Composite Structures 57 (2002) 373–375

COMPOSITE STRUCTURES

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Rehabilitation and field testing of an FRP bridge deck on a truss bridge

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Abstract

A light-weight FRP deck was used, on an experimental basis, to replace a heavy deteriorated concrete deck improving the load rating of a 60-year old truss bridge located in Wellsburg, New York. This was the first such application in New York State. Load testing was conducted after installation of the FRP deck to study its behavior. Results indicated the conservative nature of the deck design, and no composite action between the deck and the superstructure. The study also shows that the joints are only partially effective in load transfer between panels.

1. Introduction

New York State has many old truss bridges. Several of these bridges are restricted to less than legal loads due to deteriorated superstructures. Replacement is often a cost-effective option to improve the load carrying capacity. In certain cases, the load capacity of these bridges can be improved by replacing the heavy deteriorated concrete bridge decks with lighter decks. The allowable live load capacity increases with the dead load reduction and the rehabilitated bridges can carry legal loads without extensive repairs. FRP decks are relatively lighter than concrete decks and seem to offer a cost-effective alternative to complete replacement in such situations. The simple, modular nature of FRP deck construction is an additional benefit. Installation is relatively fast, reducing the inconvenience to traveling public.

New York State has installed a FRP bridge deck, weighing nearly 80% less than the concrete deck it replaced, on a truss bridge as an experimental project to improve the load rating of a 60-year old truss bridge. Reducing the dead load allowed an increase to the live load capacity of the bridge without significant repairs to the existing superstructure, thus lengthening the bridge's service life. Load testing was conducted after installation of the FRP deck to study the conservativeness of the design, ascertain the assumptions made on composite action between the deck and the superstructure, and examine the effectiveness of joints in load transfer [1]. This paper summarizes the study.

2. Bridge structure and rehabilitation

The Bentley Creek Bridge carries State Route 367 over Bentley Creek in the village of Wellsburg, Chemung County, New York (see Fig. 1). Built in 1940, it is a simply supported, single-span, inclined top chord, Warren steel truss structure with a concrete deck and asphalt wearing surface [2]. The bridge is 42.7 m long, 7.3 m wide curb to curb, and has a skew of 27°. The floor system consists of steel wide-flange floor-beams and stringers. A 1.85-m wide sidewalk is located outside the east truss. The bridge carries two lanes of traffic, has an average daily traffic (ADT) flow of 3248, and 7% of the ADT is truck traffic [3].

The bridge was weight restricted to 14 tons by the end of 1997 due to increased dead load from asphalt overlays applied over time, steel corrosion on the trusses and floor system, and a deteriorated deck. Even though the deck was seriously deteriorated, the steel trusses were found to be in relatively good condition. Replacing the existing deck with a lightweight FRP deck (weighing

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PII: S0263-8223(02)00104-6

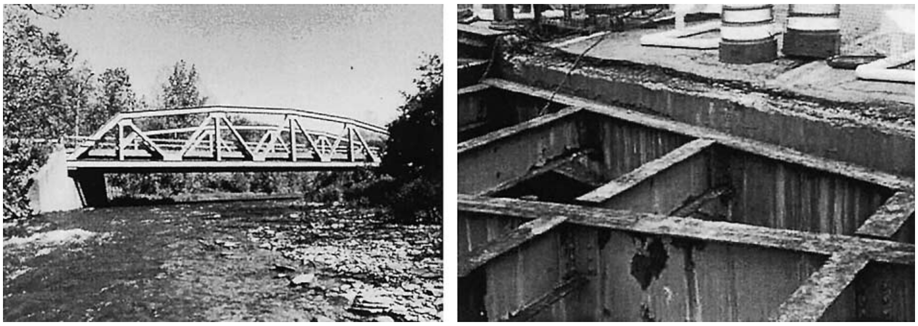

Fig. 1. Views of Bentley Creek Bridge before rehabilitation.

1.53 kPa compared to the current deck weight of 8.13 kPa) and repairing superstructure would prolong the structure's service life and also remove the load restrictions.

The old deck was replaced with a lighter GFRP deck panels, made by Hardcore Composites of Delaware (Fig. 2). The deck is a cell core structure made of E-glass stitched fiber fabric wrapped around 150 mm × 300 mm × 350 mm isocycrinate foam blocks used as stay-in-place-forms. The deck was designed for AASHTO MS23 live-load [4] using finite element analysis. Orthotropic in-plane properties were used in the analysis. Stresses in the composite materials were limited to 20% of their ultimate strength; and deflection was limited to span/800.

The deck panels were designed to span between the floor-beams. The connection details were designed to prevent composite action between the deck and the superstructure. The panels were connected to each other using epoxy. The epoxy joints consist of a longitudinal joint that runs the entire length of the bridge and four transverse joints that each span one lane. A 10-mm thick Transpo T-48 epoxy thin polymer overlay was used as the wearing surface of both the deck and sidewalk. More details on deck fabrication, design details, and construction procedures can be found in Alampalli and Kunin [1].

