

# **FABRICATION AND INSTALLATION OF MODULAR FRP COMPOSITE BRIDGE DECK**

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## **ABSTRACT**

Two highway bridges were constructed with a modular fiber reinforced polymer (FRP) composite deck in West Virginia. Laurel Lick Bridge was built as an all-composite short-span structure. Wickwire Run Bridge was constructed with a modular FRP composite deck supported by steel stringers. This paper presents the fabrication by pultrusion and the field installation of the modular FRP composite deck, and discusses the market potential for bridge construction and replacement.

## **INTRODUCTION**

According to Federal Highway Administration, of the Nation's 581,942 bridges, 31.4 % are structurally deficient or functionally obsolete [1]. Most of the bridges built during the highway construction boom of 1960s and 1970s were designed to last 30 years and soon will require major repairs or replacement. The American Association of State Highway and Transportation Officials (AASHTO) projected that just to maintain current bridge conditions, 200,000 bridges will need to be replaced or repaired during the next two decades [1]. Based on the National Bridge Inventory rating, deck geometry and deck condition are among the most prevalent items with respect to deficiency percentages [2]. Bridge deck deficiencies are related to physical deterioration due to environmental conditions, maintenance policies, and unanticipated factors such as fatigue, high friction and dynamic responses, among others.

In the search for bridge deck repair solutions, fiber reinforced polymer (FRP) composite materials offer a strong, durable, easy-to-install and lightweight bridge deck replacement solution. The challenge is to bring together two different technologies and markets: bridge construction practices and composites material fabrication and design.

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## THE COMPOSITE BRIDGES

Two bridges, located on secondary county roads in West Virginia were constructed: (1) Laurel Lick Bridge (short-span all-composite structure), and (2) Wickwire Run Bridge (FRP composite deck on steel beams). The basic design and construction data for both bridges are presented in Table I. These bridges are the first field demonstrations of the modular FRP composite deck system that was designed by West Virginia University's Constructed Facilities Center [3].

The FRP composite deck cross-section is made of two pultruded profiles: double trapezoids (trusses) and hexagons (shear keys). These profiles are interlocked and bonded to create a deck module. The fiber architecture of the pultruded profiles was design-engineered with E-glass reinforcement and a weather resistant vinyl ester resin. The US patent on the modular FRP composite deck system is pending. Creative Pultrusions, Inc. fabricated the modular FRP composite deck with the trade name Superdeck™. The FRP composite deck was designed for AASHTO standard HS25-44 highway bridge truck loads. The 8-in (20 cm) thick FRP deck modules are placed transversely to the traffic direction and are supported by longitudinal beams (typically steel) that can be spaced up to 9-ft (2.74 m) apart.

TABLE I . FRP COMPOSITE DECK IN HIGHWAY BRIDGES

Bridge	Laurel Lick	Wickwire Run
<b>Concept</b>	Short-span all-composite bridge	Deck replacement of steel-girder bridges
<b>Location</b>	Off County Rd. 26/6, Lewis Co., West Virginia	County Rd. 26, Taylor Co., West Virginia
<b>Open to traffic</b>	May 1997	September 1997
<b>Bridge Deck Design</b>	West Virginia University & WVDOH District Seven	West Virginia University & WVDOH District Four
<b>Construction</b>	WVDOH District Seven	WVDOH Central Heavy Maintenance Detachment
<b>Span &amp; width</b>	6.10 m (20 ft.) x 4.88 m (16 ft.)	9.14 m (30-ft.) x 6.60 m (21.7-ft.)
<b>Deck</b>	Modular FRP Composite Deck	Modular FRP Composite Deck
<b>Beams</b>	FRP wide-flange stringers, spaced 0.76 m (2.5-ft.) apart	Galvanized steel W stringers, spaced 1.83 m (6-ft.) apart
<b>Substructure</b>	FRP piling/columns, FRP panels & concrete cap beam	Concrete footing and walls (cast-in-place)
<b>Wearing surface</b>	Polyester PC overlay 3/8-in (1.0 cm) thick	Polyester PC overlay 1/2-in (1.27 cm) thick
<b>Curbs</b>	FRP square tubes	Concrete connected to the FRP deck with hooks
<b>Deck Expansion</b>	- - -	Expansion dams on the abutments

## FABRICATION

The FRP composite deck presents a formidable task to the pultrusion industry in terms of producing a durable bridge product at competitive prices. This new product has unique characteristics such as cross-section design and fiber architecture and is subjected, during its service life, to severe loads and harsh environments. These characteristics call for new efforts to realize the full potential of the pultrusion process and attain consistency in thermo-mechanical properties to satisfy performance requirements.

