

Field Testing of an FRP Temporary Bypass Bridge

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ABSTRACT

Composite materials have progressively made their way into many aspects of engineering applications, from reinforcing new and existing structures to repair of damaged sections and protection of critical members, etc. The possibilities are endless. The increased use of composite materials is in large part due to the creation of the Federal Highway Administration's (FHWA) Innovative Bridge Research and Construction (IBRC) program, which promotes and reinforces the use of innovative materials, construction techniques, and structures in general. This work is part of the IBRC program and was initiated by the Iowa DOT to evaluate the applicability of using a fiber reinforced polymer (FRP) composite bridge for use as a temporary bridge crossing. The entire 39-ft x 27-ft composite structure is composed of a foam core wrapped with layers of FRP and infused with resin. The structure comes in two sections, complete with curb and guardrail, which constitutes the entire superstructure of the bridge, and will replace the DOT's current steel temporary bridge. The scope of this work involves laboratory and field testing of the structure for validation of design assumptions and to obtain a full understanding of the benefits of using this type of structure for both temporary and permanent bridge applications. Results and observations obtained from this work will provide a basis for the development of design standards and details for future use of composite bridge structures.

Key words: bridge—composites—FRP

PROBLEM STATEMENT

For years the Iowa DOT has used small, mobile steel bridges for use as temporary structures for various applications. These bridge systems include sections composed of steel girders with a steel slat flooring system and steel guardrail, as illustrated in Figure 1. In general, these structures have served their purpose well. However, the heavy, cumbersome sections have worn down, deteriorated, and become outdated over the years and are in need of replacement. Therefore, the Iowa DOT, through support of the Federal Highway Administration's (FHWA) Innovative Bridge Research and Construction (IBRC) program, opted to investigate the applicability of a composite bridge as a new temporary bridge system. The replacement system, a fiber reinforced polymer (FRP) composite bridge, is lighter, potentially easier to transport, and the few components that may deteriorate are readily replaceable (see Figure 2). This new composite structure consists of two sections, each with a guardrail attached to one side, built-in lifting lugs, replaceable wearing surface, and, once the two panels are joined, a suitable two-lane structure.



Figure 1. Current steel bypass bridge used by the Iowa DOT



Figure 2. Proposed bypass bridge, w/o guardrail or other hardware, to be used by the Iowa DOT

RESEARCH OBJECTIVES

The objectives of this work are threefold: (1) to validate through laboratory and field tests the design assumptions and structural adequacy of this structure for the designated purposes; (2) to evaluate the load distribution characteristics of the bridge components and system as a whole; (3) through physical load testing determine both the short- and long-term durability of the structure. In addition, from the results this research will provide information regarding the viability of this type of structure for this and other possible applications.

The scope of work includes a review of past and current tests performed on similar structures, as well as any other research regarding composite structures. Once substantial background knowledge is obtained, laboratory tests will then be conducted to safely evaluate the load carrying characteristics and capabilities of the temporary composite bridge to be utilized by the Iowa DOT. Following the laboratory evaluation, field tests will be conducted with the structure in service and under service-level loads. Upon completion of all laboratory and field tests, a final report detailing the general, structural, and serviceability performance of the structure will be completed.

DESIGN AND FABRICATION

Based on the temporary bridge design guidelines provided by the Iowa DOT, a design was developed and presented to the Iowa DOT by Hardcore Composites, Inc. Final design calculations were completed by the fabricator, Hardcore Composites, and checked by engineers at the Iowa DOT and Iowa State University. Final design included two 13.5-ft x 39-ft, 10-in. deck panels measuring approximately 3 ft in thickness, connected together to provide for two lanes of traffic. See Figure 3 for design sketches of the panels and related details. Each panel is composed of seven layers, called plies, of TV3400 FRP fabric on the bottom and top, and three plies on each vertical side. These layers of FRP provide the resistance to bending stresses in the structure. The core of each panel is composed of 600 8-in. x 16-in. x 36-in. foam bottles individually wrapped with one ply of FRP, and as a whole provide the shear resistance for the structure. Once all the bottles are installed and wrapped with FRP plies, vinyl ester resin is infused into the structure through a process called vacuum-assisted resin transfer molding (VARTM). Figures 4 thru 7 illustrate various stages of fabrication of the FRP panels.

