OBSERVED CRACK WIDTH AND LENGTH IN A BRIDGE DECK PARTIALLY REINFORCED WITH GFRP REBARS

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Abstract

Corrosion of steel is a significant problem in bridge decks as deicing salts and combinations of moisture, temperature and chlorides through cracks, lead to concrete deterioration and loss of serviceability. FRP rebars have emerged as an alternative and practical solution to steel reinforcement corrosion. The objective of this study is to evaluate the cracks formed on the deck of a bridge partially reinforced with GFRP and partially reinforced with steel rebars. The bridge is constructed in Bourbon County in Kentucky over the Roger's Creek. This bridge has been monitored for cracks over a period of two and a half years. The major cracks observed on the deck are noted during the loaded and unloaded conditions, under different environmental conditions. Cracks observed in the GFRP reinforced and steel reinforced grids are found to be within allowable limits specified by AASHTO 1996.

Key Words: Bridge deck, GFRP rebars, crack measurement

Introduction

Cracking in bridge decks is a common problem in the United States. Exposure of bridge deck steel to a combination of moisture, temperature and chlorides from de-icing salts through surface crack leads to concrete deterioration and loss of serviceability. Furthermore, water trapped in the bridge deck cracks can freeze which in turn affect the flexural behavior of the deck, and alter the load distribution behavior [1]. Nationwide, billions of dollars have been spent replacing bridge decks deteriorated by the effects of cracking. The surface cracks predominantly occur in new bridge decks, developing shortly after construction. These cracks are typically very small, and with widths ranging between 0.004" and 0.008" (0.1 mm and 0.2 mm) and are not visible under normal conditions. Some European Countries allow cracks up to a width of 0.008" (0.2 mm) even in humid environments with the presence of deicing salts [2]. A crack width of 0.013 in (0.33 mm) is allowed in concrete decks by AASHTO, 1996 [3] and section 10.6.4 in ACI 318, 1995 [4].

This report presents the pattern of cracks observed over a period of two and half years in a bridge deck over the Roger's Creek in Bourbon County, Kentucky which is partially reinforced with Glass Fiber Reinforced Polymer (GFRP) rebars and steel rebars. The bridge was designed in 1995 and was in service since 1997. The bridge is monitored continuously for about two and a half years. The study objectives are achieved by measuring the length, width, and location of cracks in the bridge deck under loaded and unloaded conditions in both the GFRP reinforced and the steel reinforced areas at their top and bottom surfaces and comparing the observed cracks.

Bridge Description

The study is carried out for the deck of the US-460 bridge over Roger's Creek in Bourbon County, Kentucky (Figure 1). The bridge is a simply supported PCI beam structure with a length of 36' 6" (11.13 m) and a width of 36' (10.98 m). The lighter area of the mat close to the center of the bridge highlighted with dots is the GFRP rebar area as shown in Figure 2. The GFRP reinforced mesh is placed in a region of the top reinforcing mat with a size of 9' x 15' 6" (2.74 m x 4.73 m). In order to be exposed to both positive and negative bending moments, the GFRP mat runs over three supporting beams. The remaining portion of the top-reinforcing mat of the bridge deck is constructed using steel rebars [5].

Field Monitoring

After construction of the bridge, the deck has been continuously monitored for cracks over a period of two and a half years on an average of once in every month. The monitoring procedure involved: a) checking the top and bottom surfaces of the deck for cracks under loaded and unloaded conditions. b) measuring crack width and length on top and bottom surfaces of both the GFRP reinforced and the steel reinforced areas, and c) measuring ambient environmental conditions. Before checking the deck surfaces for cracks the traffic on the bridge is closed and the overall condition of the bridge is observed. A detailed inspection of the bridge deck is performed manually with the use of a magnifying glass. The observed crack width is measured using crack gauges, and crack length is measured using steel tapes. The locations of the cracks are noted based on grid markings over the GFRP and steel reinforced area. In the GFRP reinforced area, the x-axis of the grid is marked from No. 1 to No. 16 and the y-axis is marked from A to I.

Crack Observation under Loaded and Unloaded Conditions

The length, width and propagation of cracks in the GFRP and steel reinforced areas are reported for the no load condition on the top and bottom surface of the bridge deck. Similar crack measurements were made with the deck loaded by a standard truck with a wheel load of 20 kips positioned on the bridge. The position of the wheel load was selected to produce maximum flexural cracks in both the GFRP reinforced and the steel reinforced grids. All the cracks observed in the GFRP reinforced area were numbered. Additionally, temperature and relative humidity are recorded for the entire monitoring period facilitating comparisons of the collected data. Table 1 shows an example of a specific crack in the GFRP reinforced area. Similar tables are tabulated for both the GFRP and the reinforced steel grids but are not shown here for space limitation considerations. Additionally, Figure 3 shows a graphical variation of one of the largest cracks observed on top surface in the GFRP area with time and environmental conditions. Similar graphs are reported for all cracks. Comparisons of the cracks show the followings:

1) The length and width of the largest cracks observed in the top surface of the GFRP reinforced area under both the unloaded and loaded conditions are 13' 7"& 0.003" and 10'& 0.013", respectively.
2) The length and width of the largest cracks observed in the bottom surface of the GFRP reinforced area under both the unloaded and loaded conditions are 16' & 0.003" and 16' & 0.005", respectively.
3) The length and width of the largest cracks observed in the top surface of the steel reinforced area under both the unloaded and loaded conditions are 6' 10.5" & 0.003" and 3' 2" & 0.002", respectively.

