Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 83 (1999)

Artikel: Advanced composite bridges for the 21st century

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DOI: https://doi.org/10.5169/seals-62856

Advanced Composite Bridges for the 21st Century

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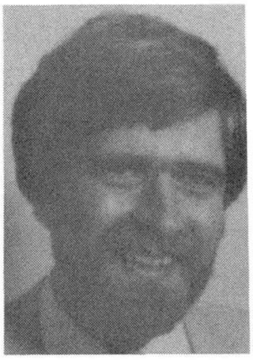

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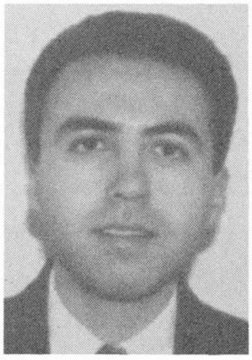


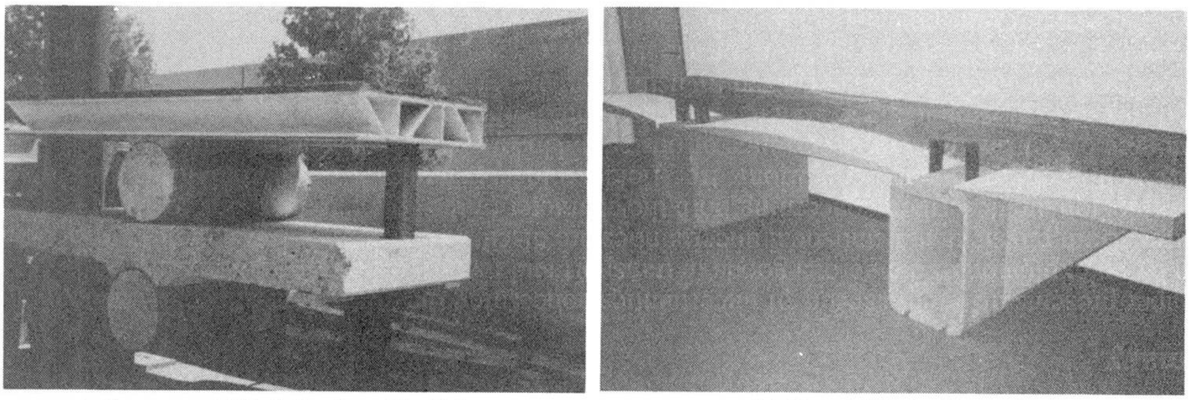
Abstract

The successful implementation of advanced composite materials, or Fiber Reinforced Polymers (FRP) in civil infrastructure depends on the development of new structural concepts and systems that combine these "new" materials with conventional construction materials such as concrete and steel. Two new design and construction systems for short- and medium-span modular bridges have been under development at the University of California, San Diego (UCSD). The concepts, consisting of carbon/concrete and carbon/glass composite systems, have been applied to columns and girders in the form of FRP tubular members. The research has initially focused on the application of both concepts to beam-and-slab bridges to provide the basis for design and analysis of new modular FRP bridge systems. The research consisted of the concept development, the development of analysis and design tools, and complete structural performance assessment, validated by full structural characterization of the different components through full-scale laboratory testing.

The concrete filled Carbon Shell System concept allows for new structural elements by using prefabricated filament-wound carbon/epoxy thin shells filled on-site with concrete. The shell serves the dual function of reinforcement and stay-in-place formwork for the concrete core. The concrete provides compression force transfer, stabilizes the thin shell against buckling, and allows the anchorage of connection elements. For superstructure components, the concrete filled carbon shells are combined with a structural deck system, which may consist of either a conventional cast-in-place reinforced concrete (RC) slab, or a modular FRP deck system, see Fig. 1a. The connection between the deck and the carbon shell girders is accomplished with conventional dowel technology by embedding shear connectors into the shell system during grouting. In the slab the dowels are either cast directly into the RC deck or anchored in polymer concrete filled sections of cellular E-glass deck systems.

