				Investigate to Determine Appropriate Repair (4, 5) or Rejection				Reject and Replace	
	0.024< x ≤ 0.028	EI/M	EI										
	x > 0.028												
Elevation: Over Land or More Than 12 feet AMHW	Crack Width	SA	MA	EA	SA	MA	EA	SA	MA	EA	SA	MA	EA
	x ≤ 0.004	NT	NT	NT	NT	NT	NT	NT	NT	NT			
	0.004< x ≤ 0.008	NT	NT	NT	NT	NT	EI/M	NT	EI/M	EI/M			
	0.008< x ≤ 0.012	NT	NT	EI/M	NT	NT	EI/M	EI/M	EI/M				
	0.012< x ≤ 0.016	NT	NT	EI/M	NT	EI/M							
	0.016< x ≤ 0.020	NT	EI/M	EI	EI/M			Investigate to Determine Appropriate Repair (4, 5) or Rejection					
	0.020< x ≤ 0.024	NT	EI/M	EI								Reject and Replace	
	0.024< x ≤ 0.028	NT	EI/M										
	x > 0.028												

Figure 11: Crack disposition table (FDOT, 2018)

Crack Disposition Methods

Crack Mapping

The methods employed to achieve the main goals of this study and the analysis of the data are presented in this section. The eastbound bridge over Hurricane Creek has precast reinforced concrete deck panels while westbound has precast prestressed concrete deck panels. This is also true for the bridges over Little River, the eastbound bridge panels are reinforced (non-prestressed) while the westbound bridge panels are prestressed – see Figures 1, 2, 12 and 13.

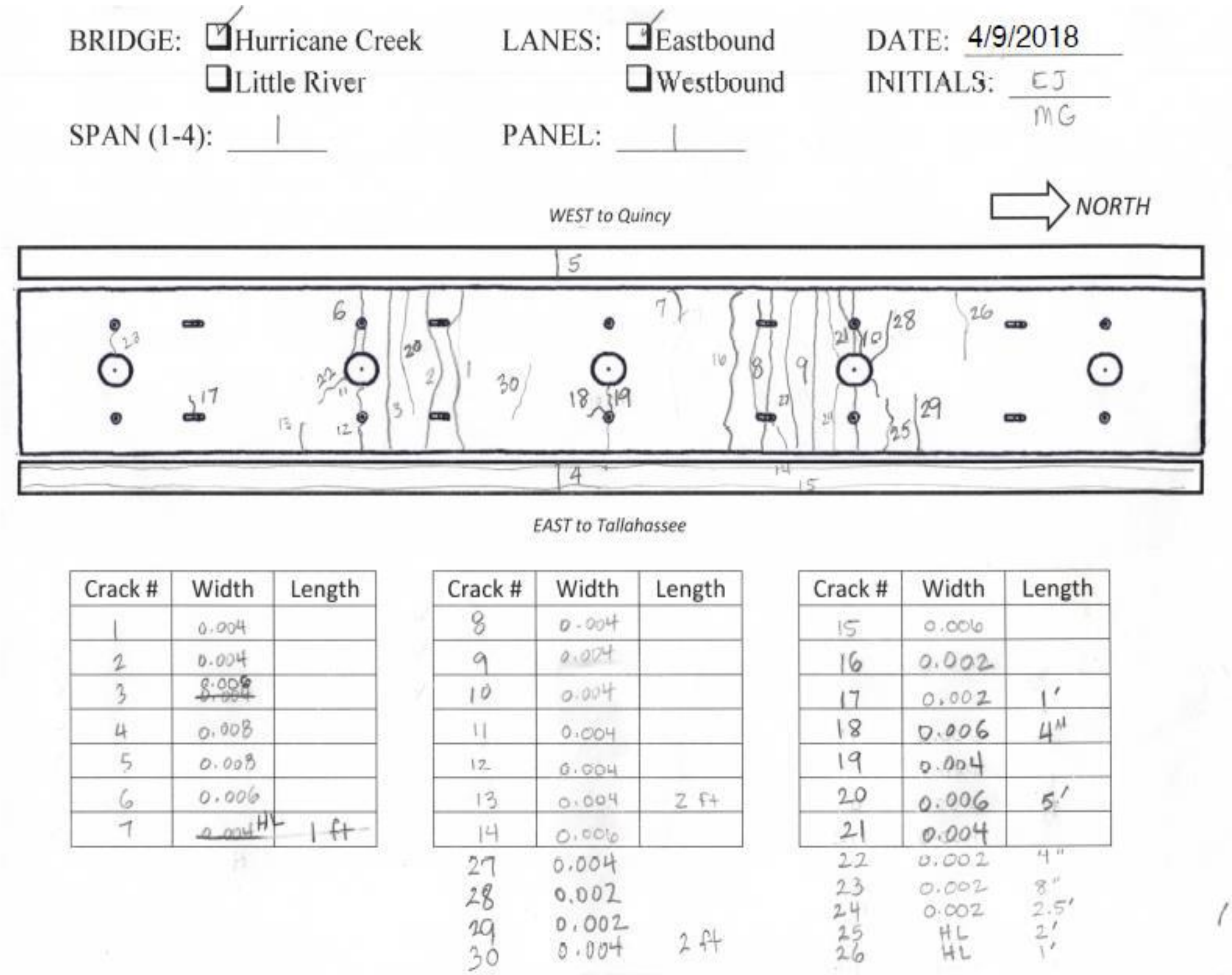
Figure 12: Non-prestressed precast concrete deck panels in casting yard (Roddenberry et al., 2019)

Figure 13: Precast prestressed concrete deck panels for LRWB (Roddenberry et al., 2019)

The panels were set on precast prestressed Florida – I beams (Figure 14). The gaps between the panels, called closure joints, were later filled with cast-in-place concrete.

Figure 14: Precast Florida-I Beams and bridge decks

To evaluate the performance of the non-prestressed precast panels and prestressed precast panels, post-service crack mapping was performed every three months for two years after the bridges were placed in service. For each panel, the cracks were sketched on a letter-sized sheet of paper with a pre-printed diagram of a single panel (see Figure 15). The diagram also included, on each side of the panel, a thin rectangle on which to record any cracks that were noticed in the closure joints. Each crack was numbered, and the number was written next to each measurement. Information about the cracks was documented in a table under the diagram. Lengths of shorter cracks was documented; the lengths of longer cracks were typically not documented if it was clear from the sketch how long the cracks were. For example, many cracks extended the entire panel width, were between the panel's edge and a shear pocket, or were between two shear pockets. Cracks were mostly inspected visually with the crack comparator. The widths were documented (in inches) on the sheet. Very fine cracks were recorded as "HL" meaning hairline. Locations where spalling had occurred were also documented.



BRIDGE: ☑ Hurricane Creek ☐ Little River

LANES: ☑ Eastbound ☐ Westbound

DATE: 4/9/2018

INITIALS: EJ MG

SPAN (1-4): 1

PANEL: 1

WEST to Quincy

NORTH

EAST to Tallahassee

Crack #	Width	Length
1	0.004	
2	0.004	
3	~~0.004~~ 0.006	
4	0.008	
5	0.008	
6	0.006	
7	~~0.004~~ HL	1 ft

Crack #	Width	Length
8	0.004	
9	0.004	
10	0.004	
11	0.004	
12	0.004	
13	0.004	2 ft
14	0.006	
27	0.004	
28	0.002	
29	0.002	
30	0.004	2 ft

Crack #	Width	Length
15	0.006	
16	0.002	
17	0.002	1'
18	0.006	4"
19	0.004	
20	0.006	5'
21	0.004	
22	0.002	4"
23	0.002	8"
24	0.002	2.5'
25	HL	2'
26	HL	1'

Figure 15: A sample of the customized crack mapping sheet

Data Analysis

All the information needed to perform the crack disposition analysis was contained in the crack mapping sheets filled out in the field. The necessary data were the bridge name, traffic direction, span number, panel number, crack number, and width and length of each crack. Spreadsheets were used to do the analysis. The end goal of the analysis was to come up with the cracking significance for each panel or LOT. The FDOT Standard Specifications for Road and Bridge Construction requires that "a LOT will typically be made up of not more than 100 square feet and not less than 25 square feet of concrete surface area for structures other than bridge decks or typically not more than 400 square feet and not less than 100 square feet for bridge decks" (FDOT, 2018). The surface area of each concrete deck panel ranges between 200 and 320 square feet. Each panel qualified to be a LOT since each had a surface area that was greater than 100 square feet and less than 400 square feet.

Cracking significance was calculated based on the total crack surface area as a percentage of the total concrete surface area (FDOT, 2018). The sum of the products of the width and length of each crack on the panel, divided by the total surface area of the panel, gave the cracking significance for that LOT or panel.

Mathematically,

$$\text{Cracking Significance} = \text{TCSA}/\text{TSA}$$

Where:

TCSA = Total Crack Surface Area, TCSA = crack width × crack length

TSA = Total Surface Area

The calculated cracking significance was categorized as Isolated, Occasional, Moderate or Severe according to the criteria in Figure 11. All four bridges are in a Slightly Aggressive (SA) environment and are less than twelve feet above mean high water.

