Fiberglass Reinforced Polymer Composite Bridge Deck Construction in Illinois

CONSTRUCTION REPORT
PHYSICAL RESEARCH REPORT NO. 145
SEPTEMBER 2002

Illinois Department of Transportation
Bureau of Materials and Physical Research
126 East Ash Street / Springfield, Illinois / 62704-4766

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/IL/PRR 145		

4. Title and Subtitle	5. Report Date
FIBERGLASS REINFORCED POLYMER COMPOSITE BRIDGE DECK CONSTRUCTION IN ILLINOIS	September 2002
	6. Performing Organization Code
	8. Performing Organization Report No. Physical Research No. 145
7. Author(s) Thomas J. Winkelman	
9. Performing Organization Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, Illinois 62704-4766	10. Work Unit (TRAIS) 11. Contract or Grant No. IHR – R07
12. Sponsoring Agency Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, Illinois 62704-4766	13. Type of Report and Period Covered Construction Report September '01 - December '01 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

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The fiber reinforced polymer composite material used was "DuraSpan™" manufactured by Martin Marietta Composites. The composite tubes are manufactured by the pultrusion process. The tubes are pre-cut to fit the dimensions of each individual bridge and bonded together in the factory to form panels. The panels are assembled on the bridge deck with epoxied field joints to form the completed bridge deck.

This report summarizes the construction activities for the structure on South Fayette Street in Jacksonville. Details of the planning, design, construction methods, and construction costs are addressed.

17. Key Words	18. Distribution Statement
Fiberglass composites, Bridge Deck, "DURASPAN", FRP, Innovative Bridge Research and Construction Program.	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	20	

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Construction Report

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ABSTRACT

An experiment was conducted using a fiber reinforced polymer composite material for the bridge deck of a low volume bridge. The test location was on South Fayette Street over the Town Brook in Jacksonville, Illinois. This project included removal of the existing single span pony truss structure and replacement with a wider, and longer, three-span plate girder structure with the experimental decking material.

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DISCLAIMER

The contents of this paper reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views, or policies, of the Morgan County Highway Department, the Illinois Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of Calvin Hance and Francis Fitzgerald of the Morgan County Highway Department for their assistance with the project status and documentation throughout the construction of this project. The author would also like to recognize the assistance of James DuBose, Matthew Mueller, and Christopher Volkman for manuscript review.

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EXECUTIVE SUMMARY

The construction of a low traffic bridge deck using a fiberglass reinforced polymer composite material was investigated. The Illinois Department of Transportation and Morgan County Highway Department joined forces to construct the experimental project on South Fayette Street in Jacksonville. Funding for the experimental material was provided through the Federal Highway Administration's Innovative Bridge Research and Construction Program.

The existing 50-foot single span pony truss structure was completely removed and replaced with a three-span plate girder structure. The new bridge deck measures 63 feet long and 36 feet wide with a 35-degree angle skew. The experimental decking material, "DuraSpan™", was supplied by Martin Marietta Composites. The decking material was delivered to the jobsite by tractor-trailer and set in place on the structure with a crane. Shear studs were welded to the girders in pre-cut holes in the composite deck, and the entire deck was grouted to the substructure for composite action. A concrete curb and a steel guardrail were installed, followed by paving of the bituminous concrete wearing surface.

The research activities included with this project involve laboratory testing of material coupons, visual surveys of the in-place structure, and full-scale load testing of the in-place structure. The research activities are planned for a duration of five years.

Early conclusions from the construction of this structure indicate that the material can be handled and placed quickly and easily. No specialized labor force or equipment is required to construct the bridge deck. No conclusions have been drawn from initial laboratory testing of the material coupons.

INTRODUCTION

The city of Jacksonville, Illinois had experienced problems with flooding along the Town Brook for many years. In particular, the structure carrying South Fayette Street over the Town Brook had flooded numerous times in recent years. This pony truss bridge, shown in Figure 1, was also in dire need of repair or replacement. Severe corrosion of the reinforcing steel and spalling of the existing concrete deck led to posted weight limits for the bridge. A project was initiated to replace the existing structure with a wider and longer structure. This project also called for raising the elevation of the structure, and the surrounding roadways, to prevent the recurring flood problems.

