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Damage Repair of a Bridge Girder Previously Retrofitted With CFRP Fabric

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Abstract

A four-span Reinforced Concrete Deck on Girder (RCDG) bridge on route KY 562 that passes over Interstate 71 in Gallatin County, Kentucky, was retrofitted using carbon fibre reinforced polymer (CFRP) fabric in May 2015 following an over-height impact. A second impact in September 2018 damaged all four girders in Span 2 of the bridge. Span 2 traverses the two northbound lanes of Interstate 71. Girder 1 in Span 2 suffered the initial impact; all steel rebars in the bottom layers were severed and bent out of plane. Damage to Girders 2, 3, and 4 in Span 2 was minor — none of the bars were severed. In Girder 1 all but one of the main rebars were replaced by detaching the bent sections and installing straight rebars connected to the existing rebars with couplers. One of the rebars could not be replaced. Heavy CFRP unidirectional fabric was deployed to replace the loss in load carrying capacity.

Keywords: CFRP, Fabric, Reinforced Concrete, Impact Damage, Retrofit

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Introduction

Bridges impacted by over-height trucks may require a load posting if the impact causes moderate to severe damage. Bridge beams damaged by over-height truck impacts affect the safety of traffic on both the bridge and the roadway that passes beneath it. Field application of externally bonded CFRP-pultruded laminates and wet-layup fabric for strengthening Reinforced Concrete (RC) bridge girders has yielded excellent results. The NCHRP 20-07/ Task 307 [1] report highlighted several methods of utilizing CFRP for Prestressed Concrete (PC) girder retrofit following impact damage. Many findings related to PC bridge girders also extend to RC bridge girders. Following several over-height bridge repair projects on both RC and PC bridges in the state of Kentucky, the authors developed a two-stage approach to the containment and/or eventual repair of a damaged area [2].

Previous Over-height Truck Impact and Retrofit

The KY 562 Bridge over Interstate 71 (I-71) in Gallatin County, Kentucky, is a four-span RCDG bridge built in 1967. The bridge's two centre spans traverse two lanes of northbound and two lanes of southbound I-71. Each span has four reinforced concrete girders, with a 190 mm reinforced concrete deck. In April of 2014, an over-height truck struck and damaged the exterior girder (Girder 1 of Span 2) over the right lane of northbound I-71. The over-height truck impact produced significant concrete spalling, large out-of-plane bending in one of the #11 rebars (diameter of 35.81 mm) of the bottom rebar layer, slight bending in two other rebars, and damage to multiple shear stirrups. Based on the observed damage and rebar deformation, the excessively bent #11 rebar was replaced. The other bent rebars were mechanically straightened and unidirectional CFRP fabric applied to strengthen the girder at the location damaged by the impact. Retrofit construction was completed in May 2015. Figure 1 depicts the damaged girder following the impact and after the retrofit, but prior to application of UV protective coating in 2015.

Figure 1: Bridge girder impacted in 2014: (a) before retrofit, (b) after retrofit

New Over-height Truck Impact and Retrofit

Another over-height truck struck the bridge in September 2018, damaging all four girders in Span 2. The same exterior girder (Girder 1 in Span 2) received the initial force of impact, and all steel rebars in the bottom layers were severed and bent out of plane. Damage in Girders 2, 3, and 4 in Span 2 was minor; none of the bars were severed. Figure 2 captures the impact

damage on Girder 1. Near the impact location, CFRP fabric from the previous retrofit was severed; sections of the fabric and concrete fell onto the roadway.

Figure 2: Bridge girder damage following impact in 2018: (a) front view, (b) bottom view

Retrofit Design

Following inspection, the capacity of the exterior girder before and after the impact damage was calculated. All but one of the #11 rebars could be replaced by cutting off the bent sections and installing straight rebar connected to the existing rebars with couplers. A heavy unidirectional CFRP fabric with a weight of 757 g/m^2, a design tensile strength of 2,344 MPa, and a manufacturer-specified tensile modulus of 139 GPa was chosen to replace the lost load carrying capacity. Strips of the 300-mm wide unidirectional CFRP fabric were to be placed on the bottom flange and the two vertical faces on either side. U-wraps of tri-axial braided quasi-isotropic (0°,+/- 60°) carbon fabric were selected for additional shear strengthening and to serve as containment for crushed concrete in the event of future over-height impacts. CFRP U-wraps were expected to increase the capacity of the heavy unidirectional CFRP fabric strengthening system by anchoring the fabric ends.

Retrofit Construction

A key difference between the CFRP retrofit executed as part of this effort and previous work conducted by the authors was this project entailed the removal of the previously applied CFRP material. While the CFRP fabric debonded near the impact site and could be removed using a chipping hammer, the vast majority of the fabric remained bonded to the concrete. Mechanical grinding proved inefficient, and removal was subsequently carried out by sand blasting. This process took multiple days due to the damage spanning both traffic lanes of northbound I-71. Figure 3 shows the removal of CFRP material near the impact-damaged region as well as away from the damaged area. The intensity of sand blasting required to remove the previous CFRP material and epoxy created small voids on the concrete surface. This required application of a trowel-grade epoxy as a subbase to achieve level surface for the new CFRP application. Following removal of the previous CFRP material, the new girder retrofit was carried out. All but one of the damaged bottom rebars were replaced by coupling new #11 rebars.

Figure 3: Removal of old CFRP material: (a) near impact region, (b) away from impact region

Figure 4: Retrofitted girders: (a) following CFRP application, (b) after UV protective coating

Damaged shear stirrups were replaced and additional shear stirrups provided. After the steel was blast cleaned, a protective coating was applied before covering the surface with rapid-setting repair mortar. Once the repair mortar had set, formwork was removed and the CFRP strengthening carried out. The competed retrofit is shown in Figure 4.

Conclusions

A four-span RCDG bridge over I-71 in Kentucky was damaged by an over-height truck impact. The beam which suffered the primary impact had previously been retrofitted using CFRP following a prior over-height impact. This paper discussed the retrofit design, which included the use of heavy unidirectional CFRP fabric for flexural strengthening of the damaged bridge girder. Retrofit construction required the removal of the previous CFRP material. The removal process was discussed along with the subsequent CFRP retrofit. The retrofit successfully replaced all of the moment capacity lost due to the impact damage.

References

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