In cases when the lengths of the cracks were not specified in the crack maps, they were estimated from the sketches. Crack mapping is not an exact science. It required some judgement of the average crack width on very rough (milled and grooved) concrete. Weather and outside light conditions could have affected the ability to see cracks, and therefore record them.

Results and Discussion

This section presents the test results and findings that were documented according to the methods and procedures discussed previously. The following paragraphs detail the results and the post-processed data accompanied by discussion of the observations. Calculated per the FDOT Standard Specifications (FDOT, 2018), the cracking significance is presented first. Then, comparisons are made between cracking in the prestressed and non-prestressed concrete bridge deck panels. Also, the initial cracking is compared with the final cracking at two years of service for both panel types.

Cracking Significance and Crack Disposition

In this section, the results of the cracking significance analysis are presented. Cracking was measured every three (3) months over a two-year period to gather enough data to enable study of crack progression. However, for this report, analyses were done for two mappings: one in June 2016, and one in April 2018, 22 months later. Each crack significance analysis performed was for a single panel, for the crack mapping performed on a given date. HCEB bridge has 13 panels, HCWB has 13, LREB has 51 panels and LRWB has 51. This is 128 panels in total, for a total of 256 cracking significance analyses. For each span, conclusions were made about any treatment or repair that was needed. Crack significance values are presented in tables and plots. For the eastbound spans, traffic is in the direction of increasing panel number from Panel 1 to Panel 12 or 13. For westbound spans, the traffic direction is opposite, in decreasing order of panel number.

HCEB and HCWB: June 2016 Crack Significance

Table 1 shows the results for the cracking significance analysis performed on HCEB (NON-PRESTRESSED) and HCWB (PRESTRESSED) using the data from the very first crack mapping in June 2016. The results are plotted in Figure 16.

Cracking significance for HCEB (NON-PRESTRESSED) in June 2016, is shown in Table 1 and in Figure 16. Cracking significance ranged from 0.003 to 0.011. Panel 9 had the highest cracking significance, while Panel 13 had the least cracking significance. Out of the 197 cracks identified on HCEB, 193 would require no treatment while four would require further investigation. The four cracks in need of further investigation are on Panel 3 with an average crack width of 0.027 in.

Cracking significance for HCWB (PRESTRESSED) in June 2016 is shown in Table 1 as well as in Figure 16. Cracking significance ranged from 0.000 to 0.014. Panel 7 had the highest cracking significance. Several panels had very low cracking significance, and Panel 11 had approximately zero cracking significance. For HCWB, 157 cracks were identified, 141 of which would not require any treatment. Four of the cracks would require epoxy injection or methacrylate, and 12 would require investigation. All four cracks that would require epoxy injection are on Panel 7 and have an average crack width of 0.01 in. Five of the 12 cracks needing further investigation are on Panel 5, six are on Panel 7 and Panel 8 has one. They collectively have an average crack width of 0.052 in. Overall, the prestressed concrete panels experienced less cracking than the non-prestressed ones except for Panels 7 and 8 where there was more cracking in the prestressed than in the non-prestressed, as seen in Figure 16.

Table 1: Cracking significance of HCEB (NON-PRESTRESSED) and HCWB (PRESTRESSED) in June 2016

PANEL NUMBER	CRACKING SIGNIFICANCE	
	HCEB (NON-PRESTRESSED)	HCWB (PRESTRESSED)
1	0.006	0.001
2	0.007	0.005
3	0.007	0.001
4	0.006	0.001
5	0.005	0.003
6	0.006	0.001
7	0.009	0.014
8	0.006	0.012
9	0.011	0.002
10	0.006	0.002
11	0.006	0.000
12	0.008	0.001
13	0.003	0.002

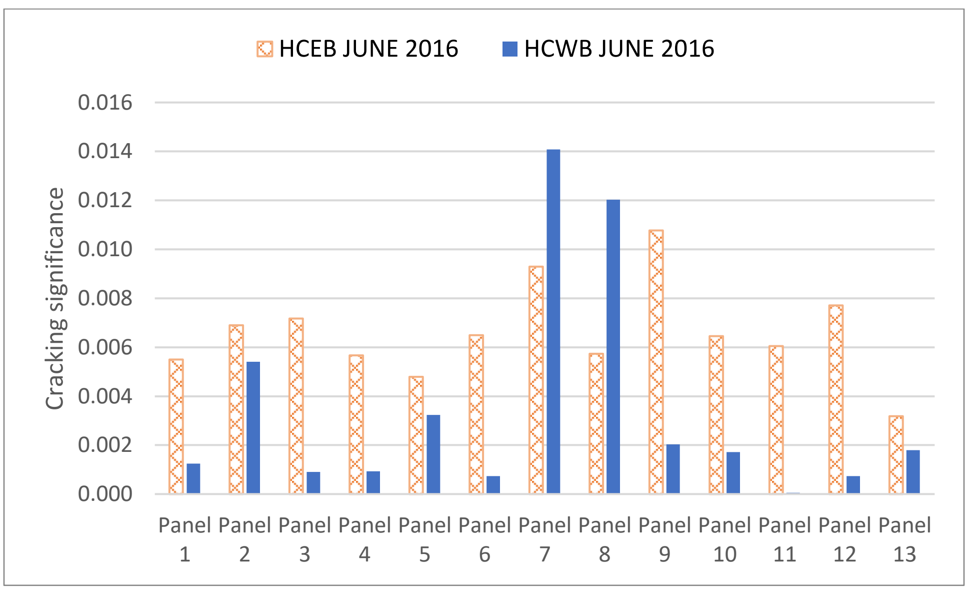


Figure 16: A plot of the cracking significance of HCEB (NON-PRESTRESSED) and HCWB (PRESTRESSED) in June 2016

LREB and LRWB June 2016 Crack Significance

Table 2 shows the results of LREB (NON-PRESTRESSED) in June 2016. The results are also plotted in Figures 17 – 20.

Table 2: Cracking significance of LREB (NON-PRESTRESSED) in June 2016

PANEL NUMBER	CRACKING SIGNIFICANCE			
	SPAN 1	SPAN 2	SPAN 3	SPAN 4
1	0.003	0.015	0.008	0.005
2	0.008	0.009	0.010	0.007
3	0.006	0.002	0.007	0.007
4	0.001	0.003	0.016	0.009
5	0.004	0.004	0.008	0.005
6	0.003	0.005	0.011	0.013
7	0.008	0.003	0.003	0.005
8	0.008	0.003	0.006	0.007
9	0.002	0.007	0.012	0.003
10	0.012	0.008	0.009	0.005
11	0.008	0.006	0.009	0.006
12	0.012	0.005	0.003	0.004
13	N/A	0.011	0.001	0.014

Table 3 shows the results of LRWB (PRESTRESSED) in June 2016. The results are also plotted in Figures 17 – 20.

Table 3: Cracking significance of LRWB (PRESTRESSED) bridge in June 2016

PANEL NUMBER	CRACKING SIGNIFICANCE			
	SPAN 1	SPAN 2	SPAN 3	SPAN 4
1	0.001	0.001	0.000	0.003
2	0.002	0.000	0.000	0.000
3	0.000	0.001	0.000	0.001
4	0.003	0.000	0.000	0.006
5	0.000	0.001	0.001	0.000
6	0.000	0.001	0.000	0.001
7	0.001	0.001	0.000	0.001
8	0.002	0.002	0.001	0.017
9	0.002	0.001	0.001	0.002
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.001	0.000	0.000	0.001
13	N/A	0.000	0.001	0.001

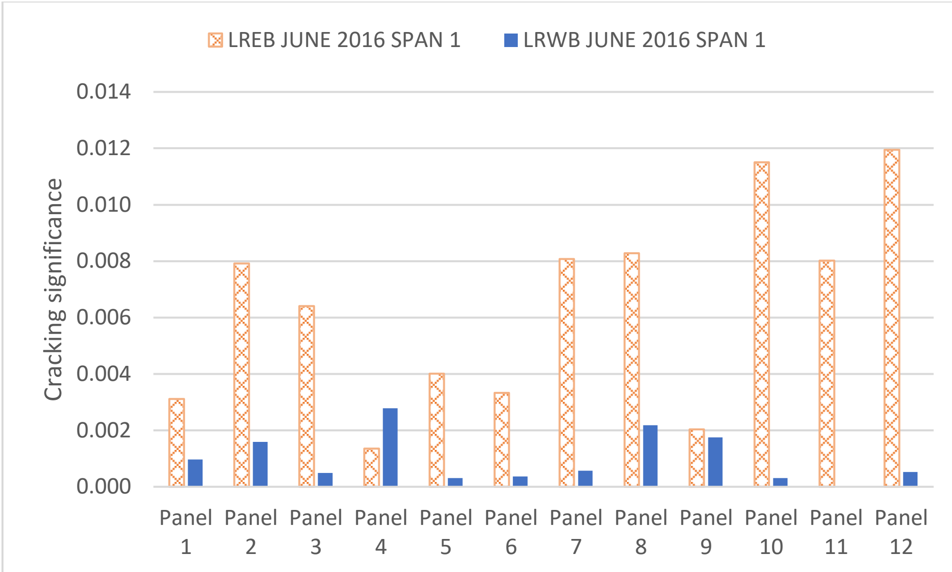


Figure 17: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 1 and LRWB (PRESTRESSED) span 1 in June 2016

