RESEARCH NOTES
THE EARTHQUAKE ENGINEERING GROUP
March 2009
Caltrans

Response of Reinforced Concrete Bridge Deck Overhang Strengthened with Near Surface Mounted CFRP

***RESULTS:* The use of near-surface-mounted (NSM) carbon fiber reinforced polymer (CFRP) reinforcement for increasing the flexural capacity of a reinforced concrete bridge deck overhang was investigated. Experimental results indicate the ultimate load carrying capacity of the FRP strengthened specimen was 78% higher than the as-built specimen. This result exceeded the desired load capacity increase of 29.7% above the experimentally validated capacity of the as-built specimen, and exhibited stable structural response as well as increased deformation capacity.**

Why We Pursued This Research

Caltrans is installing sound barriers along freeways to minimize the impact of freeway noise on local residents. These sound barriers are installed on the barrier rail located on the edge of the bridge deck. Typically, these sound barrier walls are of masonry construction, which increases the dead load of the bridge in excess of the original design loads. Often the entire edge region of the box girder is removed and rebuilt using additional reinforcement and consequently impacting traffic.

An alternative to partial replacement of the bridge deck is strengthening of the overhang using fiber reinforced polymers (FRP). The use of near-surface-mounted (NSM) FRP reinforcement for rehabilitation has a number of advantages over the more common externally bonded FRP reinforcement, including, the potential for reduced surface preparation, which in turn reduces the impact to traffic. Furthermore, this reduces the likelihood of debonding failures from the concrete surface due to significantly improved anchoring ability and improved protection from mechanical damage provided by recessing the NSM reinforcement into the concrete surface.

What We Did

This project was a preliminary experimental investigation to explore the application of composites for increasing the capacity of the overhang region of the bridge deck. The objective was to test one rehabilitation method in order to provide preliminary validation of the technique.

Description of the Work

The overall test configuration used for this experiment consisted of a conventionally reinforced concrete two-cell box girder, with a center-to-center span of 1830 mm (6 ft) between each of the girders, a deck thickness of 178 mm (7 in), and a distance from the stem wall to the edge of the overhang of 483 mm (19 in). In order to allow for multiple independent tests, the test specimen was cut into two separate sections that were 1.68 m (5ft 6in) in length.

The first portion of the concrete box girder specimen was tested as-built, without FRP strengthening and the second portion was strengthened with NSM CFRP strips prior to testing. Vertical loads were applied to the edge region of the deck slab using two hydraulic jacks spaced 1.83 m (6 feet) apart that were connected to a steel loading beam positioned 76 mm (3 in) on-center from the end of the overhang section of the deck. The overall test setup is shown in Figure 1.

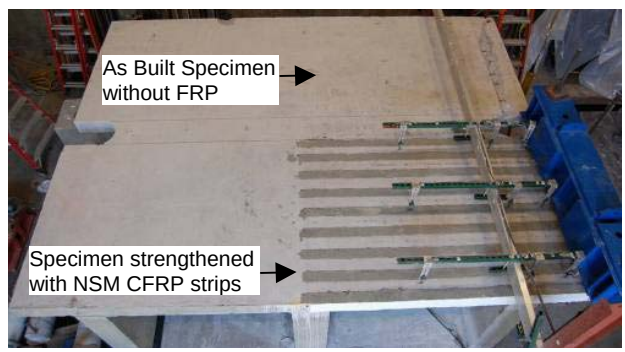

Figure 1: Test setup

The increased moment demand on the test specimen's deck slab due to the addition of the sound wall was calculated and this value was used as the basis for determining the desired capacity increase. Seven strengthening product options were evaluated for this rehabilitation design; including different pultruded carbon fiber rods and strips. From a construction viewpoint, strips as opposed to rods are far easier to implement due to required groove depth. Given that there is often less cover on the top of a slab than would be required, cutting deeper grooves is hazardous in that the cuts could easily cut through existing steel reinforcing bars. Furthermore, shallower grooves as allowed by the use of FRP strips, is preferred in Europe after extensive field use.

Based on guidelines and material cost considerations, the CarboDur strips were approved for use. Because the smallest size strip far exceeded the required moment capacity, the CarboDur S512 strips were selected, which

have a 50 mm (2 in) width. The spacing was set at 203 mm (8 in) on center for the width of the test specimen.

