



# CFRP Strengthening of KY 583 Over the Bluegrass Parkway Bridge in Hardin County

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**Kentucky Transportation Center**

176 Oliver H. Raymond Building Lexington, KY 40506-0281 (859) 257-4513 [www.ktc.uky.edu](http://www.ktc.uky.edu)

**Research Report**  
KTC-17-19/KHIT88-06-1F

**CFRP Strengthening of KY 583 Over the Bluegrass Parkway Bridge in Hardin County**

by

Abheetha Peiris, Ph.D., P.E.  
Research Engineer

and

Issam E. Harik, Ph.D.  
Professor of Civil Engineering

Kentucky Transportation Center  
College of Engineering  
University of Kentucky  
Lexington, Kentucky

**In Cooperation With**  
Kentucky Transportation Cabinet  
Commonwealth of Kentucky

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<b>16. Abstract</b> <p>The report details the planning, design, and construction of the retrofit measure on the KY 583 Bridge (047B00072N), which traverses the Bluegrass Parkway in Hardin County, Kentucky. Reinforced concrete girders within the span over the eastbound Bluegrass Parkway of the bridge had cracks that led to concrete delamination and deterioration of the girders.</p> <p>To remedy the problem, triaxial carbon fiber reinforced polymer (CFRP) fabric sheets were selected to perform a retrofit due to their strength, conformability, and flexibility. The concrete surface, over which the fabric sheets were applied, were first prepared by removing all spalling and deteriorated concrete, which exposed corroded rebars within the region. The rebars were cleaned and coated with a zinc primer. Soon after, formwork was built around the damaged area. A bonding agent was applied and repair mortar placed within the formwork to return beams to their original shape. The area targeted for strengthening was then sandblasted, and triaxial CFRP fabric was applied using a two-part saturating epoxy.</p> <p>The retrofit was completed in May of 2014, and the bridge was monitored over a three-year period. No defects were observed in the retrofit during this time. Eighteen months after the retrofit, inspectors found an additional crack location causing concrete delamination, away from the retrofit locations.</p>			
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## Table of Contents

Executive Summary .....	ii
Acknowledgements.....	iii
1. Introduction.....	1
1.1 Bridge Description.....	1
1.2 Damage Description .....	4
1.3 Objective and Scope .....	4
2. Planning and Design .....	5
3. Retrofit Construction .....	6
3.1 Bridge Access.....	6
3.2 Damage Repair .....	6
3.3 CFRP Fabric Application .....	7
4. Post-Construction Monitoring .....	10
5. Summary and Conclusion.....	11
A. Appendix: Fabric Placement Details.....	12

## List of Figures

<b>Figure 1</b> Location of KY 583 Bridge in Hardin County, KY (047B00072N) .....	1
<b>Figure 2</b> Layout of the KY 583 Bridge, Hardin County, Kentucky.....	2
<b>Figure 3</b> Damage to RC Girders in Span 2 of the KY 583 Bridge in Hardin County, KY .....	3
<b>Figure 4</b> Typical Cracking Observed on All Four Beams.....	4
<b>Figure 5</b> General Retrofit Plan .....	5
<b>Figure 6</b> Multiple Man-Lifts Used in Retrofit with a Single Lane Closure .....	6
<b>Figure 7</b> Removing Loose Concrete .....	7
<b>Figure 8</b> Blast Cleaning and Coating Exposed Steel.....	7
<b>Figure 9</b> Attaching Forms and Placing Repair Mortar.....	7
<b>Figure 10</b> Preparing the CFRP Application Surface .....	8
<b>Figure 11</b> Applying CFRP Fabric .....	8
<b>Figure 12</b> Applying Outer Layer of Epoxy .....	8
<b>Figure 13</b> Retrofit Complete .....	9
<b>Figure 14</b> Retrofit Inspection - May 2017.....	10
<b>Figure 15</b> New Crack in Girder 02 Observed in November 2015.....	10

## Executive Summary

The KY 583 Bridge (047B00072N) that traverses the Bluegrass Parkway in Hardin County, Kentucky, is a four-span (50'-62'-62'-50') reinforced concrete deck girder (RCDG) bridge. The bridge is 33 feet wide, with two 14-foot lanes in each direction. Each span has four reinforced concrete (RC) beams with a 7" deep continuous deck.