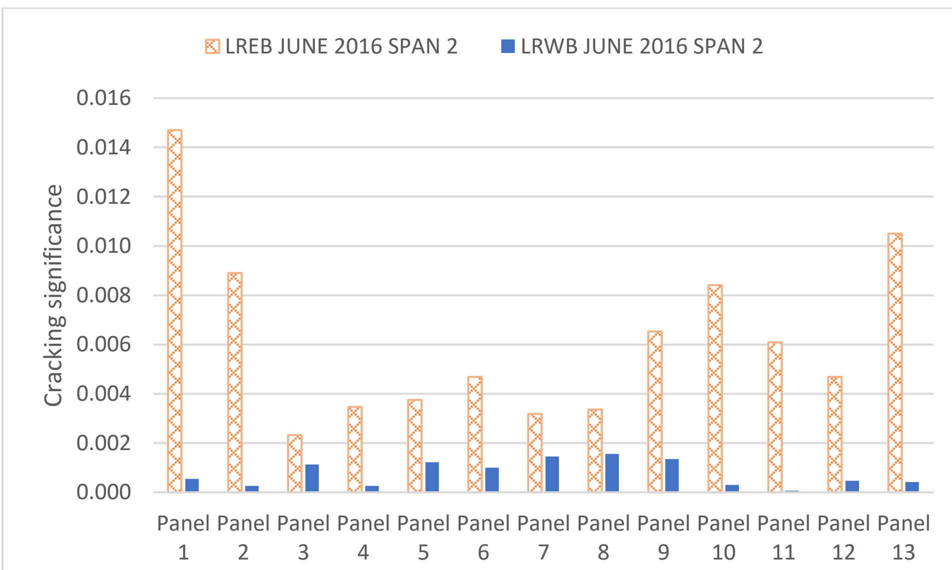


Figure 18: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 2 and LRWB (PRESTRESSED) span in June 2016

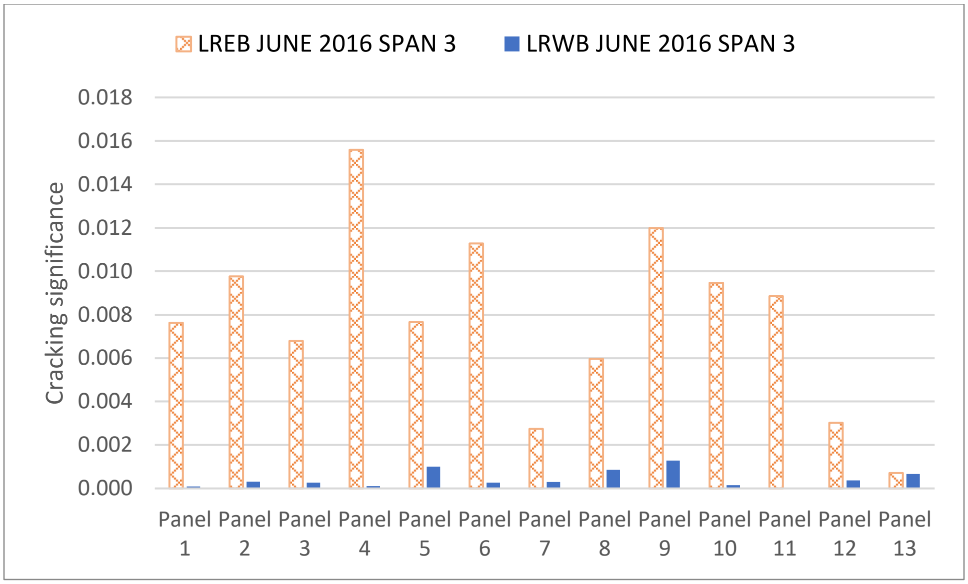


Figure 19: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 3 and LRWB (PRESTRESSED) span 3 in June 2016

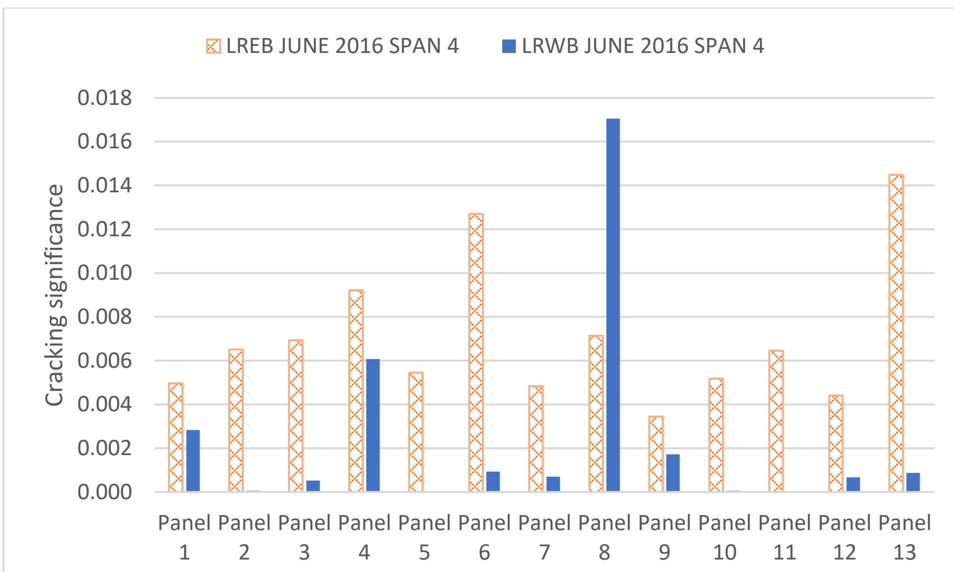


Figure 20: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 4 and LRWB (PRESTRESSED) span 4 in June 2016

For LREB (NON-PRESTRESSED) span 1, as shown in Table 2 and Figure 17, Panels 10 and 12 had roughly equal and the highest cracking significance, 0.012. Panel 4 had the least cracking significance, 0.001. For LREB, 165 cracks were identified, 163 would require no treatment, while one crack in Panel 10 with crack width of 0.03 in. needs to be investigated, and another crack in the same panel with a crack width of 0.02 in. would require epoxy injection or methacrylate.

For LREB (NON-PRESTRESSED) span 2, as shown in Table 2 and Figure 18, Panel 1 had the highest cracking significance, 0.015, followed by Panel 13, 0.013. The panel with the least cracking significance is Panel 3, 0.002. None of the 169 cracks identified require treatment or investigation.

For LREB (NON-PRESTRESSED) span 3, as shown in Table 2 and Figure 19, Panel 4 had the highest cracking significance in this span, 0.016, while Panel 13 had the least, 0.013. Of the 174 cracks identified, only one crack in Panel 10 with a crack width of 0.02 in. would require epoxy injection or methacrylate, and the rest would require no treatment or investigation.

For LREB (NON-PRESTRESSED) span 4, as shown in Table 2, and Figure 20, Panel 13 had the highest cracking significance, 0.014, followed by Panel 6, 0.013. The panel with the least cracking significance is Panel 9. All 185 cracks identified would require no treatment or investigation.

For LRWB (PRESTRESSED) span 1, as shown in Table 3 and Figure 17, Panel 4 has the highest cracking significance, 0.003. Several panels had zero cracks. Of the 111 cracks identified, none would require any form of treatment or investigation.

For LRWB (PRESTRESSED) span 2, as shown in Table 3 and Figure 18, Panel 8 has the highest cracking significance, 0.002. All other panels had a value of 0.001 or zero. Of the 106 cracks identified, only one crack in Panel 7 with a crack width of 0.032 in. needs investigation.

For LRWB (PRESTRESSED) span 3, as shown in Table 3 and Figure 19, all panels had cracking significance less than 0.002, with most panels having zero. Eighty-nine cracks were identified, and only one crack in Panel 5 with a crack width of 0.03 in. needs investigation.

For LRWB (PRESTRESSED) span 4, as shown in Table 3 and Figure 20, Panel 8 had the highest cracking significance, 0.017, followed by Panel 4, 0.006. Panels 2, 5, 10, and 11 have roughly zero cracking significance. Of the 114 cracks identified, four would require epoxy injection or methacrylate, and three require investigation. In Panel 4, two cracks would require epoxy injection or methacrylate each with a crack width 0.02 in., and in Panel 8, two cracks would require epoxy injection or methacrylate having a crack width of 0.02 in. each. In Panel 7, one crack with a crack width of 0.03 needs investigation, and in Panel 8 there are two 0.32 in. spalls which require investigation.