Figure 1
Existing Pony Truss Bridge

In an attempt to reduce the project cost to the City of Jacksonville, an application was made for federal funding through the Innovative Bridge Research and Construction Program (IBRC). In order to fulfill the requirements for the funding, an experimental material or construction process was required with the bridge construction. The decision was made to use a fiberglass reinforced polymer (FRP) composite material for the bridge deck. The selected composite material was "DuraSpan™" from Martin Marietta Composites. This report will cover the planning and design of the bridge, construction of the bridge with the FRP deck, and the project costs.

OBJECTIVE

The objective of this project is to evaluate the constructibility and performance of an FRP composite bridge deck system. This objective will be accomplished through construction inspection, performance monitoring, and laboratory testing. This report details the constructibility of the bridge deck system.

This project was constructed with partial funding from the Federal Highway Administration's IBRC program. This program was established to assist state, county, and local municipalities' incorporate innovative materials into their bridge projects. The intent of the program is to reduce the life-cycle cost of bridges, increase safety, and reduce congestion and delays associated with bridge construction.

PLANNING AND DESIGN

The plan for this project included replacing the existing structure on South Fayette Street over the Town Brook, and raising the elevation of the structure nearly six feet to place it above the 100-year high water elevation. South Fayette Street was raised and improved, as well as the adjacent intersection with West Chambers Street. Utility adjustments and earthwork were also required to complete the project.

The existing single-span pony truss structure was believed to be over 70 years old. The existing structure was 50 feet long and 24 feet wide. The bridge incorporated concrete column foundations to support the pony trusses. The pony trusses were secured together with hot rivets. The design of the new bridge included a three-span structure with W14 X 61 steel plate girders, the FRP composite decking material, and a bituminous concrete wearing surface. The new bridge is 63 feet long and 36 feet wide with a 35° right-ahead skew. The AASHTO design loading for the new bridge includes the dead load plus 25 pounds per square foot for a future wearing surface and an HS20 live load plus impact. Deflection tolerances of the deck were limited to L / 800 where L is the distance between adjacent plate girders.

The "DuraSpan™" composite material is a pultruded material composed of E-glass fibers in various fiber orientations and an isophthalic polyester resin binder. The pultrusion process involves pulling the glass fibers through a liquid resin bath and a set of heated dies to form the final geometric shape (tube) of the material, shown in Figure 2.

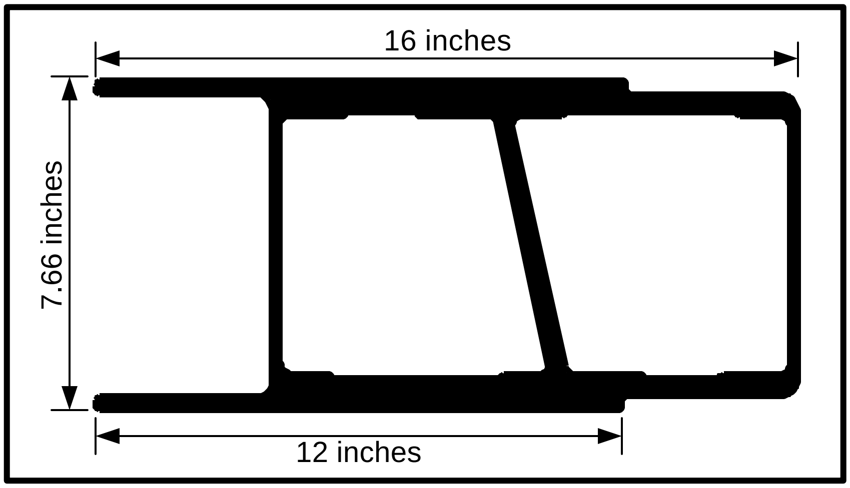

Figure 2
"DuraSpan™" Geometric Shape

The pultrusion process is a continuous process. Therefore, the tube must be cut to the proper length while the pultrusion process continues. Once several tubes of the material have been fabricated, they are bonded together in the factory with a two-part polyurethane adhesive to form a panel. The length of these panels is typically equal to the width of the bridge. The width of the panels varies from eight to ten feet based on transportation constraints. The final steps are cutting the shear stud pockets and applying a surface finish.