At calculated locations, eight foam bottles in each panel were replaced with bottles outfitted with lifting hardware, as shown in Figure 8. The lifting hardware consists of an anchored steel plate with a threaded hole to accept bolt-on D-rings. Connection of the two panels is accomplished by means of 1-in.-thick by 16-in.-wide steel plates running the length of the bridge on the top and bottom of the centerline joint. The top and bottom plates are then connected with threaded rod through the FRP panels (see Figure 3c). Attachment of the guardrail is completed by means of a base plate attached to each guardrail post and a plate on the bottom of the deck; again, the two plates are connected with threaded rod through the FRP panels. The guardrail system for the temporary composite bridge is composed of all-steel components, including a w-shape rail post, steel tube rails, and a curb constructed of steel angle and gusset plates. Figure 3c illustrates a cross-section view of the guardrail system. The wearing surface of the deck panels consists of a 3/8-in. layer of abrasive epoxy covering the entire deck surface, except the areas occupied by connection plates (see Figures 7 and 9).



Figure 3. Iowa DOT FRP bypass bridge

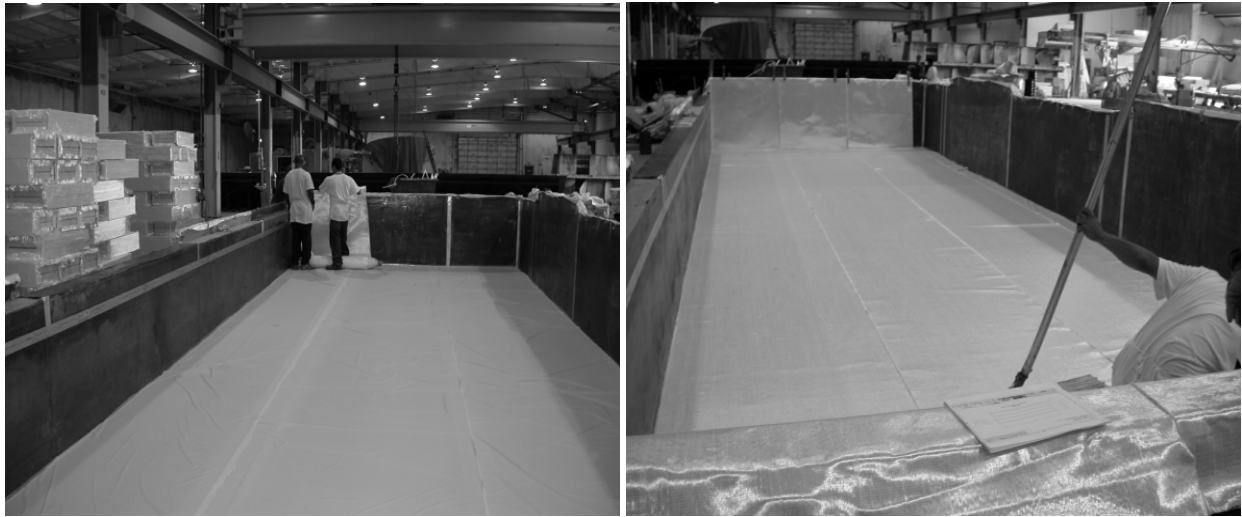


Figure 4. Installation of bottom FRP plies



Figure 5. Installation of FRP wrapped foam bottles



Figure 6. Example of VARTM process



Figure 7. Guardrail and centerline attachment locations



Figure 8. Threaded insert for installation of lifting lugs

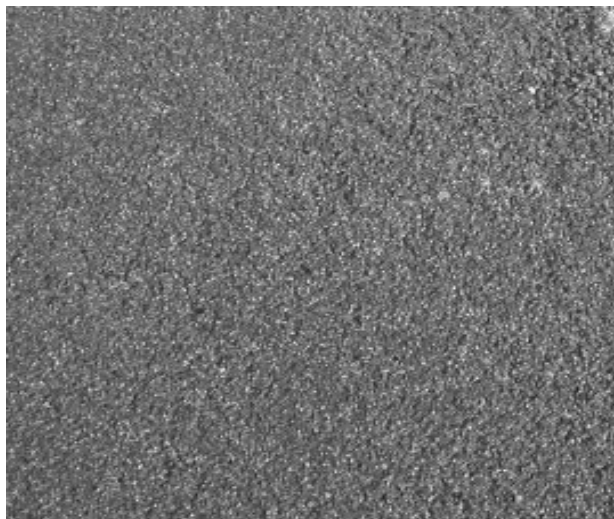


Figure 9. Epoxy wearing surface

INSTALLATION

Delivery and placement of the FRP deck panels was accomplished by means of a semi-trailer and a medium-sized truck crane. In the case of the Iowa DOT bypass bridge, the deck panels were both delivered on one flatbed semi trailer stacked one on top of the other (see Figure 10). Load testing of the deck panels was initially intended to take place in one of Iowa State University's structural engineering testing laboratories. However, due to tight tolerances between the width of the deck panels and the width of the overhead door, testing was moved to an outdoor area on Iowa DOT property.



Figure 10a. Side view



Figure 10b. Rear view

Figure 10. Delivery of Iowa DOT composite bridge

Two 30-ft-long w-shapes were placed on the ground and braced for use as temporary abutments, and a 65-ton hydraulic truck crane was rented for unloading and setting the deck panels (see Figures 11 and 12). Each of the deck panels, weighing approximately 17,000 lbs each, was unloaded and placed on the temporary abutments with 10 in. of bearing on neoprene pads at each abutment and a 1-in. gap between the deck panels, as specified in the plans. Once the panels were in the proper location, a steel fabricator was brought in to take measurements for the center connection plates and the guardrail attachment plates. Installation of the center connection plates, guardrails, and s-clips used to attach the panels to the abutments will occur immediately after fabrication of the various custom pieces and testing of an individual panel.