Cracks developed along the vertical and bottom faces of the RC beams near the center of the span over the eastbound lanes of the Bluegrass Parkway. Cracks were found on all four beams in the span (Span 2), which led to concrete delamination and spalling of concrete. Pre-construction monitoring of crack movement was carried out concurrently with planning and design of retrofit measures.

Based on the observed damage and crack orientation, braided triaxial carbon fiber reinforced polymer (CFRP) fabric sheets were selected as the retrofit material. A dry layup of the fabric was carried out using a high strength two-part saturating epoxy for a quick and efficient construction. CFRP fabric strengthening was carried out on all four cracked beams. Work was completed in May 2014 and post-construction monitoring carried out over the next three years. No defects were observed in the retrofit during this period. Eighteen months after the retrofit, inspectors found an additional crack location causing concrete delamination, away from the retrofit locations.

## **Acknowledgements**

The financial support for this project was provided by the Kentucky Transportation Cabinet (KYTC) and the Federal Highway Administration (FHWA). The contribution of Mr. David Steele and Mr. David Kemper in this project is greatly appreciated. The project would not have been a success without the guidance provided by the KYTC Study Advisory Committee and the assistance by the KYTC District 04 bridge crew during retrofit construction. The help provided by Mr. Aaron Cole in creating this report is especially noted.

# 1. Introduction

## 1.1 Bridge Description

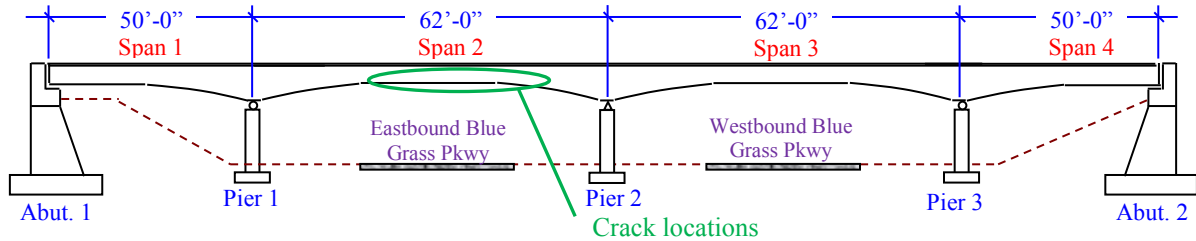
The KY 583 Bridge (hereafter referred to as the KY 583 Bridge) traverses the Bluegrass Parkway in Hardin County, Kentucky (Figure 1).



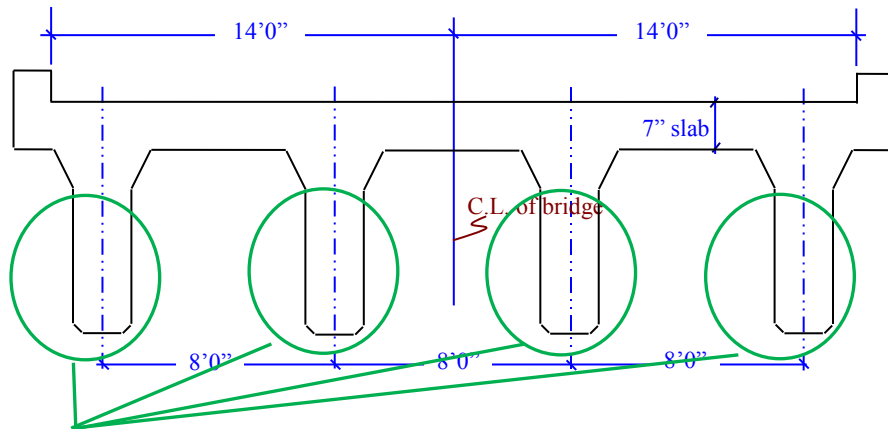
**Figure 1** Location of KY 583 Bridge in Hardin County, KY (047B00072N)



