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DEMONSTRATION FOOTBRIDGES MADE OF ULTRA-HIGH-PERFORMANCE CONCRETE AND FRP COMPOSITES

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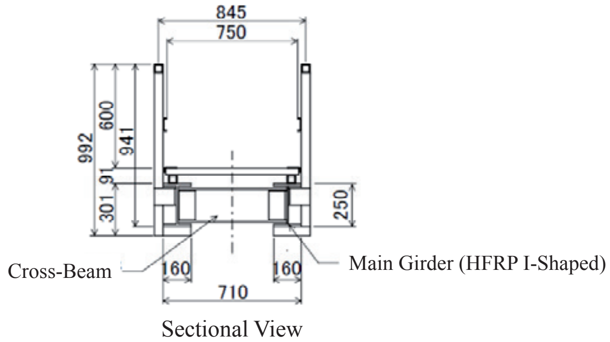
Summary

Civil infrastructure systems play an important role in many countries and the world is now facing a major challenge to build safe and sound bridge systems with long-term durability and low maintenance cost. A solution to this challenge can be obtained by proper utilization of advanced materials and innovative hybrid structural systems. Fiber-reinforced polymer (FRP) composites and ultra-high-performance concrete (UHPC) were used in this study to build light-weight, sustainable and cost-effective footbridges that can be applied in high-corrosive environments. The primary objective of this paper is to present case studies of two demonstration FRP-composite footbridges in Japan. The use of FRP-composite components (i.e. slabs, girders, handrails, cross-beams, etc.) in these bridges resulted in reduced self-weight and durable superstructure system. The two footbridges were designed and constructed based on the results of an extensive experimental program and theoretical/numerical analyses. The major components of the first bridge was composed of all-FRP materials. This bridge was assembled and erected in Hiroshima, Japan in 2011 to replace an existing deteriorated steel bridge. Following the successful construction of the first entire-FRP bridge, the second bridge was designed and fabricated in Miyagi, Japan in 2012 to enhance the strength and stiffness of the first bridge. The bridge consists of FRP-composite girders and ultra-high performance fiber-reinforced concrete (UHPFRC) deck slabs. An overview of the two demonstration footbridges is discussed in the following sections.

Keywords: FRP composites; ultra-high-performance concrete; footbridges; design and construction

1. Demonstration Hybrid Carbon/Glass FRP (HFRP) Footbridge

A demonstration footbridge using HFRP I-girders was constructed in Kure city, Hiroshima prefecture, Japan, in 2011 (Fig. 1). The bridge was used to replace an existing corroded steel bridge. The HFRP footbridge was designed and manufactured through a collaborative effort among universities, FRP manufacturers, and industries in Japan. It was designed following the Japanese Guidelines for Designing Facilities for Fishing Ports and Fishing Grounds. The bridge is simply supported and spanning between a concrete deck and a floating dock (a.k.a. pontoon) in a fishery harbor. It is composed of a GFRP grating deck supported by two HFRP I-girders. It has a single span with a total length of 12 m and an effective width of 0.75 m. The bridge's proximity to the ocean subjects it to a highly corrosive environment. All I-shaped HFRP girders were manufactured by pultrusion process at a plant in Aichi prefecture in Japan. Unidirectional carbon fibers (fibers were oriented at zero degree to the longitudinal direction) were used in the top and bottom flanges of the HFRP girders. Bi-directional glass fiber fabric (fibers were oriented at 0°/90°, ±45°, or ±45°/0° directions) and glass fiber continuous strand mat (fibers were randomly oriented) were used in the flanges and the web of the HFRP I-girders. The overall height of the HFRP girders was 250 mm and the flange width was 160 mm. The flange thickness was 14 mm and the web thickness was 9 mm. The HFRP bridge superstructure was formed by a GFRP grating deck (provided by Daikure Co., Ltd.) topped with two HFRP I-girders. Two sizes of the GFRP grating panels were used for the deck slab including three 2,967 × 764 (length × width) panels and two 1,540 × 764 panels.

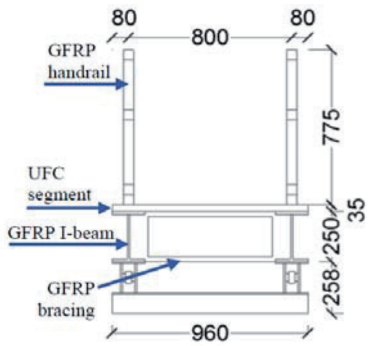


(a) (b)

Fig. 1. Demonstration footbridge in Hiroshima, Japan: (a) footbridge's cross-section (dimensions in millimeters); and (b) HFRP footbridge spanning between a pontoon and a concrete deck

2. Demonstration Footbridge Composed of GFRP I-Girders and Ultra-High-Performance Fiber-Reinforced Concrete (UHPFRC) Segmental Precast Slabs

Following the successful construction of the first entire-FRP bridge, the second bridge was designed and fabricated in Onagawa town, Miyagi prefecture, Japan in 2012. Instead of using GFRP grating deck, UHPFRC segmental precast slabs were used in the second bridge to improve the bridge's strength and stiffness. Pultruded GFRP I-girders were used to support the UHPFRC deck slabs. The effective width and the overall length of the bridge were 750 mm and 6,000 mm, respectively. The bridge was constructed in a fishing port, where chloride attack is of a great concern (Fig. 2). Therefore, GFRP bolts were used in conjunction with epoxy adhesive to connect the GFRP I-girders and the UHPFRC slab. The use of the epoxy adhesive was verified by the authors to be very effective in obtaining a full interaction for the FRP-UHPFRC composite girders. The bridge was designed with a deflection limit of $L/500 = 12$ mm, where L is the bridge's span length. The design live load of the bridge was 3.5 kN/m^2.



(a) (b)

Fig. 2. Demonstration footbridge in Miyagi, Japan: (a) footbridge's cross-section (dimensions in millimeters); and (b) GFRP-UHPFRC footbridge connecting a concrete pier and a pontoon

3. Acknowledgements

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