HCEB and HCWB April 2018 Crack Significance

Table 4 shows the results for the crack significance analysis performed on HCEB (NON-PRESTRESSED) and HCWB (PRESTRESSED) using the data from the crack mapping performed in April 2018. The results are plotted in Figure 21.

For HCEB (NON-PRESTRESSED), as shown Table 4 and Figure 21, Panel 6 has the highest cracking significance, 0.022, while Panel 13 has the least, 0.009. For this bridge, a total of 524 cracks were recorded, where six would require epoxy injection, another six need to be investigated, and the remaining would require no treatment or investigation. Five of the cracks needing epoxy injection or methacrylate are in Panel 3, and the other one is in Panel 4. They have an average crack width of 0.012 in. Four of the cracks that require investigation are in Panel 3, one is in Panel 5, and one is in Panel 6. They have an average crack width of 0.026 in.

For HCWB (PRESTRESSED), as shown Table 4 and Figure 21, Panel 7 has the highest cracking significance, 0.018, followed by Panel 8, 0.014. Values for all other panels are 0.003 or less. Of the 336 cracks identified, two would require epoxy injection or methacrylate, while 11 cracks require investigation. The two cracks that would require epoxy injection or methacrylate are on Panel 7 with an average crack width of 0.01 in. Panels 5 and 7 each have five of the cracks that need investigation, while Panel 8 has one. They have an average width of 0.054 in.

Table 4: Cracking significance of HCEB (NON-PRESTRESSED) and HCWB (PRESTRESSED) in April 2018

PANEL NUMBER	CRACKING SIGNIFICANCE	
	HCEB (NON-PRESTRESSED)	HCWB (PRESTRESSED)
1	0.012	0.002
2	0.010	0.001
3	0.020	0.002
4	0.013	0.001
5	0.012	0.002
6	0.022	0.001
7	0.014	0.018
8	0.016	0.014
9	0.016	0.003
10	0.010	0.003
11	0.013	0.001
12	0.015	0.001
13	0.009	0.001

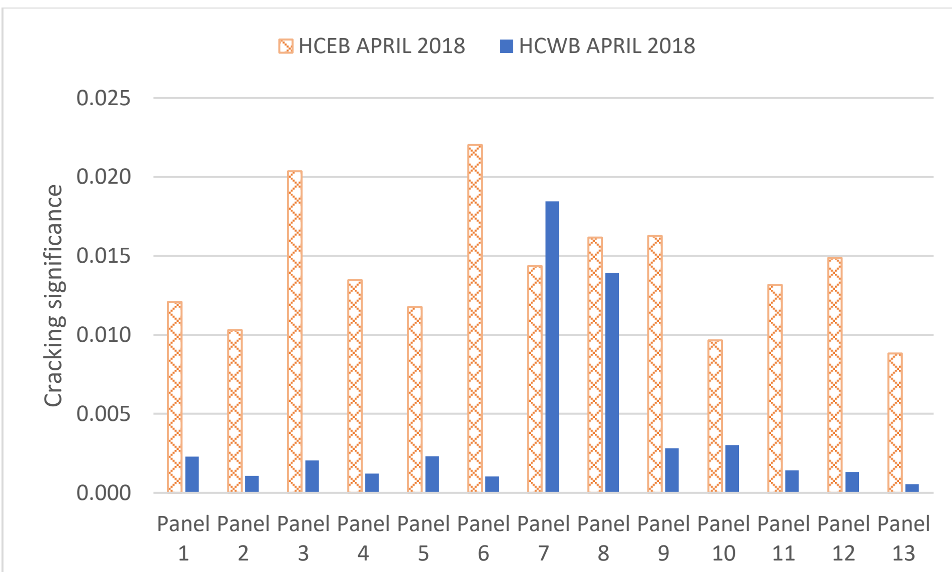


Figure 21: A plot of the cracking significance of HCEB (NON-PRESTRESSED) in April 2018 and HCWB (PRESTRESSED) in April 2018

LREB and LRWB April 2018 Crack Significance

Tables 5 and 6 show the results for the crack significance analysis performed on LREB (NON-PRESTRESSED) and LRWB (PRESTRESSED) using the data from the crack mapping performed in April 2018. The results are plotted in Figures 22-25.

Table 5: Cracking significance of LREB (NON-PRESTRESSED) in April 2018

PANEL NUMBER	CRACKING SIGNIFICANCE			
	SPAN 1	SPAN 2	SPAN 3	SPAN 4
1	0.004	0.040	0.010	0.009
2	0.011	0.011	0.010	0.010
3	0.008	0.011	0.012	0.020
4	0.005	0.007	0.019	0.014
5	0.009	0.006	0.015	0.007
6	0.006	0.010	0.017	0.022
7	0.009	0.006	0.009	0.011
8	0.007	0.006	0.009	0.016
9	0.006	0.010	0.016	0.007
10	0.011	0.008	0.014	0.007
11	0.021	0.010	0.010	0.010
12	0.017	0.008	0.006	0.011
13	N/A	0.026	0.007	0.018

Table 6: Cracking significance of LRWB (PRESTRESSED) in April 2018

PANEL NUMBER	CRACKING SIGNIFICANCE			
	SPAN 1	SPAN 2	SPAN 3	SPAN 4
1	0.001	0.001	0.002	0.005
2	0.002	0.001	0.001	0.001
3	0.003	0.002	0.002	0.003
4	0.004	0.003	0.001	0.010
5	0.001	0.002	0.002	0.001
6	0.002	0.005	0.002	0.001
7	0.003	0.003	0.003	0.002
8	0.004	0.002	0.001	0.019
9	0.002	0.003	0.002	0.001
10	0.005	0.002	0.001	0.001
11	0.003	0.000	0.000	0.001
12	0.001	0.003	0.001	0.001
13	N/A	0.001	0.001	0.002

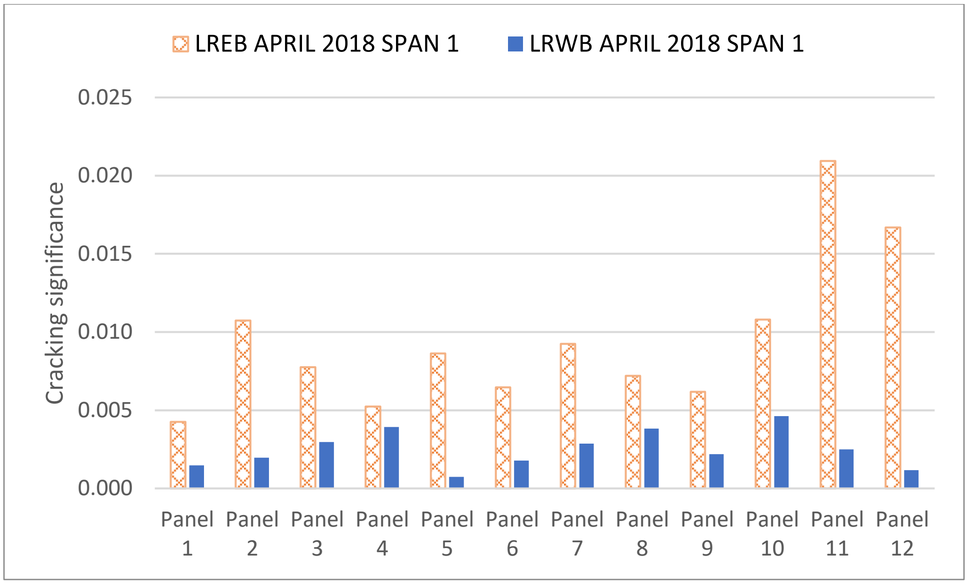


Figure 22: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 1 in April 2018 and LRWB (PRESTRESSED) span 1 in April 2018

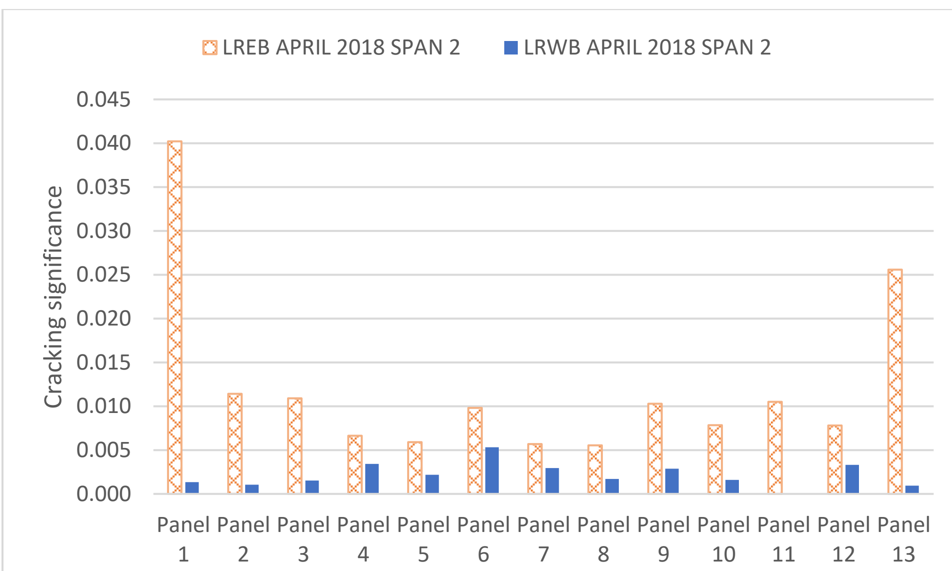


Figure 23: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 2 in April 2018 and LRWB (PRESTRESSED) Span 2 in April 2018