The pultrusion process offers many distinct advantages for the mass fabrication of the FRP composite deck, such as low operating costs, high production rate, product reproducibility and dimensional tolerances. The pultruded deck profiles make efficient use of E-glass reinforcement to deliver the required structural performance. Unidirectional continuous strand rovings are the main responsible for providing the longitudinal mechanical properties. Directional multi-axial stitched fabrics and continuous filament mat are responsible for providing the transverse properties of the structural profiles.

The Superdeck™ truss and hexagonal profiles are pultruded at a rate of approximately one-foot every 90 seconds (one meter every 295 seconds). With two pultrusion machines, 100 square feet (9.29 m<sup>2</sup>) of FRP deck can be manufactured every two and a half hours. A bridge deck with similar area to Wickwire Run, 651 square feet (60.3 m<sup>2</sup>), is produced in approximately 16.5 hours. When the market demand warrants faster production of the Superdeck™, additional pultrusion dies and pulling machines will be placed in service.

Once the truss and hexagonal profiles are pultruded, the deck modules are assembled. The first step involves the surface preparation for the interlocking and adhesive bonding of the hexagon to the truss. The bonding areas of the profiles are grit blasted until the glass fibers are exposed. The surface is then solvent-wiped in final preparation for the structural adhesive. Pliogrip® polyurethane structural adhesive, supplied by Ashland Chemical, is then applied to the prepared area in order to form the structural bond between the truss and hexagonal profiles. The deck module or panel is then placed into a fixture and pressed together for two hours until the structural adhesive is cured. The deck modules are then removed from the press and prepared for shipment to the construction site.

The bridge deck modules are assembled in eight-foot (2.44 m) wide sections in order to be efficiently transported to the construction site. The length of the deck modules has virtually no limitations and is determined by the width of the bridge deck to be constructed. For example, the Wickwire Run Bridge deck modules were manufactured in three 8-ft. x 21.7-ft. (2.43 m x 6.60 m) and one 6-ft. x 21.7-ft. (1.83 m x 6.60 m) modules forming the thirty foot span of the bridge. The FRP deck weighs approximately 22-lb./sq. ft. (106 kg/m<sup>2</sup>).

All manufacturing procedures for Superdeck™ are performed in climate controlled buildings, ensuring the highest quality product. Production line operators and quality control personnel constantly monitor the production process. Retainer samples of all production runs are tested in accordance with ASTM testing procedures.

## INSTALLATION OF WICKWIRE RUN BRIDGE DECK

Wickwire Run Bridge was constructed by the West Virginia Division of Highways' Central Heavy Maintenance Detachment during the Summer of 1997 and opened to traffic in September [4]. The new bridge replaced an existing steel I-beam bridge with a timber decking that was rated in poor condition. Four galvanized steel W24x104 stringers support the new FRP composite bridge deck.

The steel beams were shipped with holes pre-drilled for the bolted connectors. The underside area of the FRP modules to be in contact with the steel beams was sandblasted, as well as the top surface of the steel beams. After placing the first FRP module in position, holes were drilled in the deck underside.

A primer was applied to the steel surface prior to the application of Pliogrip® 7770/300 polyurethane adhesive from Ashland Chemicals to assure good bond with the FRP deck module. The primer, Pliogrip® 6031/6032, is a two-part epoxy system with low viscosity that was applied with a brush to the top surface of all stringers at one time. The stringers were then covered with Styrofoam sheets to allow curing to take place (a minimum curing time of 16 to 24 hours at 23°C is required), as well as to protect the primer from abrasion. Then, the polyurethane adhesive was applied to the previously primed steel surface where the first deck module would be installed. The adhesive has a working time of approximately 35 minutes. One manual gun and two pneumatic guns were adequate to dispense the adhesive over the steel beams as well as the deck flange and expansion dam.

Using a lifting hook setup (Figure 1), the first module was lowered onto the steel stringers and lined up by the previously drilled holes. The module was pushed into place against the expansion dam using hydraulic jacks that were clamped to the steel beams. Once in place, the FRP composite deck module was connected to the supporting steel beams using engineered ½-in (13-mm) BOM® blind bolts (BOM-R16-24) from Huck International, Inc. The steel expansion dam (tube) installed at the end of the bridge was also bonded and bolted to the FRP deck.