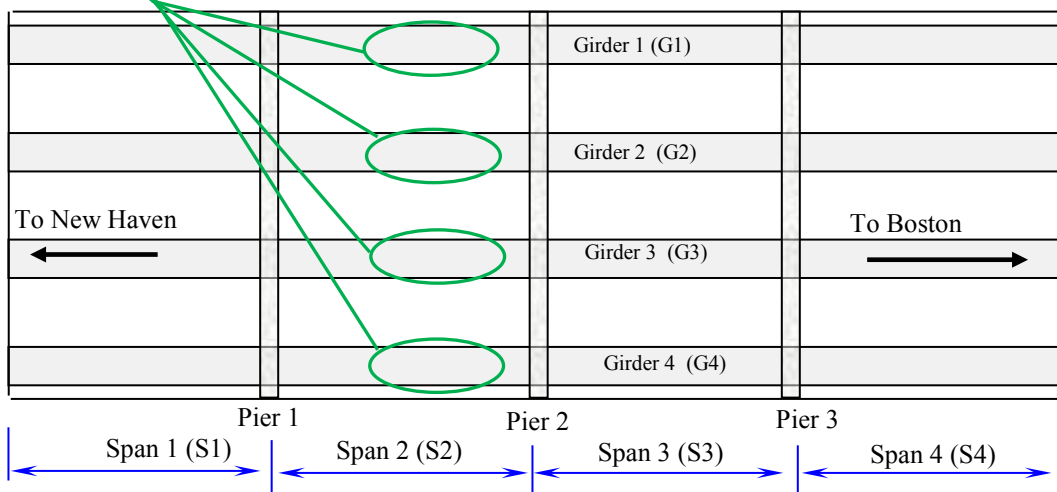
The bridge is a four-span (50'-62'-62'-50') reinforced concrete deck girder (RCDG) bridge that was constructed in 1964. It is 33 feet wide with two 14-foot lanes in each direction, and has four reinforced concrete (RC) beams per span, with a 7" deep continuous deck. Figure 2 illustrates the general layout of the bridge and a typical cross section along with the damage locations.