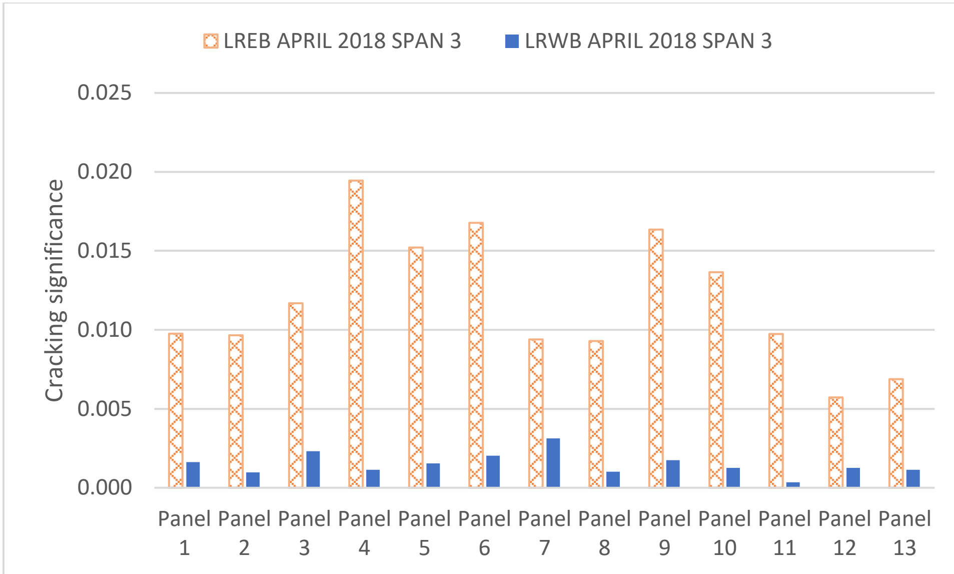


Figure 24: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 3 in April 2018 and LRWB (PRESTRESSED) span 3 in April 2018

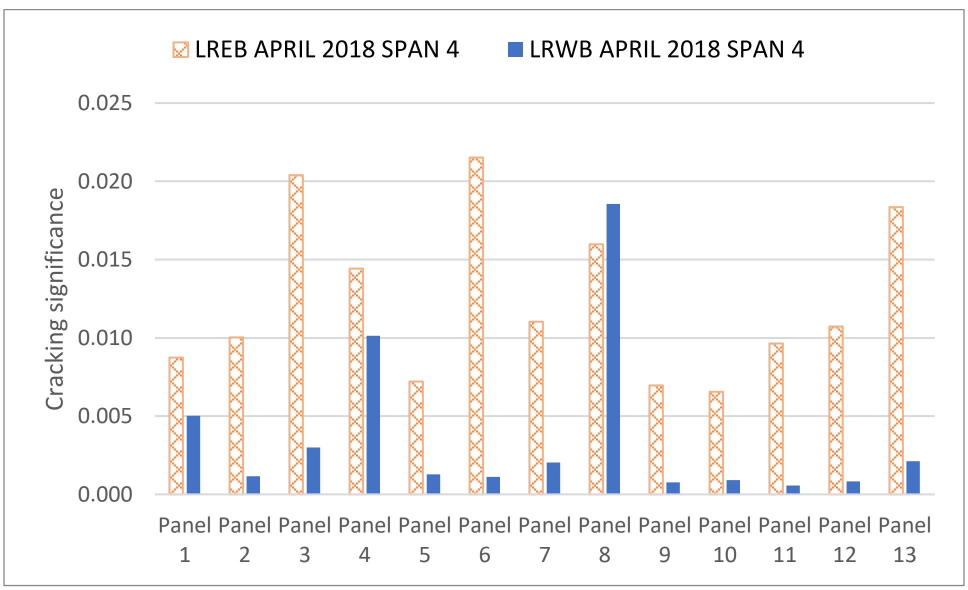


Figure 25: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 4 in April 2018 and LRWB (PRESTRESSED) span 4 in April 2018

For LREB (NON-PRESTRESSED) span 1, as shown in Table 5 and Figure 22, Panel 11 has the highest cracking significance, 0.021, while Panel 1 has the least, 0.004. Panel 12 also has a relatively large cracking significance, 0.017. Two of the 408 cracks identified would require epoxy injection or methacrylate, while three of them need investigation, and the remaining would require no treatment or investigation. Panels 10, 11, and 12 each have one of the cracks that require investigation with an average width of 0.03 in. Panels 10 and 12 each have one of the cracks that would need epoxy injection or methacrylate with an average crack width of 0.02 in.

For LREB (NON-PRESTRESSED) span 2, as shown in Table 5 and Figure 23, Panel 1 has the highest cracking significance, 0.040, while three panels have the least, 0.006. Investigation is required for 39 of the cracks identified, the remaining 416 cracks would require no treatment or investigation. All the cracks needing investigation are located on Panel 1 with an average crack width of 0.266 in.

For LREB (NON-PRESTRESSED) span 3, as shown in Table 5 and Figure 24, Panel 4 has the highest cracking significance, 0.019, while Panel 12 has the least, 0.006. One crack, on Panel 10, with a crack width of 0.02 in., out of 414 in the span, would require epoxy injection or methacrylate, while the remaining would require no treatment or investigation.

For LREB (NON-PRESTRESSED) span 4, as shown in Table 5 and Figure 25, Panel 6 has the highest cracking significance, 0.022, followed by Panel 3, 0.020. Of the 438 cracks identified, 11 would require epoxy injection, and only two require investigation. Seven of the cracks that would require epoxy injection or methacrylate are on Panel 7 while the remaining four are on Panel 13 and have an average crack width of 0.011 in. The two cracks needing investigation are on Panel 13 with an average crack width of 0.016 in.

For LRWB (PRESTRESSED) span 1, as shown in Table 6 and Figure 22, Panel 10 has the highest cracking significance, 0.005, while Panel 5 has the least, 0.001. Of the 286 cracks identified, none would require treatment.

For LRWB (PRESTRESSED) span 2, as shown in Table 6 and Figure 23, Panel 6 has the highest cracking significance, 0.005, while Panel 11 has zero. Of the 275 cracks identified, one crack with a 0.032 in. width, on Panel 7, requires investigation, while the remaining cracks would require no treatment.

For LRWB (PRESTRESSED) span 3, as shown in Table 6 and Figure 24, Panel 7 has the highest cracking significance, 0.003, while all other panels have values between zero and 0.002. Of the 246 cracks identified, none would require any treatment.

For LRWB (PRESTRESSED) span 4, as shown in Table 6 and Figure 25, Panel 8 has the highest cracking significance, 0.019, while over half the panels have a value of zero or 0.001. Of the 319 cracks identified, 19 would require epoxy injection or methacrylate, 5 require investigation while the remaining would require no treatment. Panel 4 has two of the cracks needing epoxy injection or methacrylate, while Panel 8 has the remaining 17 cracks. They have an average crack width of 0.0085 in. Panel 7 has one of the cracks that requires investigation, which has a width of 0.03 in. Panel 8 has two cracks with an average width of 0.019 in. which require investigation and two spalls with a width of 0.32 in., which also require investigation.

Comparison of June 2016 and April 2018 Crack Significance

As seen in Table 7, all bridges exhibited crack growth. For example, HCEB in 2016 had a total of 197 cracks, none needed epoxy injection or methacrylate and only four required investigation. For HCWB in the same year, 157 cracks were noted, four of which needed epoxy injection or methacrylate and twelve required investigation. In 2018 however, the cracks had grown from 197 cracks for HCEB to 524 cracks with six cracks needing epoxy injection or methacrylate and another six cracks requiring investigation. Similarly, cracks grew from 157 for HCWB to 336 with two needing epoxy injection or methacrylate and 11 requiring investigation.

In 2016, the total length of cracks needing investigation in the non-prestressed panels was 4 ft and the total length which would need epoxy injection or methacrylate was also 4 ft. In prestressed panels, 16.25 ft total length of cracks required investigation and 9.34 ft would need epoxy injection or methacrylate. In 2018, the total length of cracks in non-prestressed panels needing investigation grew from 4 ft to 159.79 ft. The growth of cracks for which epoxy injection or methacrylate was appropriate was from 4 ft to 55.88 ft, total length. In prestressed panels, the total length of cracks needing investigation increased to 17.1 ft and for epoxy injection and methacrylate treatment, the total length increased to 28.13 ft. Significantly more crack growth is seen to have occurred in the non-prestressed precast concrete panels.

