TECHSUMMARY March 2014

State Project No. 736-99-1370 / LTRC Project No. 05-5ST

Development and Performance Evaluation of Fiber Reinforced Polymer Bridge

INTRODUCTION

Conventionally, highway bridge decks in the US are predominantly made of steel-reinforced concrete. However, repair and maintenance costs of these bridges incurred at the federal and state levels are overwhelming. As a result, for many years, there has been pressure on transportation agencies to find new cost-effective and reliable construction materials. A very promising alternative is the fiber reinforced polymer (FRP) bridge deck system. FRP composites have found increasing applications in bridge design and construction. Light weight, high strength and stiffness, durability, and ease of construction are major advantages of FRP material. Meanwhile, issues such as high initial construction cost, lack of design guidelines or standards, and the materials' sensitivity to ultraviolet radiation, etc. do still stand against FRP's widespread application.

OBJECTIVE AND SCOPE

The objectives of this research were to develop a FRP-wrapped balsa wood bridge deck system suitable for replacing a damaged steel grid deck in the bridge chosen for this project, assess the options for long term monitoring, and develop long-term monitoring guidelines.

These objectives were achieved by focusing on detailed literature review, planning and designing to opt for the best FRP deck configuration, and developing comprehensive plans to provide performance evaluation and continuous monitoring of the new structural system developed in this project. The ultimate objective was to take advantage of the promising characteristics of FRP materials to develop a more durable, less maintenance intensive bridge system to save the limited budget for more urgent needs in the transportation infrastructure system.

The scope of this work included finite element prediction, performance evaluation and quality assurance through laboratory and field bridge testing, along with development of long-term monitoring strategies. The FRP-wrapped balsa wood deck system was selected and provided by the DOTD to the research team.

Figure 1 . Old damaged steel grid deck and new FRP-wrapped balsa wood deck

LTRC Report 472

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METHODOLOGY

To achieve the research objectives, the research work was classified into four parts. The first part involved developing a numerical prediction procedure whose results were compared to available laboratory or field testing results to calibrate the finite element models. The second part was to use the predicted bridge performance to design instrumentation and monitoring systems. The third part involved field installation and testing, and the final part developed a long-term monitoring strategy.

CONCLUSIONS

A pilot demonstration project of a FRP-wrapped balsa wood bridge deck system was developed and has been installed in Louisiana. Extensive monitoring strategies were implemented to evaluate both the short- and long-term performance of this bridge using conventional gauges along with the new generation fiber optic sensors. The small size, light weight, and passive monitoring capabilities of fiber optic sensors make them an optimal choice in continuous long-term applications such as in this bridge.

After installation, a live-load test scheme was conducted to study the initial performance of the new bridge system. The analysis of the data collected from various gauges used during this test led researchers to arrive at these preliminary conclusions:

- The maximum tensile strain measured at both deck and girder members remained well below the original design limit, thus assuring the structural integrity of the new deck girder system.
- The strain data collected from both BDI and FBG strain gauges enabled neutral axis estimation and revealed that partial-composite action was pertinent between the epoxy glued FRP deck and steel girder.
- Although the tensile strain profiles of the steel girders from field data were similar to those from finite-element analysis of the composite model of the bridge superstructure, only a non-composite model could generate strain profiles similar to those collected from the deck. Uncertainties in the overall material property estimations used as inputs in the FEM model may have influenced the discrepancies visible in field and analytical data comparisons.
- The acoustic sensors used during this load test helped to establish a baseline AE data trend to assess the integrity of glued FRP bridge deck-steel girder bond. Any change in this trend in a future test can help to reveal any discontinuities in this bond line over time.
- The existence of partial composite action between the superstructure components was also ascertained from the accelerometer readings.
- The similarities obtained by comparing strain profiles gathered at the same locations by both BDI and FBG sensors allows for the continued use of the permanently installed FBG sensors on the bridge for long-term bridge performance monitoring.

Problems Encountered after Bridge Opening

Several years after the deck had been placed and opened to traffic, local residents started complaining about loud noised at night when trucks crossed the bridge. A DOTD team went the bridge site to investigate the complaint. Trucks crossed the bridge and no loud noises could be heard. As complaints continued, the DOTD bridge maintenance team went and took a full-depth core from the deck. It was discovered that there was a delamination problem between the hardwire wrapping material and the top FRP layer. As a result, DOTD decided to remove the deck and replace it with a new steel grating.

In November 2013, an inspection of the six bridge panels stored at the bridge maintenance yard revealed that five of the six did not show any sign of delamination. The manufacturer of the bridge panel indicated that he experienced a problem during the infusion of the epoxy in the system. The top FRP surface shifted during fabrication. The fabrication process had to be stopped to rearrange that surface. That led to a delay in completing the infusion and could have resulted in too little epoxy at the top of that one panel.

RECOMMENDATIONS AND IMPLEMENTATION

Despite the fabrication problems encountered several years after the bridge had been opened to traffic, this project has demonstrated the practical potentials of both FRP-wrapped balsa wood decks as viable counterparts of conventional deck grating and concrete decks.

It is recommended that DOTD implement this product with tighter QC/QA in order to avoid any potential fabrication problem.