(a) General layout of the bridge

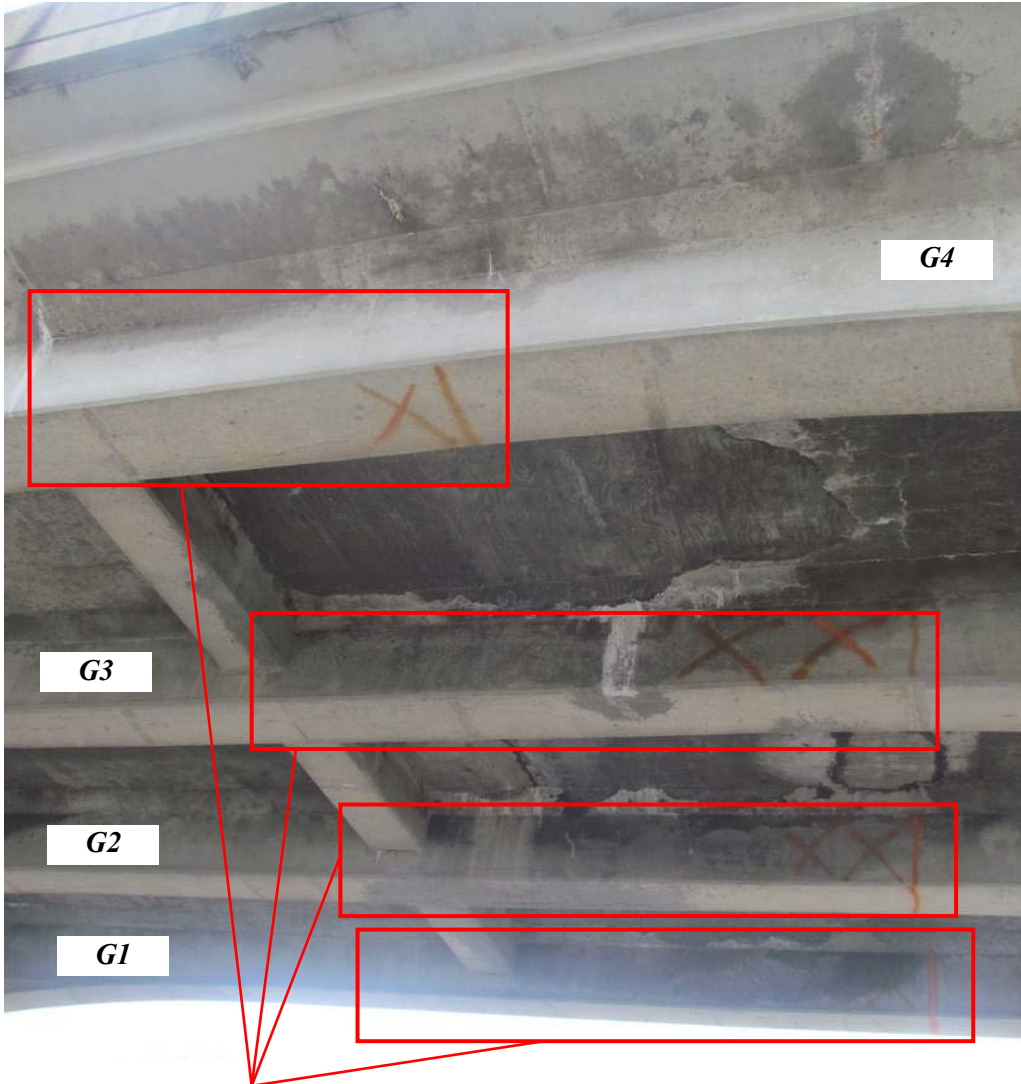


(b) Cross section of the bridge



(c) Plan view showing the location of damage

**Figure 2** Layout of the KY 583 Bridge, Hardin County, Kentucky



**Crack locations**

**Figure 3** Damage to RC Girders in Span 2 of the KY 583 Bridge in Hardin County, KY (damage within constant depth area of all beams)

## 1.2 Damage Description

As indicated by Figure 3, large cracks appeared on all four girders on the span over the eastbound lanes of the Bluegrass Parkway. The cracks materialized along the vertical faces of the beams as well as along the bottom faces. The cracks produced concrete delamination and spalling. The longest cracks were nearly 12 feet long and spanned the vertical face longitudinally, while shorter longitudinal and diagonal cracks were observed. All the cracks and damaged area over the left lane of eastbound Bluegrass Parkway were within the constant depth region of the beams. An additional cracked area in Girder 3 over the right lane of eastbound Bluegrass Parkway was within the varying depth section of the beam. This was identified later and retrofitted by the KYTC D04 bridge crew.



**Figure 4** Typical Cracking Observed on All Four Beams

## 1.3 Objective and Scope

While cracking may blemish a bridge's aesthetics, of greater concern is the fact that cracks will accelerate the corrosion of reinforcing steel and deterioration of concrete. This could reduce the durability of structural elements and ultimately lead to structural failure or loss of serviceability.

The objective of this project was to repair the concrete girders to prevent the cracks from growing or further propagating. The selection of the repair technique and material was based on the ability to carry out a rapid retrofit and minimizing traffic disruptions on the Bluegrass Parkway.