The change in crack significance between June 2016 and April 2018 for the ten spans is shown in Figures 26 – 35. Cracking was observed to have increased in both the non-prestressed and prestressed panels from 2016 to 2018.

Table 7: Crack disposition summary for 2016 and 2018

2016												
	SPAN 1			SPAN 2			SPAN 3			SPAN 4		
	NT	EI/M	INV	NT	EI/M	INV	NT	EI/M	INV	NT	EI/M	INV
HCEB NPS	193	0	4									
HCWB PS	141	4	12									
LREB NPS	163	1	1	169	0	0	173	1	0	185	0	0
LRWB PS	111	0	0	105	0	1	88	0	1	107	4	3
2018												
	SPAN 1			SPAN 2			SPAN 3			SPAN 4		
	NT	EI/M	INV	NT	EI/M	INV	NT	EI/M	INV	NT	EI/M	INV
HCEB NPS	512	6	6									
HCWB PS	323	2	11									
LREB NPS	403	2	3	416	0	39	413	1	0	425	11	2
LRWB PS	286	0	0	274	0	1	246	0	0	295	19	5

Where:

NT = NO TREATMENT

EI/M = EPOXY INJECTION OR METHACRYLATE

INV = INVESTIGATION

NPS = NON-PRESTRESSED

PS = PRESTRESSED

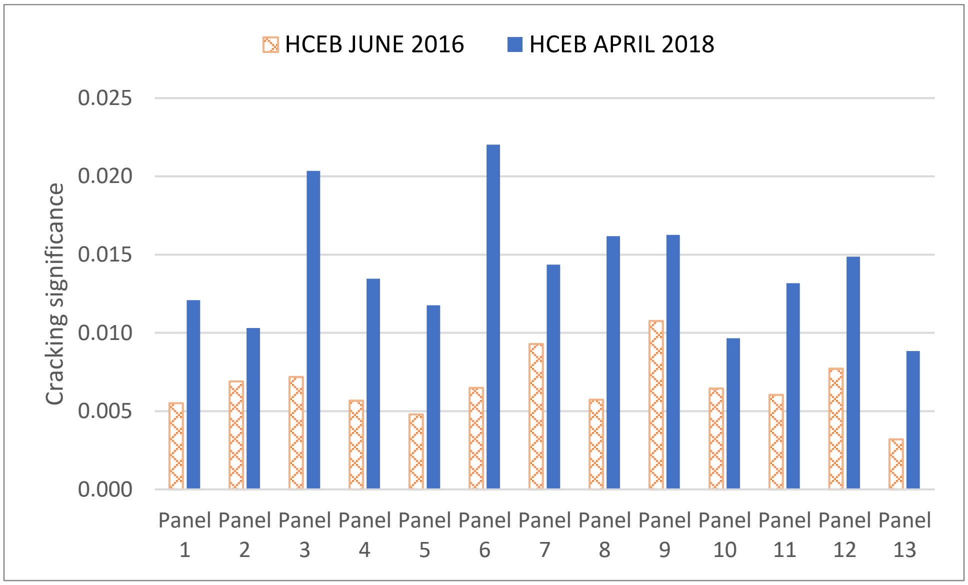


Figure 26: A plot of the cracking significance of HCEB (NON-PRESTRESSED) in June 2016 and HCEB (NON-PRESTRESSED) in April 2018

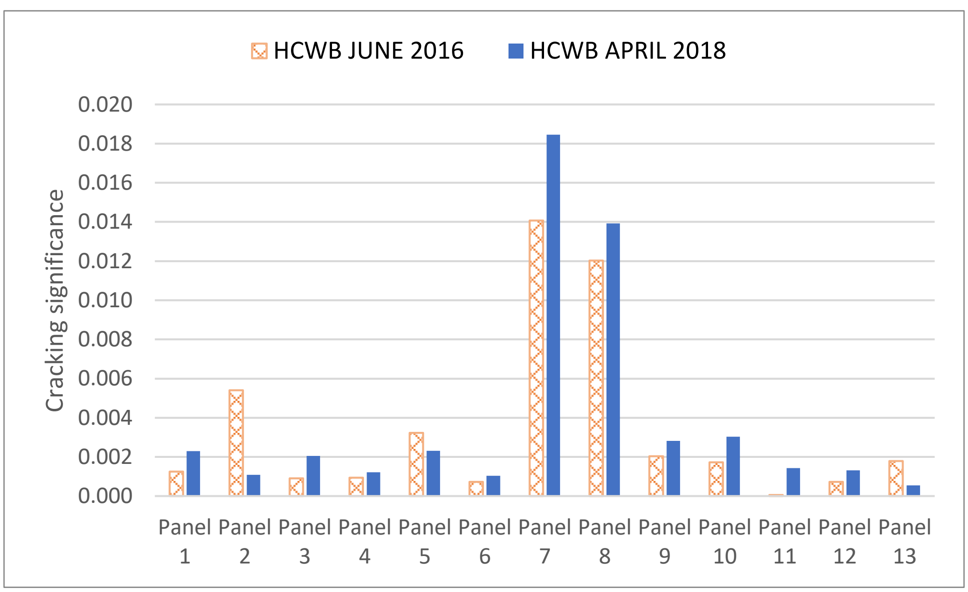


Figure 27: A plot of the cracking significance of HCWB (PRESTRESSED) in June 2016 and HCWB (PRESTRESSED) in April 2018

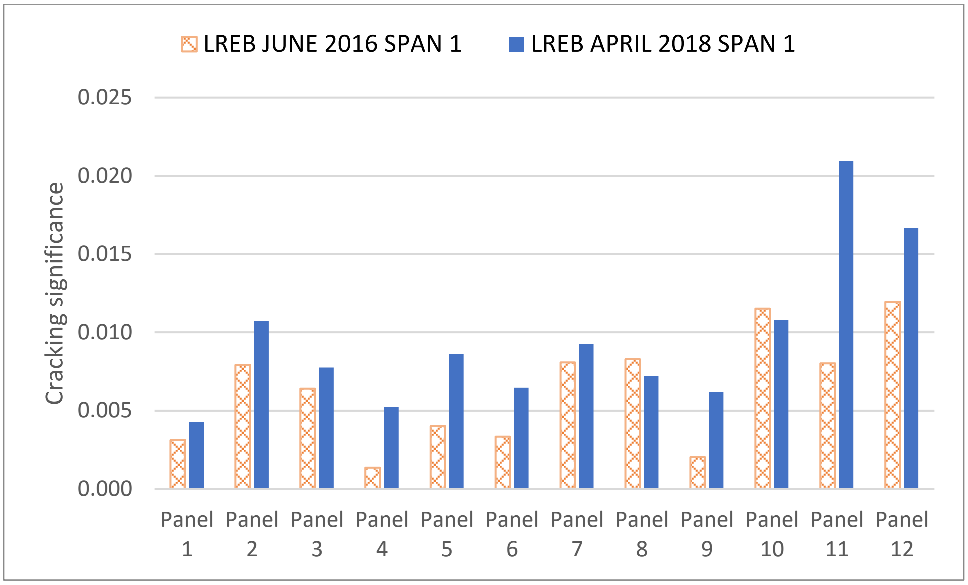


Figure 28: A plot of the Cracking significance of LREB (NON-PRESTRESSED) Span 1 in June 2016 and LREB (NON-PRESTRESSED) Span 1 in April 2018

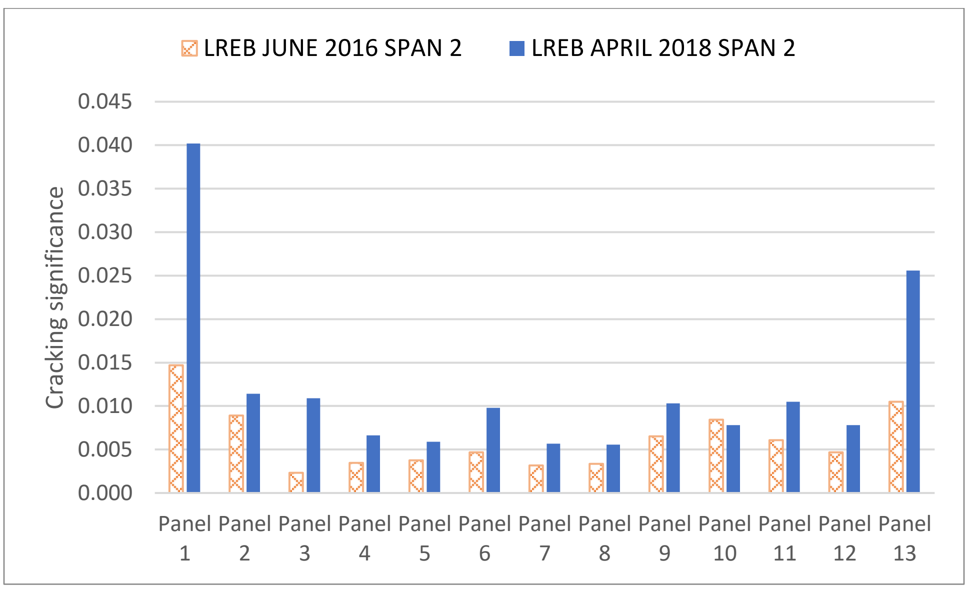


Figure 29: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 2 in June 2016 and LREB (NON-PRESTRESSED) span 2 in April 2018