Figure 11. Unloading of individual deck panels



Figure 12. Temporary abutments for Iowa DOT composite bridge

RESEARCH METHODOLOGY

In an attempt to validate the design assumptions/calculations and to obtain as much information about the load distribution and serviceability characteristics of this structure, controlled outdoor laboratory tests will be conducted, in addition to a full-scale load tests, once the structure is in service. For the outdoor laboratory tests, the structure will be loaded from below using individual point loads reacting against the self-weight of the structure. These point loads of predetermined magnitude will be positioned at strategic locations such that, through the principal of superposition, stresses, strains, and deflections analogous to the design truck may be obtained. For completeness, tests will be conducted on one individual panel independently before being connected to the adjacent panel; similar tests will then be repeated on the two-panel system after being connected. Once in service, the structure will then be field tested with a fully-loaded truck to re-evaluate both the design assumptions and the results obtained from the laboratory style testing. The instrumentation layout for the in-service field load tests will duplicate that used for the laboratory style testing completed previously.

Instrumentation will include string potentiometer deflection transducers and strain gages from Bridge Diagnostics, Inc. (BDI). Displacement transducers will be installed underneath the panels for the measurement of global deflection of the individual panel and the two-panel system. In addition, deflections measured transversely across an individual panel and the two-panel system will provide an indication of the level of transverse load distribution of the FRP composite bridge. Strain gages will be strategically placed in areas and arrangements such that the following structural behaviors may be assessed: (1) validation of the transverse load distribution behavior, both from panel to panel and from bottle to bottle in an individual panel; (2) longitudinal load distribution; (3) strain distribution; (4) strain developed in the center steel connection plate; (5) type of behavior (slab vs. girder); (6) validation of design moments; and (7) strain distribution and location of the neutral axis. The BDI strain gages on the bottom of the deck will be attached directly to the structure with epoxy and will require minor preparation work. However, in order to obtain accurate strain measurements on the top of the deck, small areas of the wearing surface will be removed to allow for proper attachment of the strain gages to the panels. In addition, strain gages will be applied on the exterior side of the panels and the steel connection plate on both the top and bottom of the bridge to obtain as much information as possible about the structure. See Figure 13 for tentative instrumentation plans for testing of the Iowa DOT temporary bypass bridge.