CONSTRUCTION

The construction of this project took place in the Fall of 2001. South Fayette Street and the adjacent intersection with West Chambers Street were completely closed to through traffic for the duration of construction. The existing structure was removed in mid-September and metal shell piles were driven for the new piers. The metal shell piles were filled and encased with concrete as shown in Figure 3.

Figure 3
Concrete Encased Metal Shell Piles

The pier caps and abutments were formed and finished, followed by placement of the steel plate girders on October 17th. Once the girders were set and anchored down, the contractor began tack welding L 2" X 3" X 0.125" angle irons onto the top flanges of the steel girders as shown in Figure 4. These angle irons were used as a temporary support for the FRP panels until they could be grouted in place. The void created by the angle irons was eventually filled with non-shrink grout in order to provide full contact between the steel girders and the FRP panels.

Figure 4
Angle Irons Tack Welded to the Girder Top Flange

The FRP panels arrived at the project by tractor-trailer, as shown in Figure 5, on October 30th. The panels were unloaded from the tractor-trailer by crane and stacked on the ground in their order of placement on the bridge. The first step was to clean all of the areas that would become part of a field joint with an acetone wash. Following the acetone wash, a primer coat was applied to the same areas. This process was completed with small paint rollers as seen in Figure 6.

Figure 5
Panel Delivery by Tractor-Trailer

Figure 6
Prime Coat Application

Prior to panel placement on the bridge structure, a bead of silicone caulk was applied to the top of the angle iron supports to seal the FRP panels to the angle iron and prevent future leaks of the non-shrink grout. In addition, the two-part epoxy used to bond the panels together in the field was mixed as seen in Figure 7. This epoxy was then applied to the top and front (Figure 8) of the male side of the joint, and to the bottom of the female side of the joint (Figure 9).

Figure 7
Mixing of Two-Part Epoxy

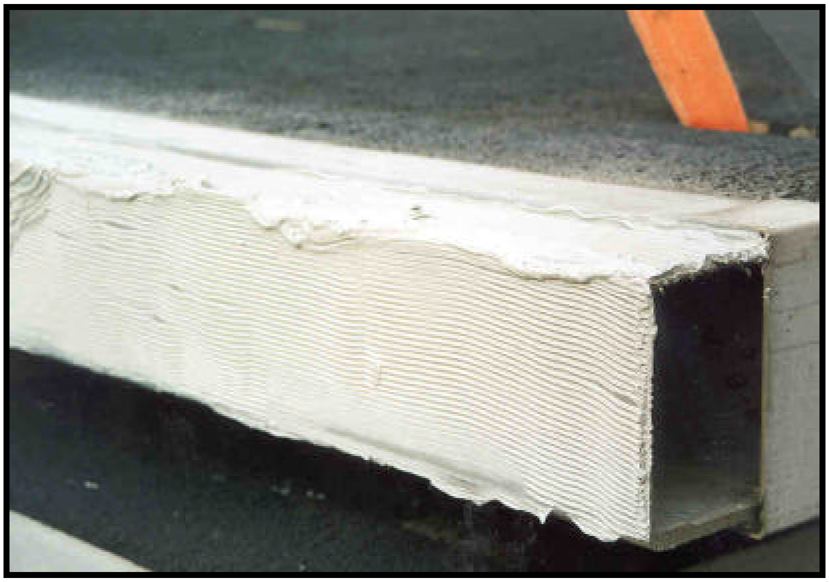

Figure 8
Epoxy Application to the Male Side of the Panel

Figure 9
Epoxy Application to the Female Side of the Panel

The FRP panels were set in place on the bridge with a crane and the joints were compressed together with hydraulic hand jacks as shown in Figure 10. Once a panel was in its final position, composite dowels were secured through the joint to hold the panels in place as shown in Figure 11.

Figure 10
Compression of the Field Joints with Hydraulic Hand Jacks

Figure 11
Composite Doweling of the Field Joints

Once all of the panels were set in place, additional composite strips were placed over the field joints for added strength. The field joints were first cleaned with an acetone wash. This was followed by the application of a vinyl ester resin and the composite material strip over the joint as shown in Figures 12 and 13. The completed joint may be seen in Figure 14.