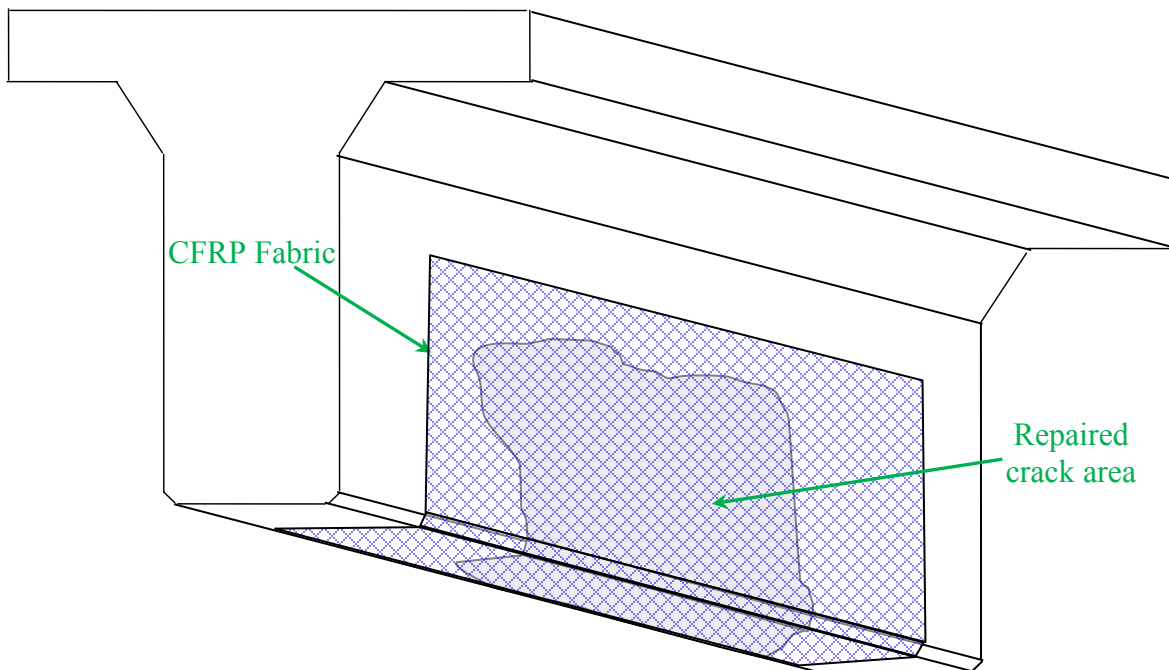
## 2. Planning and Design

The Kentucky Transportation Center (KTC) Structures Program designed the retrofitting. KTC selected a braided quasi-isotropic carbon fiber reinforced polymer fabric (CFRP) to strengthen the beams. This material was chosen for its tri-axial ( $0^\circ$ ,  $+60^\circ$ ,  $-60^\circ$ ) fiber orientation, which can provide an equal amount of strengthening in every direction in the plane of the fabric. The fabric's manufacturer-specified tensile strength is over 116 ksi while its tensile modulus exceeds 6300 ksi in both longitudinal and transverse directions.

The repair and subsequent strengthening consisted of the following tasks:

1. All loose and spalling concrete caused by the cracking was removed and the damaged area cleaned and prepped for new repair mortar.
2. Exposed steel was sandblasted and cleaned; a coat of zinc primer was applied to prevent further corrosion.
3. Formwork was set up and repair mortar placed to return the beam to its original shape.
4. CFRP fabric was applied utilizing a dry-layup process with a two-part saturating high-strength epoxy.

The general layout of the retrofit is shown in Figure 5. The fabric was applied in U-wraps around the bottom of each beam perpendicular to the longitudinal direction of the beams. Each U-wrap is 52" wide with a 4" overlap between adjacent pieces. The CFRP fabric must extend a minimum of 6" beyond the end of the repaired region. Appendix A provides more details on the CFRP fabric strengthening and placement.



**Figure 5** General Retrofit Plan

### 3. Retrofit Construction

Personnel from KTC and the Kentucky Transportation Cabinet (KYTC) District 04 bridge crew performed the retrofit. The construction was performed in eight days over a four-week period, including a two-week interval between the application of the rapid-set repair mortar and CFRP strengthening. KYTC District 04 personnel oversaw traffic control during construction.

