RECENT ADVANCES IN THE USE OF POLYMER COMPOSITES IN HIGHWAY BRIDGE APPLICATIONS

Ayman S. Mosallam, Ph.D., P.E.
University of California, Irvine, USA
E-Mail: Mosallam@uci.edu

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1 General Introduction

This paper provides an overview on some of the latest advances in bridge rehabilitation and safety. In the rehabilitation side, innovative polymer composite systems were developed, evaluated and applied on a portion of the Sauvie Island highway steel bridge in Portland, Oregon. A description of the field application of the composite systems is presented. The use of hybrid composite decks for providing an efficient solution for the chronic fatigue problem of the lift span of the Schuyler Heim highway bridge in Long Beach, California is also presented. In addition to weight saving, the composite deck has a superior fatigue properties and high strength-to-weight and stiffness-to-weight ratios as compared to the existing welded steel gratings. In this program, a pilot project in developing field emergency repair procedure was conducted and the repaired deck exceeded the strength of the undamaged deck by over 25%. Rapid and emergency repair of reinforced concrete bridge columns is another successful application of FRP composites. The results of a pilot project aiming at evaluating repaired shear-deficient columns damaged by a simulated gravity and cyclic forces are summarized. Experimental results indicated that the use of composites as external jackets can be performed rapidly in the field with minimum workmanship requirements in addition of being a cost-effective solution capable of not only restoring the original capacity of the damaged columns, but also increases its shear strength and ductility. In addition, details of an innovative functionally-degraded sandwich system for enhancing the high-energy impact resistance of reinforced concrete highway bridge girders are discussed.

2 Structural Upgrade of Steel Bridges

The innovative sandwich system was developed by the author specifically for steel strengthening applications. The reinforcing honeycomb polymer composite panels consist of high strength composite facie sheets bonded to a lightweight high-density/high-strength aluminum core. The H-Lam panels were designed such that they are both thermally and mechanically balanced. The face sheets of the composite sandwich panels are comprised of $0^o/90^o$ carbon/epoxy laminates with E-glass/epoxy thin laminates at the interface with the steel girder and the aluminum honeycomb core. The H-Lam used in this study also has an E-glass/epoxy cover layers to protect the carbon-based composite panel from galvanic corrosion (*the galvanic corrosion occurs upon direct contact of the carbon/epoxy to steel in the presence of moisture, which in this application is unavoidable*). In addition, the H-Lam panels have an E-glass peel-ply (*refer to Figure 1-a*) to protect the pretreated face sheet to be bonded to the steel bottom girder. The cyclic results indicated the stability of the bond line of the H-Lam strengthened beam at both zero and maximum shear stresses locations, while the CFRP strips may have shown instability, at end locations where shear stresses are maximum. The results of the ultimate tests indicated that the use of the composite system increases the flexural capacity of the control beams. The net strength gain for specimens strengthened with the H-Lam system was almost double of the strength of the beam strengthened with the CFRP strips (27.5% vs. 15.4% as compared to the ultimate capacity of the control steel beam). Based on the successful verification tests results, the H-Lam system was approved by the bridge division for actual bridge installation. The field application was performed on selected steel girders of a selected span of the Sauvie Island Bridge (refer to Figure 1-b).

3 Composite Bridge Decks Applications

The lift span of the 55-year old, 1,212-ft (370 m) long four-lane Schuyler Heim steel bridge located in Long Beach, California (see Figure 2), have been suffering from localized failure of welded steel gratings due to the high fatigue and impact loads resulting from the heavy truck traffic in and out the Terminal Island of the Long Beach Harbor.

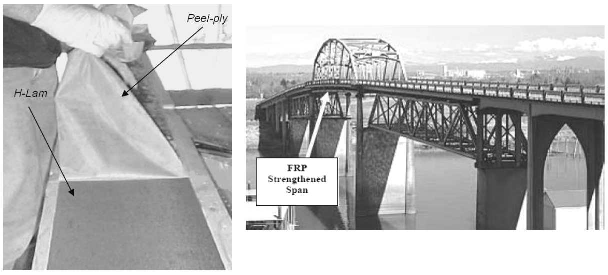

Fig. 1 (a) The H-Lam Strengthening System, (b) The Sauvie Island Bridge, Portland, Oregon, USA