3. Load testing

A load-test with known truck weights was conducted, in November 1999, to verify some of the design assumptions considered critical for future projects. The main test objectives included checking if composite action exists between the FRP deck and the floor-beams, and determining the effectiveness of the deck joints in transferring loads [1].

The FRP deck and a steel floor-beam were instrumented with strain gages at selected locations to meet the objectives of the testing. A total of 18 strain gages were used, 6 bonded to a steel floor-beam and 12 bonded to the bottom face of the FRP deck. Two NYSDOT dump trucks were used to load the bridge (see Fig. 3). Each fully loaded truck closely resembles a M-18 AASHTO live-loading [1,4]. Both static and semi-static tests were conducted. In the semi-static case, each truck was driven across the bridge—only one truck was on the bridge at a time—in the northbound lane at 5 km/h.

4. Load test results

Strain gages were mounted on a steel floor-beam supporting the FRP deck to determine neutral axis of the deck–floor-beam system. The results showed that the

Fig. 2. Composite deck panels during installation.

Fig. 3. Load testing.

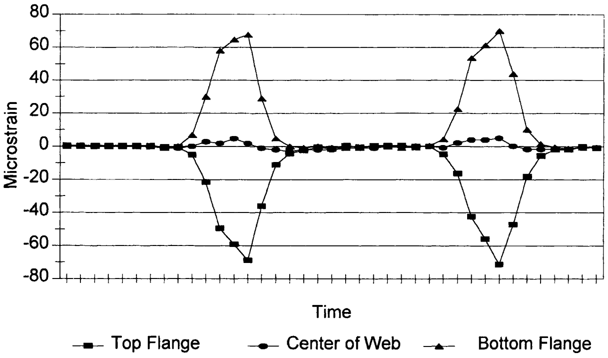

Fig. 4. Data from strain gages on steel floor-beam.

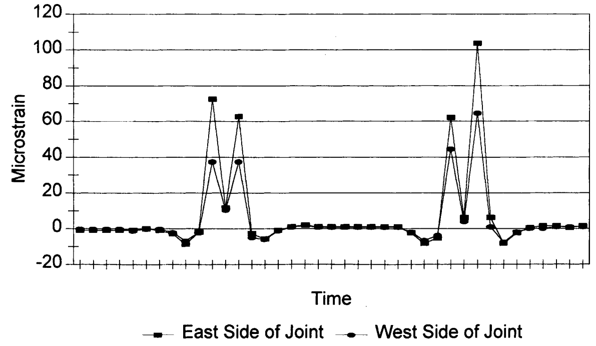

Fig. 5. Data from strain gages on both sides of the longitudinal joint.

strains in bottom and top flanges are almost the same except for the sign, with negligible strain at the center of the girder (see Fig. 4). This indicates that the neutral axis of the girder is unchanged with the addition of the FRP deck. This validates the design, which assumed no composite action between the deck and the floor-beams.

The deck panels were connected to each other with epoxy resin on the vertical faces as well as with top and bottom FRP cover plates. There is no other mechanical shear-key mechanism. Strain gages were installed on both sides of the longitudinal joint and the panel one side of the joint was loaded to study the effectiveness of the joint. These results, as shown in Fig. 5, indicate that the longitudinal joint is transmitting loads from one deck segment to the other, but the load is not completely carried across the joint.

The maximum longitudinal and transverse stresses during the load tests were 2.9 and 1.6 MPa, respectively. These values relatively small when compared to ultimate strength of the FRP decks (221 MPa). Thus, the deflection criteria, limiting maximum deflection to span/800, controlled the design. Figs. 4 and 5 show the strain distributions, under semi-static live load, in both the floor-beam and the bottom face of the deck. The data shows that the deck strains directly under wheel loads are a combination of global bending and local bending. The results show that the strains are very high under the wheel loads and rapidly decrease (when compared to floor-beam strains), indicating that local bending effects dominate the deck strains. These local effects may play a major role in the performance of bridge components such as wearing surfaces and should be properly accounted for in future designs.

5. Conclusions

The first fiber reinforced polymer deck, installed on a 42.7 m truss bridge in New York State was load tested to study its behavior. The FRP deck was designed and fabricated conservatively. No composite action between the deck and the superstructure exists as assumed in the design. The longitudinal joint is transmitting loads from one deck segment to the other, but the load is not completely carried across the joint. The test data indicates that localized bending effects may play a role in the strain distribution of FRP decks and should be appropriately considered.

Acknowledgements

Instrumentation and data collection for this project was conducted by George Schongar and Harry Greenberg of the Transportation Research and Development Bureau. The authors acknowledge Jerome O'Connor, Regional Bridge Management Engineer in Region 6 of NYSDOT, and his staff members for their assistance with the test coordination and traffic control.

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