#### 3.1 Bridge Access

The second span of the KY 583 Bridge is an overpass over the eastbound lanes of Bluegrass Parkway. The section of the span that required retrofitting is located over the left lane of the eastbound Bluegrass Parkway. Consequently, only one lane of traffic had to be closed. The construction of the retrofit measure was carried out using multiple man-lifts. The man-lifts easily accessed the needed areas of the span with the single lane closure (see Figure 6). An additional beam was identified and retrofitted by the KYTC District 04 bridge crew over the eastbound right lane at a later date.



**Figure 6** Multiple Man-Lifts Used in Retrofit with a Single Lane Closure

#### 3.2 Damage Repair

Before repairs commenced, all loose concrete was removed from the cracked regions of the beams. Crew members used pneumatic chipping hammers to remove the material and expose at least one inch of non-corroded reinforcing steel. The steel was then sandblasted to remove rust, and a zinc primer was applied with a brush after wiping it with a solvent. Wooden forms were erected to ensure the repair mortar cured appropriately to provide the original shape of the beam. A bonding agent was applied to facilitate bonding between the old concrete and repair mortar. The repair mortar was then placed and vibrated to prevent voids.



**Figure 7** Removing Loose Concrete



**Figure 8** Blast Cleaning and Coating Exposed Steel



**Figure 9** Attaching Forms and Placing Repair Mortar

### **3.3 CFRP Fabric Application**

Once the repair mortar cured the forms were removed. The mortar was ground to remove any in-plane variations between the repair mortar and pre-existing concrete. The entire region was then sandblasted to create a clean surface for the CFRP fabric to bond to. The two-part saturating epoxy was applied to the clean concrete; fabric was placed over the epoxy by hand. All air pockets and irregularities were smoothed out of the fabric with laminating rollers. An outer layer of the same epoxy was placed over the fabric with paint rollers to ensure adequate coverage. After the epoxy cured, a UV protective coating was applied to the outside and bottom faces of the outer beams on either side of the span.



**Figure 10** Preparing the CFRP Application Surface



**Figure 11** Applying CFRP Fabric



**Figure 12** Applying Outer Layer of Epoxy

The retrofitted beams, prior to the application of the protective coating on the outside beams, are shown in Figure 13. After the epoxy cured, the UV protective coating was applied to the outside and bottom faces of the two edge beams. As previously stated, an additional beam (Girder 3) over the right lane of the Bluegrass Parkway had concrete damage due to cracks. This was also retrofitted by the KYTC District 04 bridge crew. The retrofit of the all the bridge beams was completed in May 2014.



**Figure 13** Retrofit Complete



#### 4. Post-Construction Monitoring

Following the completion of the retrofit construction, KTC monitored the retrofit for three years. A May 2017 inspection revealed no defects (e.g., delamination or separation of the CFRP fabric) in the retrofitted beams. Figure 14 shows the retrofitted areas, including the additional retrofit area over the eastbound right lane of the Bluegrass Parkway. Some epoxy discoloration occurred on the interior girders that lacked a UV protective coating.



**Figure 14** Retrofit Inspection - May 2017

A routine inspection in November 2015 uncovered a new crack in Girder 2 causing concrete delamination. The damaged area was within the varying depth region of the beam over the left lane of eastbound Bluegrass Parkway and away from the previously retrofitted area (Figure 15). No additional cracks or concrete delamination was observed for the remainder of the monitoring period.