Figure 12
Vinyl Ester Resin Application to Field Joint

Figure 13
Composite Material Strip Used Over Field Joints

Figure 14
Completed Field Joint

The following day, October 31st, shear studs were welded to the top flange of the steel girders. Two shear studs were welded in each precut hole of the FRP panels as shown in Figure 15. At the same time, concrete was poured on the abutments to lock in the FRP panels and the ends of the steel girders as shown in Figures 16 through 18.

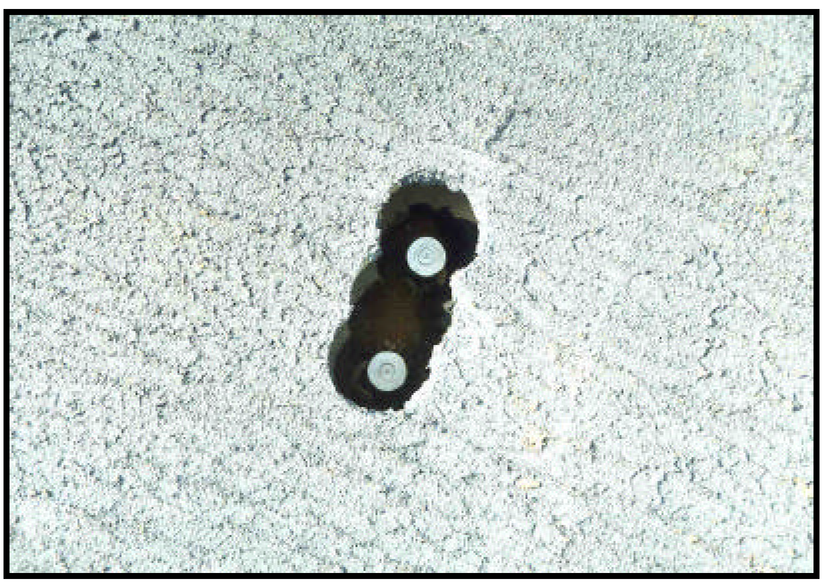

Figure 15
Shear Stud Pocket with Shear Studs

Figure 16
Forming for Abutments and Encasement of Girder Ends

Figure 17
Styrofoam Dams in FRP Panels to Prevent Concrete and Grout Flow

Figure 18
Finished Concrete Abutment

The shear stud pockets and the voids between the FRP panels and the girder flanges were grouted on November 1st. The mixture ratio for the grout was approximately four gallons of water per 250 pounds of grout. The grout used was a non-shrinking, multi-purpose construction grout. The grouting process is shown in Figure 19. The angle irons that were tack welded to the steel girders and the caulk sealant worked very well to prevent leaks of the grout mixture. Only a few small leaks were noted on the underside of the bridge deck.

Figure 19
Grouting Process

Following the grouting of the FRP panels to the steel girders and shear studs, the curb and guardrail were installed. Epoxy coated steel reinforcing bars were grouted into the outside shear stud pocket, as shown in Figure 20, to secure the curb to the bride deck. The concrete curb was formed and poured by hand. The steel tubing used for the guardrail was bolted to the concrete curb and the fascia girder as shown in Figure 21.

Figure 20
Steel Reinforcement for the Concrete Curb

Figure 21
Bolted Connections for the Steel Guardrail

Approximately one month was spent raising the elevation of the approach pavements and improving the adjacent intersection. Storm sewers, potable water lines, and overhead utilities were relocated as part of the improvement.

The final construction process, before opening the bridge deck to traffic, was to pave the bituminous concrete wearing surface. The roadway crown across the bridge surface was constructed with bituminous concrete, since the FRP panels were placed flat. The centerline bituminous concrete thickness is 4.25-inches, while the thickness adjacent to the curb is 1.25-inches. The paving of the surface course may be seen in Figure 22. The breakdown roller shown in Figure 22 was run in "static" mode across the bridge to prevent unnecessary vibrations of the bridge deck. The bridge deck was opened to traffic in mid-December.

Figure 22
Bituminous Concrete Paving of the Surface Course

PROJECT COSTS

The material costs for constructing this type of bridge decking system are more than for a traditional concrete deck. The increased cost of manufacturing and supplying the FRP material increased the initial cost of the project over traditional construction methods.

