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# Joining techniques for fiber reinforced polymer composite bridge deck systems

Aixi Zhou *, Thomas Keller

*Composite Construction Laboratory, Swiss Federal Institute of Technology—Lausanne, EPFL-CCLab, BAT. BP, CH-1015 Lausanne, Switzerland*

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**Abstract**

Bridge decks made from fiber reinforced polymer (FRP) composites have been increasingly used in rehabilitation and new construction of pedestrian and highway bridges. For each application, connections are inevitable due to limitations on shape size and the requirements of transportation. Connections for FRP bridge decks include primary and secondary load-carrying joints and non-structural joints. Primary and secondary load-carrying connections are most concerned in construction, which include component–component connection, panel–panel connection, and deck-to-support connection. Unfortunately, the technical background, development and design guides of FRP bridge deck connections have not been documented adequately in literature. This paper attempts to provide technical background, developed joining techniques, and design principles concerning the joining of FRP decks. Design requirements, characteristics, performances, advantages and disadvantages of developed FRP deck connection techniques are discussed. Design principles for adhesively bonded joints and mechanical fixing and hybrid joints involving cutouts are also provided.



*Keywords:* Fiber reinforced polymer; Composites; Bridge deck; Superstructure; Connections; Design; Construction

## 1. Introduction

Structural shapes made from Fiber Reinforced Polymer (FRP) composites have been increasingly used in structural systems for rehabilitation and new construction of pedestrian and highway bridge decks [1–12]. FRP bridge decks are usually provided in modular panel forms. In construction, deck panels are usually connected to their supports to transfer loads transversely to the supports that bear on abutments. Current commercially available FRP decks for rehabilitation and new construction can be classified into two categories according to the types of assembly and construction: sandwich panels and multi-cellular type panels. Sandwich panels have two basic forms: foam core sandwich panel and honeycomb sandwich panel. Multi-cellular panels have varied geometrical forms and can be used without or with foam core materials. Two basic cellular FRP deck panels have been developed according to the techniques of processing and assembly: panels from adhesively bonded pultruded shapes and panels from adhesively bonded filament-wound shapes. For each modular FRP deck panel form, connections are inevitable due to limitations on shape size imposed by the manufacturing process and the requirements of transportation.

Three classes of connections involving composites are identified in the Eurocomp Design Code and Handbook [3]: (1) primary joints, which carry major strength and stiffness to an assembly for the whole-life of the structure; (2) secondary structural joints, whose failure would be only local failure without compromising the entire structure; (3) non-structural connections, whose main purpose is to exclude the external environment. Connections for FRP bridge decks include all these categories. However,

* Corresponding author. Tel.: +41 21 693 3225; fax: +41 21 693 3240.

*E-mail address:* aixi.zhou@epfl.ch (A. Zhou).

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this research focuses on primary and secondary load-carrying connections for FRP bridge decks. These load-carrying connections include component–component connections to form modular FRP bridge deck panels (henceforth referred as component level connection, or CLC), panel–panel connections to form FRP bridge deck systems (henceforth referred as panel level connection, or PLC), and FRP deck-to-supports connections to form bridge superstructures (including deck-girder, deck-abutment and deck-barrier connections, etc., henceforth referred as system level connection, or SLC).

In general, bridge systems shall be designed for specified limit states to achieve the objectives of safety, serviceability and constructability with regards to the issues of durability, inspectability, economy and aesthetics. FRP deck connections shall be designed under the guideline of this philosophy to achieve the specified limit states for each construction. However, specific design requirements for FRP deck connections vary with the levels of connection. In component level connections, the main objective is to ensure the integrity of the deck panel and the load transfer efficiency between the jointed components. In the panel level, major concerns are the deck system's load transferring and carrying capability (bending moment and shear force, and resistance to dynamic loads, etc.), panel–panel compatibility to deformations imposed by thermal or moisture effects, and the constructability of connections. In the system level, shear transfer and connection constructability are major concerns. The advantages of advanced FRP composites would be lost if the characteristics of the associated joints were not properly understood and the connections were not properly designed.

Key manners for joining FRP composites are mechanical fastening and adhesive bonding. The combination of bonding and fastening can be used to take the advantages of both methods when the connection is properly designed and constructed. Due to its advantages of the simplification of processing and thus a saving of production cost and possible refined joint geometry, adhesive bonding is generally used for connecting permanent FRP deck components to form bridge deck panels. In panel and system levels, adhesive bonding, mechanical fastening and the combination of bonding and fastening have been used. However, the development of connecting techniques for FRP bridge deck systems, especially in panel and system levels, has not come up with the growing demands of the FRP deck rehabilitation and new construction. In some demonstration FRP bridge deck projects, cracks and damages appeared in deck connection regions after field exposure to real traffic loadings and environmental conditions, as shown in Fig. 1. The need for efficient and reliable load-carrying joints that can endure long-term fatigue and environmental attacks has become apparent.

Unfortunately, the technical background and the development of FRP bridge deck connections have not been documented adequately in literature. In a previous paper by Zhou and Keller [13], only joining techniques for FRP decks were briefly reviewed. This paper provides more details for the technical background, developed joining techniques, and design principles concerning the joining of FRP decks in component level, panel level and system level. In this paper, the development of connection techniques for FRP bridge decks is presented. Joining techniques for component–component connections, panel–panel connections and deck-to-support connections that have been developed in past decade will be reviewed. These techniques include mechanical fastening, adhesive bonding, and hybrid joining. Characteristics and performance of each connection technique will be discussed. Design guides for adhesively bonded FRP deck joints are also presented. Finally, guides for the design of mechanically fixed or hybrid FRP deck connections involving cutouts will be provided.

## 2. Joining techniques for FRP bridge decks

### 2.1. Component level connections for FRP bridge deck panels

Component level connections are usually permanent. The main objective for CLC joining is to ensure the

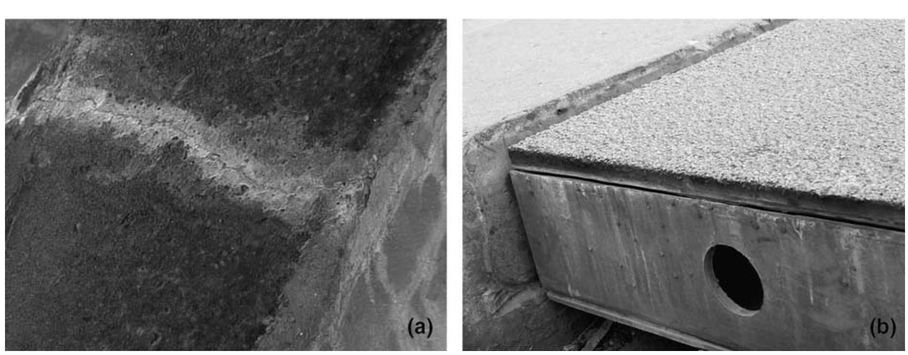


Fig. 1. Cracking at FRP deck connection regions. (a) At panel connection. (b) At component connection.