**Figure 15** New Crack in Girder 02 Observed in November 2015

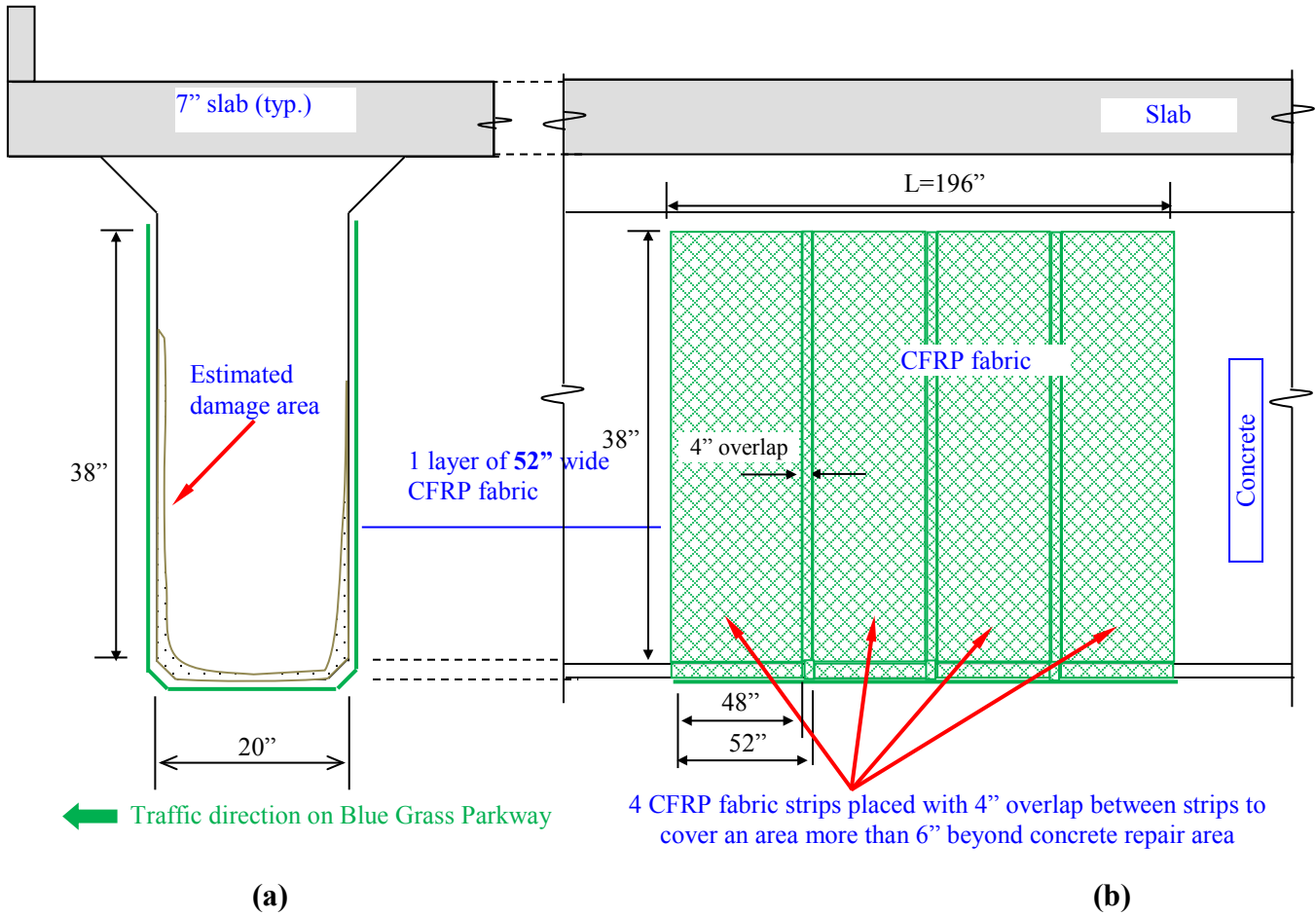
## **5. Summary and Conclusion**

This report detailed the work carried out for the retrofitting of the KY 583 Bridge in Hardin County, Kentucky, a four-span (50'-62'-62'-50') RCDG bridge. The bridge is 33 feet wide with two 14-foot lanes in each direction and traverses the Bluegrass Parkway. Each span has four RC beams with a 7" deep continuous deck. The report described the cracks discovered within the RC beams that led to delamination and spalling of concrete, the planning and design of the retrofit, as well as the retrofit construction.

Cracks developed along the vertical and bottom faces of the RC beams near the center of the span over the eastbound lanes of the Bluegrass Parkway. Cracks occurred on all four beams in the span leading to concrete delamination and spalling of concrete. Pre-construction monitoring of crack movement and/or propagation was carried out alongside planning and design of retrofit measures.

