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MODULAR COMPOSITE DECK SYSTEM FOR BRIDGE CONSTRUCTION AND REPLACEMENT

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ABSTRACT

Fiber reinforced polymer (FRP) composite materials were used to develop a modular bridge deck that has high strength and stiffness to weight ratios, that is non-corrosive, and that has good fatigue resistance. The composite deck cross-section and fiber architecture were designed to provide optimal structural performance for highway bridge loads. The basis for improved properties derives from an understanding of micro- and macro-mechanics and its role in defining global structural response. An engineering approach based on mechanics of laminated composites structures was applied for the analysis and design of the composite deck. FRP composite deck modules were fabricated by pultrusion. Deck prototypes were tested under static and fatigue loads. Experimental strains and deflections were satisfactorily correlated with Finite Element method predictions. Two bridge demonstration projects are being constructed. The composite deck system is expected to be utilized to replace aged concrete or timber decks, and to construct new bridge decks.

INTRODUCTION

In this work a composite deck product that was designed to meet highway bridge performance requirements and to be cost-competitive is presented. Two demonstration bridges have been selected to apply the new composite deck system: (1) A bridge with a composite deck on steel beams, and (2) An all-composite short-span bridge superstructure (deck and beams). The modular composite deck concept is based on pre-fabrication and modular construction leading to reduction in use of heavy equipment, short field installation time, minimum disruption to vehicular traffic, and reduction of seasonal costs.

Composite deck prototypes were tested under static and cyclic loads to evaluate the orthotropic stiffness properties and to characterize the mode of failure. The potential of the composite deck to compete with existing bridge deck technologies is discussed. The objective of this work is to present the development and characterization of a modular composite deck system that was designed and fabricated for highway bridge deck replacement.

MODULAR COMPOSITE DECK SYSTEM

The composite deck cross-sectional shape and fiber architecture were design-engineered to withstand highway bridge loads with minimum material weight. After several iterations, and based on previous experience with other composite deck configurations, it was found that a cross-section made of full-depth hexagons and half-depth trapezoids has enhanced performance for bridge decks. The resulting product is called H-deck. The composite deck modules are placed transversely to the traffic direction and are supported by longitudinal steel or composite beams. The supporting beams can be spaced up to 2.74 m apart. The fiber architecture incorporates E-glass fibers in the form of multi-axial stitched fabrics, continuous rovings, and chopped strand mats. The matrix is a vinyl ester resin with good weatherability and resistance to harsh environments. The deck depth was constrained to 203 mm, which is the average thickness of concrete decks in the U.S., in order to utilize the modular system for concrete deck replacement.

The composite deck modules are joined through a shear key that provides mechanical interlock and an extensive bonding surface. At the manufacturing plant, and under controlled conditions, high performance adhesive bonding is used to assemble the component into large modules. During field installation, the large modules are connected with shear keys. In the shear keys that are installed in the field, mechanical connectors (blind fasteners) are used in addition to adhesive bonding to guarantee the required shear transfer capacity.

ROAD TO IMPLEMENTATION

Two bridges located on secondary roads in two different West Virginia, U.S., highway districts have been selected for demonstration projects.

Laurel Lick Bridge

This short-span bridge located off county route 26/6 in Lewis County, WV was constructed in April 1997 with a composite deck supported by wide-flange pultruded beams 305 x 305 x 12.7 mm resulting in an all-composite superstructure. The length of the bridge deck is 6.10 m and the width is 4.88 m In addition, the abutments are made of wide-flange pultruded column/piles 305 x 305 x 12.7 mm with a reinforced concrete cap beam. The fiber architecture of the beam and column profiles were optimized to improve stiffness and strength and fabricated by Creative Pultrusions (See Lopez-Anido et al. 1996).

Wickwire Run Bridge

This bridge is located off US Route 119 in Taylor County, WV. The bridge is being constructed with a composite deck supported by four longitudinal steel stringers spaced 1.83 m apart. The length of the bridge is 9.14 m and the width is 6.60 m. The composite components will be instrumented with sensors to monitor their long-term performance.

FABRICATION

H-deck modules for laboratory testing and field demonstration were fabricated by pultrusion. The fiber architecture of the pultruded components is made of continuous rovings and triaxial stitched fabrics with binderless CSM. The profiles were also reinforced in the axial direction with continuous roving. Composite deck components (double-trapezoid and hexagon) for laboratory testing and for field demonstration were fabricated by Creative Pultrusion, Inc.

The deck components are bonded using an adhesive at the fabrication plant under controlled conditions, ensuring quality and taking advantage of their lightweight. The adhesive selected for the demonstration bridges is a two-part urethane, from Ashland Chemicals. The pultruded components are assembled into a deck module up to 2.44 m wide (based on shipping restrictions) that weighs approximately 106 kg/m^2. The length of the deck module corresponds to the bridge width.

MODELING OF COMPOSITE DECKS

The computation of deflections and strains was conducted through two different approaches. First, an engineering approach was used to design the H-deck (Lopez-Anido et al. 1996). A portion of the deck along the main stiffness direction was modeled as a composite beam. The cross-sectional bending and shear stiffness properties were obtained using mechanics of laminated composite beams (Barbero et al. 1993). Second, the Finite Element method (FEM) was applied to model the H-deck and obtain a more accurate prediction of strains and localized deflections. Strains and deflections predictions using FEM were correlated with deck experimental data. In addition, a FEM model was developed to analyze the two demonstration bridges.

DISCUSSION AND CONCLUSION

The composite deck has 6 to 7 times the load capacity of a reinforced concrete deck with only 20 % of the weight. The deck stiffness in the direction perpendicular to traffic is approximately 50 % the stiffness of a reinforced concrete deck. Furthermore, the reduction in the mass of the deck leads to enhanced seismic response of the bridge structure. The design of the composite H-deck is controlled by local deflections in-between supporting beams. The results of the experimental program indicate that the composite deck design can be safely used for highway bridge applications.

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