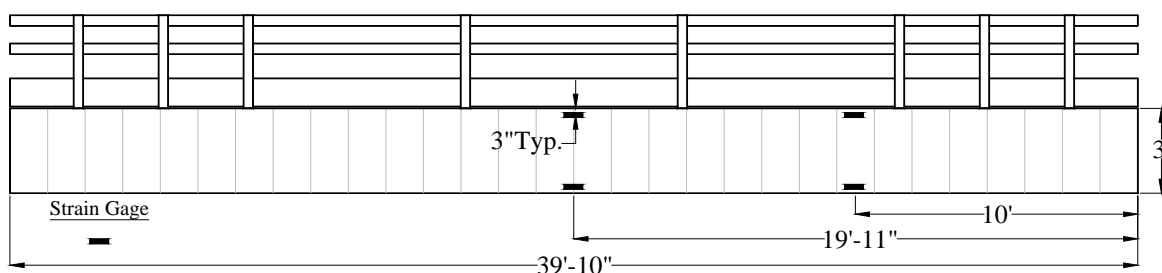


Figure 13a. Location of strain gages on side of panels

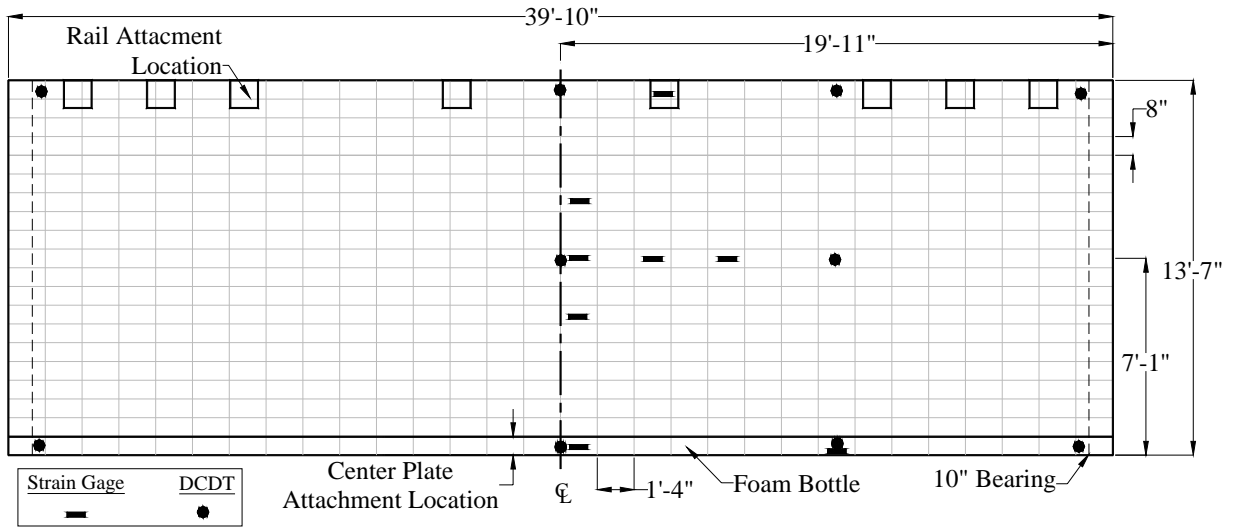


Figure 13b. Plan view of instrumentation layout for test of individual panel

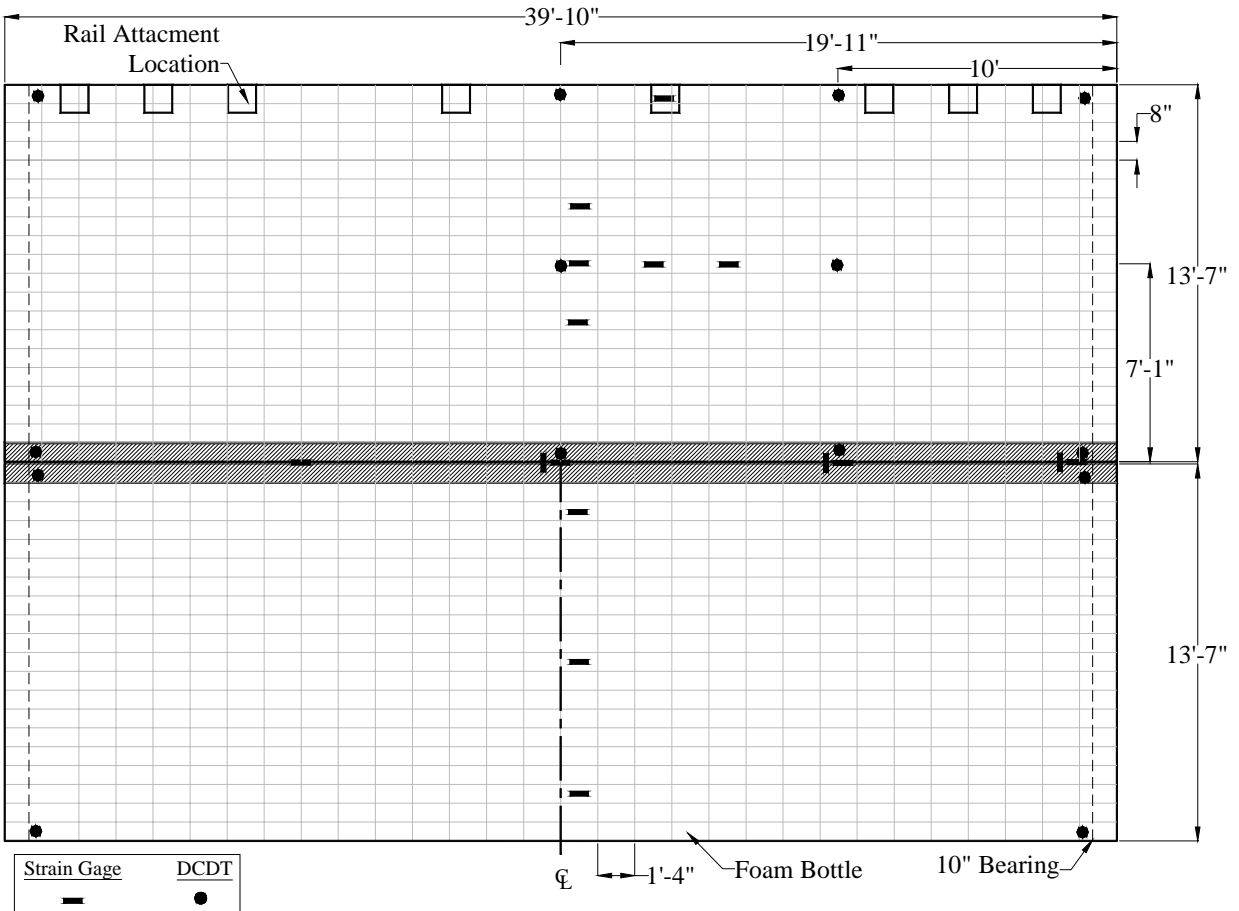


Figure 13c. Plan view of instrumentation layout for test of complete bridge system

Figure 13. Tentative instrumentation plan for testing of the Iowa DOT temporary bypass bridge

ANTICIPATED RESULTS

The test results obtained from both the outside laboratory tests and the field load testing of the bridge will be used to develop a better understanding of the structural characteristics of this type of bridge, such as load distribution, stress/strain distribution, and deflection behavior. In addition, over the life of the project, condition evaluations will be conducted to assess the durability of the structure. The combination of all the findings into a comprehensive report detailing the tips for optimizing installation procedures, expected performance of similar structures, and modes of deterioration to look for, if any, will provide a useful tool for those looking to invest in a comparable composite deck bridge. Furthermore, information obtained from this and other tests may be used to develop a rating system for this structure for the long-term use of the structure, as well as for future use and development of these structures in general.

SUMMARY

With the help of the FHWA's IBRC program, the Iowa DOT is experimenting with using a composite bridge as a temporary structure for use on various projects. The benefits of using this type of bridge include reduced weight, the entire bridge breaks down and is transportable on a single tractor-trailer semi, requires minimal setup time, and is highly resistant to deterioration. This type of technology is not new, but the actual structural behavior and response of these types of bridges is still undetermined and uncertain. The full-scale laboratory and field tests included in this work, along with other research, will both provide useful knowledge into the structural performance of composite bridges and will lead to the development of design standards, code references, and a general understanding of the uses of composite structures.

REFERENCES

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