Based on the observed damage and crack orientation, braided triaxial CFRP fabric sheets were selected as the retrofit material. A dry layup of the fabric was carried out using a high strength two-part saturating epoxy for a quick and efficient construction. CFRP fabric strengthening was carried out on all four cracked beams. Work was completed in May 2014 and post-construction monitoring was carried out over the next three years. No defects were observed in the retrofit during this period. Eighteen months after the retrofit, inspections uncovered an additional crack location causing concrete delamination, away from the retrofit locations.

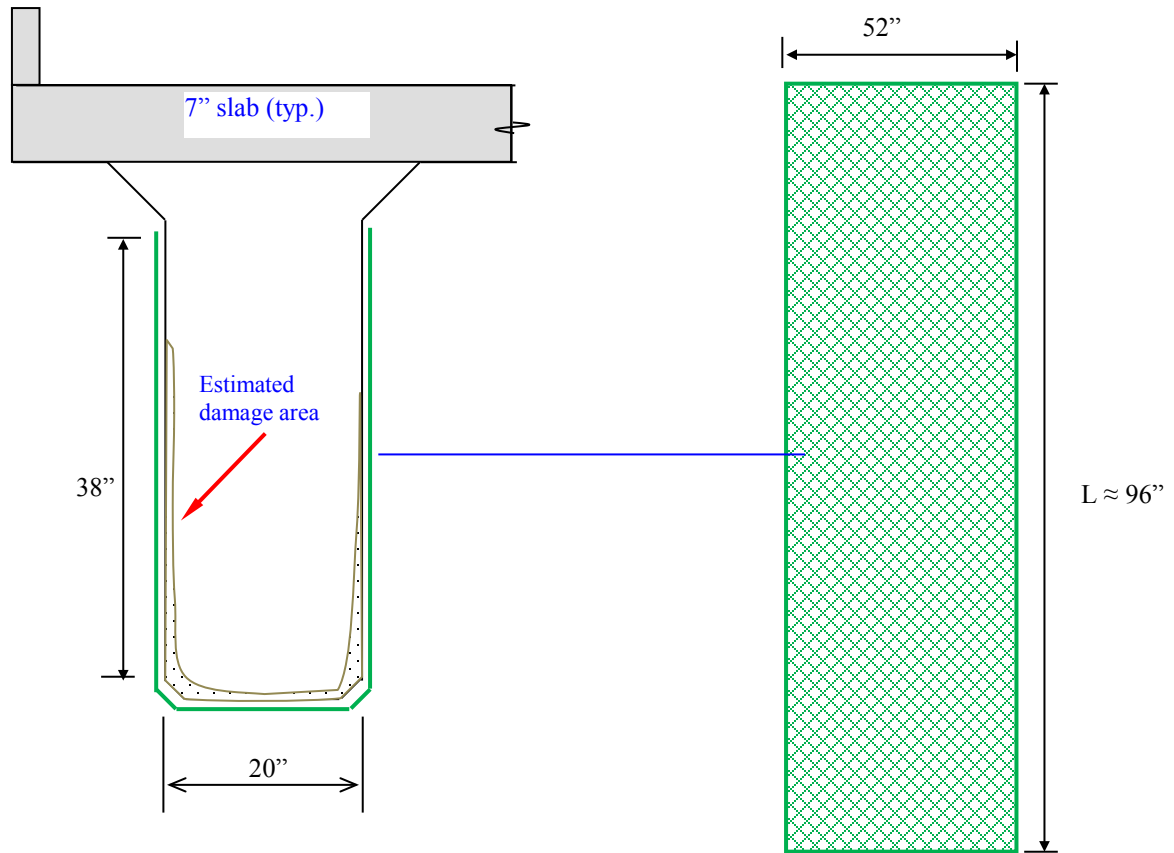
### A. Appendix: Fabric Placement Details



CFRP Fabric = QISO-L-C-52  
 Epoxy = Sikadur 330 High Strength Impregnating Resin

Figure 0.1

**Fig. A1: Typical placement of the CFRP fabric at damaged locations**



**Fig. A2: Typical cuts for the CFRP fabric**