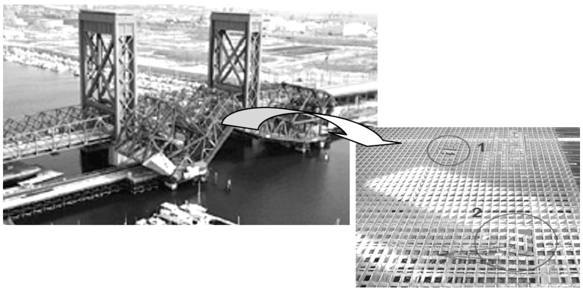

Fig. 2 Fatigue Damages of the Lift Span of the Schuyler Heim Highway Steel Bridge

California Department of Transportation (Caltrans) decided to take the advantages of the known high fatigue characteristics of composites to establish an effective remedy to this problem. The primary design criteria were limited by weight and profile depth. The weight of the composite deck was limited to 24 lbs/ft^2 (1.15 kPa) with a maximum total depth of 5 inches (127 mm) in order to match the existing grades of the bridge. The new composite deck was designed to carry 1.25 of the current rated capacity of the welded steel bridge deck (90 kips/400kN vs. 72 kips/320kN) and maximum deflection of (Span/500) or in this case 0.096" (2.5 mm). A comprehensive component- and system-level testing program was conducted at UCI and optimization to the deck design was performed using GENOA software prior to field applications. The construction was conducted in two consecutive weekends in 2003 for minimum traffic interruption. In order to monitor the long-term performance of the composite deck, strain gages were applied to different sections and are currently being monitored. No damages have reported since October 2003.

4 Emergency Seismic Repair of Reinforced Concrete Bridge Shear Columns

In a pilot study conducted at UCI, a shear-damaged RC circular column was repaired by a combination of fast setting epoxy mortar and carbon/epoxy jacket, and retested under lateral cyclic loading (see Fig. 3). Test results indicated that the column regained both its strength and ductility in comparison with a similar as-built column retrofitted by a composite jacket. This clearly demonstrates the effectiveness of such a scheme of repair that can be used to provide fast emergency repair of bridge columns, thereby reducing the traffic impacts due to bridge closure.

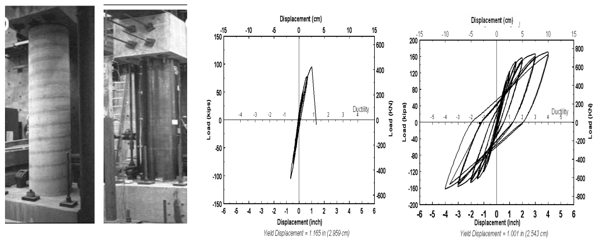

Fig. 3: Full-Scale Cyclic Tests of As-Built and FRP-Repaired Columns

5 Impact Protection of Bridges

One of common damages in existing highway bridges is the localized damage at the bottom corners or edges of the reinforced concrete beams or box girders induced by an impact of trucks exceeding the allowable height clearance of the bridges. Due to collision impact of the trucks, the bottom or outer layers of concrete girders are usually peeled off (see Figure 4) so that the steel reinforcements are exposed to the surrounding environment and subjected to corrosion. An over height collision protection or scarifying system is was developed to protect concrete girders from such impact damage. Full-scale impact test results confirmed the success of the I-Lam system in protecting the RC beams from both localized and global damages. Based on the success of the I-Lam system, Ohio Department of Transportation (ODOT) has approved the installation of the system on one of problematic bridges. The installation will occur in the next few months. Following the installation, an integrated health monitoring system will be implemented using piezoelectric sensors.

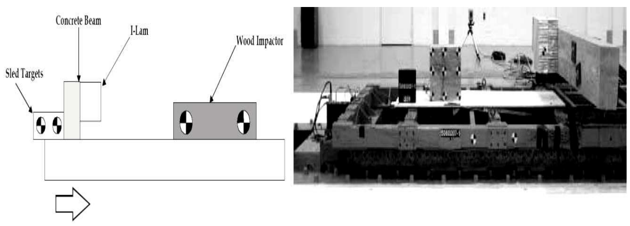

Fig. 4 Typical Test Setup for Full-Scale Impact Tests