In general, it was observed that the maximum crack length is 13' 7" in the top surface and is 16' in the bottom surface of the bridge deck. The maximum crack width is 0.013" while the majority of the crack widths are below 0.005". This shows that all cracks are within the allowable limits specified by AASHTO (1996) and ACI 318 (1995). It should be mentioned that since the GFRP grid was in a specific location of the bridge, the results of this study might not be generalized rather assist in future understanding of GFRP Bridge deck cracking.

Conclusions

In general, crack widths in the range of 0.004” to 0.04” (0.1 to 1 mm) arise primarily from temperature gradients, humidity gradient, and chemical corrosion such as corrosion of reinforcement and alkali-aggregate reaction. Cracks observed in the GFRP reinforced and steel reinforced areas are found to be within allowable limits specified by AASHTO (1996) and ACI 318 (1995). It should be mentioned that since the GFRP grid was partially inserted in a specific location of the bridge, the outcomes of this study might not be generalized rather than they might assist in future understanding of crack propagation in GFRP Bridge decks.

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Table 1. Details of a Crack Observed on the Top Surface of the Bridge Deck in the GFRP Reinforced Area

Inspection #	**Temp.**	**Relative Humidity**	**No Load on Bridge**		**Truck Load on Bridge**	
	(^{0}F)	(%)	Crack Width (in)	Crack Length (in)	Crack width (in)	Crack Length (in)
1st	45	40	0.003	120		
2nd	38	45	0.002	120		
3rd	40	50	0.003	120	0.001	120
4th	75.2	36	0.005	120		
5th	79.9	59	0.005	102		
6th	74.3	88.8	0.003	163		
7th	94.6	36.9	0.003	115		
8th	75.2	52	0.007	116	0.009	116
9th	68	18.3	0.005	106		
10th	62.8	44.5	0.005	112	0.013	112
11th	65.5	58	0.003	106		
12th	38.3	42	0.005	120	0.013	120

Figure 1. Roger's Creek Bridge - Bourbon County, Kentucky, USA

Figure 2. Photograph of Bridge Deck Prior to Concrete Placement. (Dots were Sketched to Identify the Location of GFRP Reinforcement)

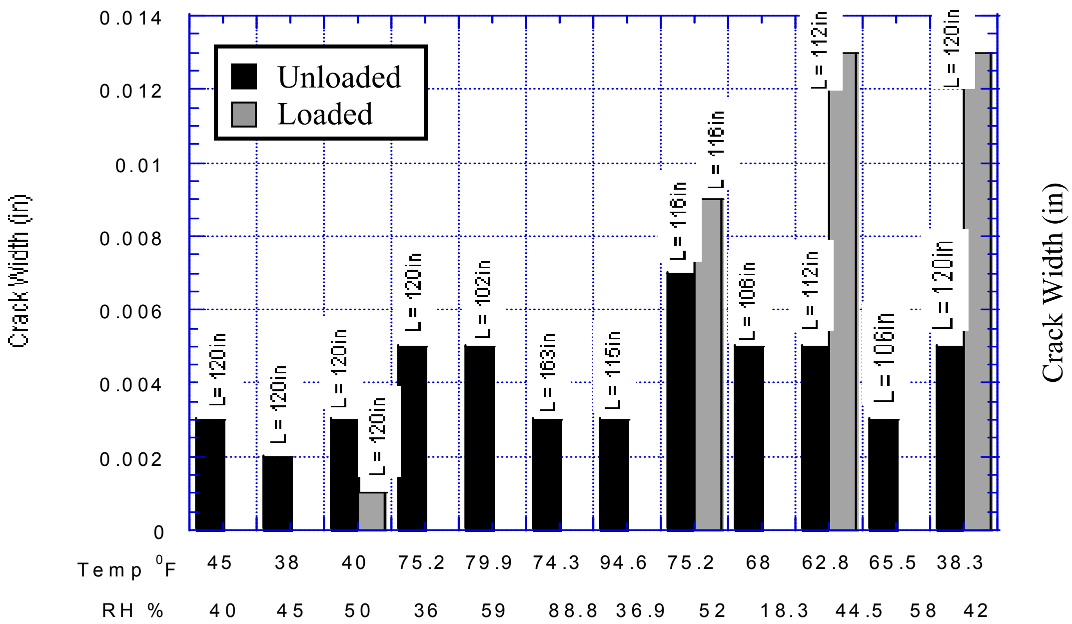

Figure 3. Graphical Variation of a Crack Observed on the Top Surface of the Bridge Deck in GFRP Reinforced Area