Outlined below in Table 1 are the construction costs for the bridge superstructure elements. Also included is the total initial FRP bridge deck construction cost and an approximate concrete bridge deck construction cost for the same structure.

Table 1
Project Construction Costs

Item	Units	Cost Per Unit	Total Cost
Furnish and Erect FRP Deck Panels	2,180 sq. ft.	$125.01	$272,521.80
Shear Stud Connectors	464 each	$4.22	$1,958.08
Epoxy Coated Reinforcement Bars	1,450 lbs	$1.29	$1,870.50
Superstructure Concrete	13 cu. yd.	$1,032.90	$13,427.70
Nonshrink Grout for FRP Panels	8.7 cu. yd.	$1,243.39	$10,817.49
Bituminous Binder Course	22 ton	$89.71	$1,973.62
Bituminous Surface Course	18 ton	$56.99	$1,025.82
QC / QA Bituminous	40 ton	$2.11	$84.40
Total FRP Deck Construction Cost			**$303,679.41**
Approximate Concrete Deck Construction Cost			**$107,795.00**

RESEARCH ACTIVITIES

A significant objective for this project is the performance monitoring of the completed structure. Several laboratory tests and experiments have been selected to accomplish this portion of the objective. Material coupon samples have been collected to complete the testing over the course of five years. The following laboratory tests have been selected to monitor the FRP composite material integrity.

OUTDOOR WEATHERING

The material coupon samples that have been obtained for testing will be exposed to weather and sunlight according to ASTM D 1435. The samples will be mounted in a 45-degree angle, south facing rack for durations of one, two, three, four, and five years. At the end of each time duration, selected samples will be removed in order to determine the following properties.

TENSILE PROPERTIES

The tensile properties of selected material samples will be tested according to ASTM D 638. Five samples in the longitudinal fiber direction and five samples in the transverse fiber direction will be tested for their ultimate tensile strength, elongation, and modulus of elasticity.

FLEXURAL PROPERTIES

The flexural properties of selected material samples will be tested according to ASTM D 790. Four samples in the longitudinal fiber direction and placed flat and four samples in the longitudinal fiber direction and placed on edge will be tested for their ultimate flexural strength, deflection, and modulus of elasticity.

COMPRESSIVE PROPERTIES

The compressive properties of selected material samples will be tested according to ASTM D 695. Five samples in the longitudinal fiber direction and five samples in the transverse fiber direction will be tested for their ultimate compressive strength and amount of compression.

IGNITION LOSS

The fiber and resin contents, respectively, will be determined on two selected material samples according to ASTM D 2584.

WATER ABSORPTION

The two-hour boiling water immersion and long term immersion, respectively, of three selected material samples will be determined according to ASTM D 570. These tests will be performed with the initial group of samples only.

GLOSS AND COLOR LOSS

The changes in gloss and color of selected material samples will also be determined. The gloss testing will be according to ASTM D 523. The color testing will be performed using a color spectrophotometer with a 45-degree circumferential / zero-degree geometry, illuminate C, and two-degree observer angle. The color instrument shall measure the visible spectrum from 380 to 720 nm with a wavelength measurement interval and spectral band pass of 10 nm.

In addition to the laboratory research and testing, additional testing will be performed on the full-scale structure. Visual surveys of the completed structure will be performed on an annual basis to document any distressed areas or noticeable changes. Full-scale load testing is also planned for the structure.

CONCLUSIONS

An experimental fiberglass reinforced polymer composite material was used to construct a bridge deck on South Fayette Street in Jacksonville. This structure crosses the Town Brook, which has been prone to flooding problems in recent years. The experimental FRP composite material selected for this project was "DuraSpan™" from Martin Marietta Composites. The construction of the bridge took place between September and December of 2001.

After monitoring construction of this bridge deck with the experimental material, the following conclusions were made:

1. The construction of the bridge deck was expedited. The entire deck surface was delivered and placed on the bridge in one day.

2. The material is easy to work with and easy to place.

3. The use of angle irons for fillets and grout dams worked well.

4. The use of pre-cut shear stud pockets in the FRP panels worked well.