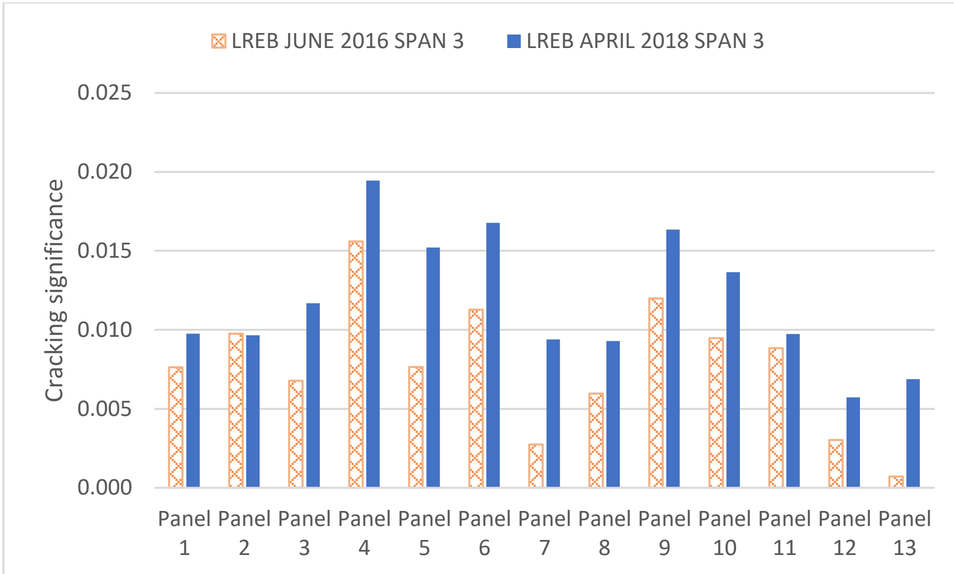


Figure 30: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 3 in June 2016 and LREB (NON-PRESTRESSED) span 3 in April 2018

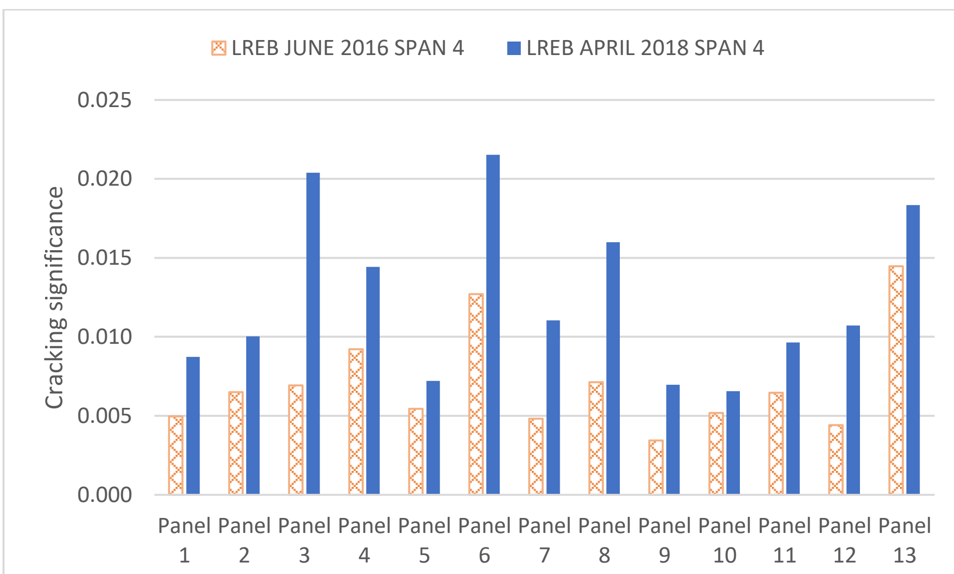


Figure 31: A plot of the cracking significance of LREB (NON-PRESTRESSED) span 4 in June 2016 and LREB (NON-PRESTRESSED) span 4 in April 2018

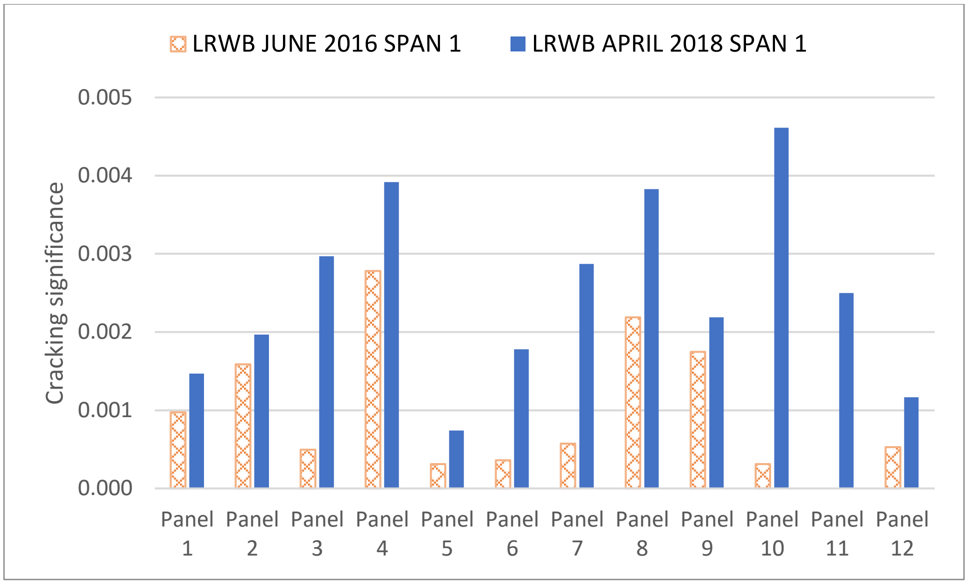


Figure 32: A plot of the cracking significance of LRWB (PRESTRESSED) Span 1 in June 2016 and LRWB (PRESTRESSED) span 1 in April 2018

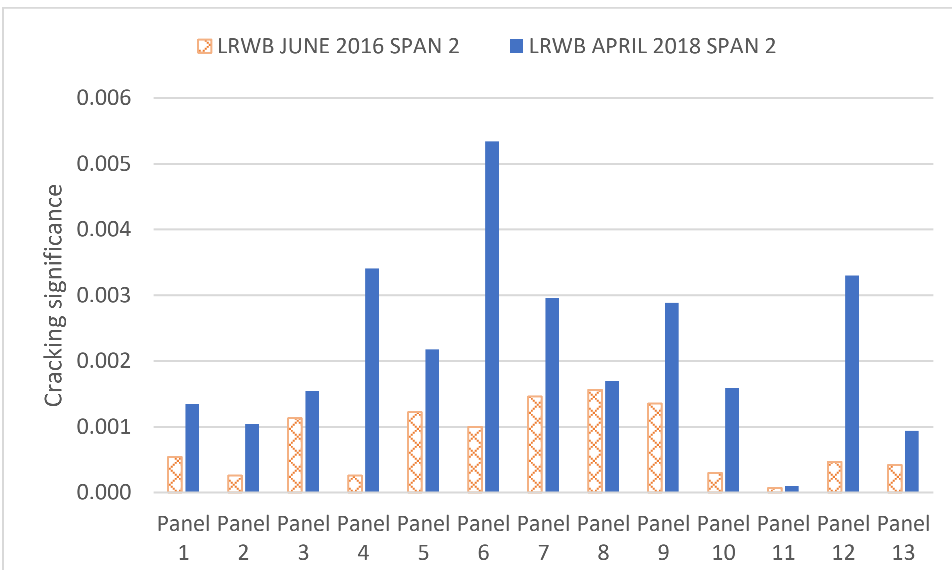


Figure 33: A plot of the cracking significance of LRWB (PRESTRESSED) Span 2 in June 2016 and LRWB (PRESTRESSED) span 2 in April 2018