Research Results

Experimental results from the rehabilitated specimen indicate the NSM strengthening scheme was successful at achieving the desired capacity increase. The ultimate load carrying capacity of the FRP rehabilitated specimen was 196 kN (44 kips) per hydraulic jack, which was 78% higher that the ultimate load of the as - built specimen of 114 kN (26 kips) per hydraulic jack. This value exceeded the desired load capacity increase of 29.7% above the experimentally determined capacity of the as-built specimen. As shown in Figure 2, the specimen exhibited a stable structural response and increased deformation capacity as shown by the load versus deflection profile.

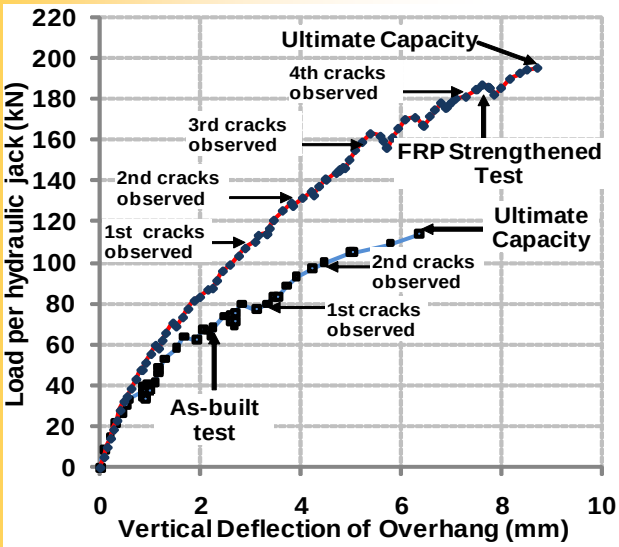

Figure 2: Response of as-built and strengthened specimen

An examination of the strain profiles throughout the strengthened specimen indicates the maximum strain in the CFRP strips occurs directly above the edge of the stem wall adjacent to the deck overhang, as shown by strain gage "5B" in Figure 3. The sharp drop in strain values at distances away from the adjacent stem wall and the insignificant strains within these regions indicate significantly shorter lengths of CFRP strips could be used to improve constructability without affecting load transfer and the overall system response.

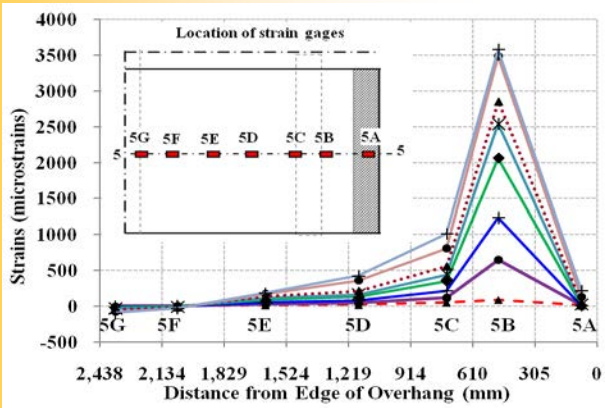

Figure 3: Strain Profile along the middle of the specimen

The FRP strip failure surface is shown in Figure 4. The center portion of the strip with the firmly attached concrete was the region in which the interfacial failure in the concrete occurred during the test, as opposed to the outer sections of the strip that were detached from the resin system after the test was complete.

Figure 4: Detail of concrete failure surface of FRP strip

The NSM FRP rehabilitated specimen exhibited a variety of structural performance improvements over the as-built specimen including increased ultimate load carrying capacity, enhanced deformation capacity and more stable overall structural performance. Design options for the CFRP strengthening schemes allow for flexibility in terms of tailoring the reinforcement parameters for specific applications, as well as minimizing traffic disruptions.

Recommendations

The purpose of this study was to experimentally demonstrate the efficacy of NSM for purposes of strengthening. Based on this work, additional study of the following items are recommended as a follow-on project:

- complete review and comparison of the failure modes and mechanisms for bars/rods and flat strips;
- optimize groove dimensions and spacing for NSM use through analytical and experimental study;
- study adhesive rheology bond quality and durability;
- study minimum development length and effect of insertion into girder stems; and
- develop design guidelines and examples.

It is emphasized that the studies should be conducted on specimens of sufficient size since small specimens are likely to provide erroneous results due to effects of scale and configuration. It is recommended that these tests only be conducted after a review of advances in Europe and Australia are completed and sufficient analytical work is completed on optimization of groove dimensions and spacing.

For more information on this project, contact

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