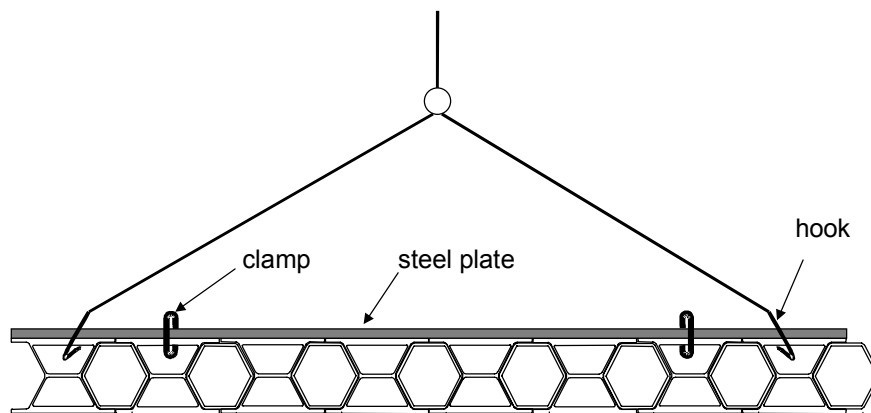


FIGURE 1. FRP DECK MODULE: LIFTING HOOK SETUP

The second deck module was placed next. However, this module was not pre-drilled. To allow the polyurethane adhesive more working time, the section was lowered and jacked into place and a concrete barrier was placed on top. The

concrete barrier acted as a weight to insure good contact and adhesion to the beams. Once the section was in place, holes were drilled and the blind bolts were installed to tie down the FRP deck.

In addition to adhesive bonding, self-countersinking FLOORTIGHT® blind fasteners (PMF-R10-26) from Huck International, Inc. were used to facilitate the connection of modules with shear keys, and to provide reserve shear strength. The remaining modules were placed in the same manner.

The open edges of the FRP deck were then covered with a cap consisting of two pultruded angles. The rail system used is flex beam guardrail on steel posts. The guardrail posts were connected to the exterior steel beams.

A thin polymer concrete (PC) overlay or wearing surface was applied on the FRP composite deck. After sand blasting the deck surface, a urethane-based primer was applied to enhance adhesion of the PC overlay to the FRP composite deck. Then, the PC was applied by layers through the “broom and seed” method with a final thickness of approximately ½-in. (1.27 cm). The polymer concrete binder was an isophthalic unsaturated polyester resin from Reichhold Chemicals and the aggregate was fine silica sand [5].

The WVDOH Bridge Engineer and construction crew made recommendations for future FRP bridge deck installations [4]. The first recommendation was to use specialized drill bits such as carbon tipped bits. Another suggestion was to use a one-piece end cap, such as a pultruded channel section. This would expedite installation, eliminate the longitudinal joint and provide a better appearance. A recommendation was also made to use longer blind bolts with greater grip range. This would overcome the excessive gap between the FRP deck and the steel beam, as well as help insure adequate bolt tension and reduce crushing of the FRP material. It is preferable to have a curb made of pultruded tubes similar to Laurel Lick Bridge, as opposed to the concrete curb used in Wickwire Run Bridge.

It was estimated that a typical construction crew of six people needs one day to install the FRP deck modules for a bridge of 651 square feet (60.3 m<sup>2</sup>) similar to Wickwire Run.

## **MOVING INTO THE CONSTRUCTION MARKET**

The FRP composite deck faces two main obstacles to enter into the highway bridge market: initial cost and user acceptance. Ongoing efforts between West Virginia University researchers, Creative Pultrusions and other member companies of SPI-Composites Institute are focused on reducing fabrication costs through weight reduction, process optimization and part consolidation. To justify the use of FRP composite decks for bridge construction and replacements an economic evaluation process is needed. For this purpose, Life Cycle Cost (LCC) analysis [6] is the most appropriate economic evaluation process as it takes into consideration all costs from construction, maintenance of the facility, replacement, and associated user impacts over the specific period, usually encompassing the service life of all alternatives.

To develop nationally recognized product performance benchmarks, the modular FRP composite bridge deck is presently in the evaluation program of Highway Innovative Technology Evaluation Center (HITEC). HITEC is a service

center of the Civil Engineering Research Foundation for implementing innovative technologies and expediting their transfer into practice.

The two composite bridges built in West Virginia are being instrumented to monitor its performance during three years. During this period the bridges will be load tested. The field-monitoring program is expected to provide valuable information on durability of the FRP composite deck.

## **ACKNOWLEDGMENT**

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