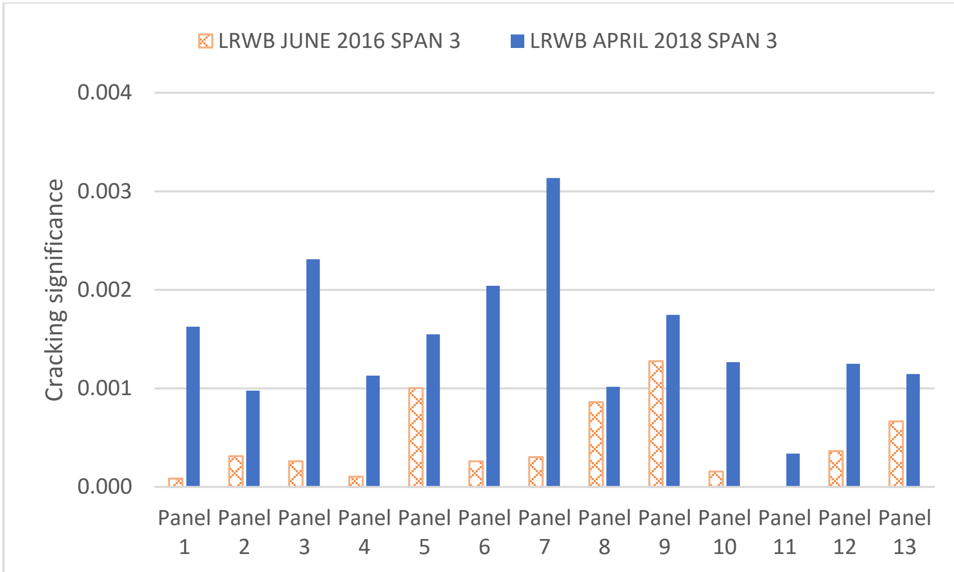


Figure 34: A plot of the cracking significance of LRWB (PRESTRESSED) span 3 in June in 2016 and LRWB (PRESTRESSED) span 3 in April 2018

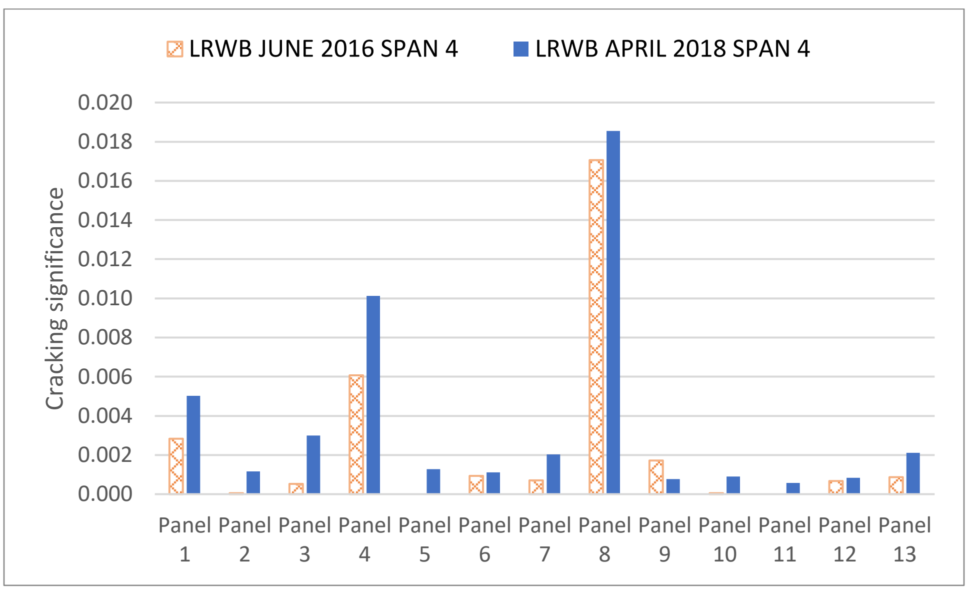


Figure 35: A plot of the cracking significance of LRWB (PRESTRESSED) span 4 in June 2016 and LRWB (PRESTRESSED) span 4 in April 2018

Summary of Crack Disposition

A summary of the crack disposition, determined according to FDOT (2018), is provided in Table 8. It shows the average crack significance for all ten (10) spans studied. The values were calculated by averaging the crack significance value for all 12 or 13 panels in the span. For example, HCEB(NON-PRESTRESSED) 2016 average crack significance of 0.007 was found by averaging the value shown in the second column of Table 1. The average crack significance in 2016 for the eastbound spans ranged from 0.006 to 0.008, whereas, for the westbound spans the range was from 0.000 to 0.003, much less than eastbound. Also provided in Table 8 are the ratios of eastbound to westbound values, for each span, for both 2016 and 2018 crack mappings.

In 2016, the eastbound spans had 2.0 to 18.0 times the crack significance of the westbound spans. In 2018, eastbound crack significance was 3.0 to 6.0 times that of westbound. The eastbound spans consistently had more cracking than the westbound spans in both 2016 and 2018, meaning that the prestressed panels cracked much less than the non-prestressed panels.

Regarding crack growth between the June 2016 and April 2018 mapping, Table 8 provides ratios of 2018 to 2016 crack significance for each span. In 2018, the eastbound spans had 1.5 to 2.0 times the cracking in 2016. The westbound spans had 1.3 to 4.7 times the cracking. Therefore, the non-prestressed panels experienced similar ratios of crack growth relative to the initial measurements taken in 2016, but the magnitudes were significantly more for the non-prestressed panels than for the prestressed panels.

Table 8: Cracking significance summary for 2016 and 2018

DESCRIPTION	AVERAGE CRACKING SIGNIFICANCE 2016	EB TO WB RATIO 2016	STANDARD DEVIATION	AVERAGE CRACKING SIGNIFICANCE 2018	EB TO WB RATIO 2018	STANDARD DEVIATION	RATIO 2018 TO 2016
HCEB NPS	0.0066	1.89	0.0019	0.014	3.50	0.0039	2.12
HCWB PS	0.0035		0.0045	0.0040		0.0056	1.14
LREB NPS SPAN 1	0.0063	6.36	0.0035	0.0095	3.80	0.0049	1.51
LRWB PS SPAN 1	0.00099		0.00088	0.0025		0.0012	2.53
LREB NPS SPAN 2	0.0062	8.05	0.0036	0.012	5.45	0.0099	1.94
LRWB PS SPAN 2	0.00077		0.00053	0.0022		0.0014	2.86
LREB NPS SPAN 3	0.0078	18.1	0.0041	0.012	8.00	0.0041	1.54
LRWB PS SPAN 3	0.00043		0.00039	0.0015		0.00070	3.49
LREB NPS SPAN 4	0.0071	2.96	0.0033	0.012	3.24	0.0052	1.69
LRWB PS SPAN 4	0.0024		0.0047	0.0037		0.0052	1.54

Summary and Conclusions

This study investigated cracking in precast concrete panels on four bridges over Hurricane Creek and Little River. Two of the bridges had reinforced (non-prestressed) panels while the other two had prestressed concrete panels. Cracking in the bridge deck panels (top surface only) was mapped, where the crack lengths and widths were measured. Crack mapping was done every three months for two years once the bridges were placed in service. Crack significance analysis was done for all the panels in the bridges, for the first mapping performed in June 2016 and for the last mapping in April 2018. The main goals of the study were to compare cracking in prestressed concrete panels with cracking in non-prestressed concrete panels, compare initial cracking with the final cracking on both panel types, and to do crack disposition according to Florida Department of Transportation (2018).

The results from the cracking significance analysis showed that the prestressed concrete panels performed significantly better than the non-prestressed concrete panels. For example, the average cracking significance for HCEB (NON-PRESTRESSED) bridge deck was 0.007, while the average cracking significance for HCWB (PRESTRESSED) was 0.003 as of June 2016. As of April 2018, the average cracking significance for HCEB (NON-PRESTRESSED) doubled from 0.007 to 0.012, while the average cracking significance for HCWB (PRESTRESSED) only increased from 0.002 to 0.003.

Some of the main conclusions of this study include:

- Almost all the panels performed well with less than 3% of the cracks needing investigation or treatment as of April 2018.
- As of 2018, a total of 41 cracks needed to be injected with epoxy or methacrylate while a total of 67 cracks needed to be investigated.
- It is expected that cracking will be more in the non-prestressed concrete deck panels than in the prestressed concrete panels. The latter are permanently compressed due to the prestressing, thereby counteracting some of the tensile stresses due to service loads.
- Practically all the cracks observed in the panels are transverse to the panels, or longitudinal to the bridge.
- Researchers agree that cracks propagate when cracked concrete is exposed to loads. This is consistent with the results obtained in this study, as all the bridge deck panels exhibited crack growth.
- Cracks in the non-prestressed concrete panels generally grew more than in the prestressed concrete bridge deck panels.

According to the literature review, researchers have studied cracking in cast-in-place reinforced concrete. However, much work is still needed on cracking in precast concrete bridge decks. This study explored only the in-service performance of the bridges in relation to cracking and so it is recommended that a similar study be done to explore pre-service performance. More research is needed to explore cracking of precast concrete especially as a comparison of how cracking differs in precast concrete from cast-in-place concrete.

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