Large-scale experimental flexural characterization and analytical modeling of the concrete filled carbon shell system showed that the concrete core contribution to stiffness and strength is minimal and its function reduces mainly to that of stabilizing the thin shell and allowing connector anchorage. This motivated the development of a new FRP girder system that features thicker walled sections and an anchorage concept for connectors that allows the girder to be used hollow. The new modular FRP bridge system was developed based on the pultrusion and hand-layup of a carbon/glass hybrid material system. The Hybrid Tube System beam-and-slab bridge consists of hollow E-glass beams connected along their tops with a fiber reinforced concrete deck system. The girders are pultruded E-glass rectangular sections with longitudinal carbon reinforcement in the

flanges. The tubes are left ungrouted except for the ends of connection regions. An FRP form panel is snap-locked to the pultruded girders providing a tension tie between girders and the stay-in-place form for a fiber reinforced arch-action-type concrete deck. To provide stiffness to the form panels, the transverse FRP membrane is overlaid with lightweight polymer concrete in a parabolic shape to allow for full construction loads. Prefabricated pultruded snap-in stirrups provide the horizontal shear transfer between the concrete deck and the hybrid tubes. This modular bridge system is depicted in Fig. 1b.



a) Concrete Filled Carbon Shell System *b) Hybrid Tube System*

Fig. 1 Modular FRP Beam-and-Slab Bridge Systems

In order to implement the carbon shell and hybrid tube technology to complete bridge systems and develop appropriate performance-based design guidelines, the experimental evaluation of the critical components and connections is required. A comprehensive experimental program that used a building-block approach to characterize different components as steps towards the development of a carbon shell prototype bridge system was undertaken. The experimental characterization of carbon shell beam-and-slab assemblies for short and medium span bridges was investigated on two full-scale four-point bending tests. The geometry and dimensions for the test units were determined from a design study performed for a two span beam-and-slab bridge.

To demonstrate the application of the developed advanced composite bridge systems presented above, a 137m long cable-stayed bridge supported by a 46m high A-frame pylon was designed to be built at UCSD utilizing advanced composites. The bridge structure is designed for two 3.7m vehicular lanes, two bicycle lanes, pedestrian walkways, and a utility service tunnel. Based on a preliminary study of different structural systems, the solution presented in Fig. 2 was selected. The structure proposes the use of the carbon shell system for the pylon and edge girders with a dual cable plane system. In the transverse direction, partially grouted carbon tube cross-beams are employed, which in turn support longitudinally spanning prefabricated E-glass or RC deck panels.

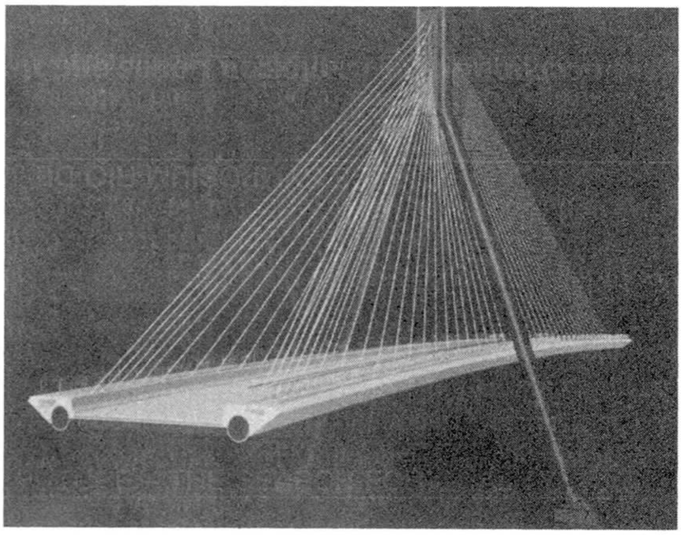


Fig. 2 The I-5/Gilman Advanced Technology Bridge