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Double-composite rectangular truss bridge and its joint analysis

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ABSTRACT

This paper describes a novel composite tubular truss bridge with concrete slab and concrete-filled rectangular chords. With concrete slab plus truss system and joints reinforced with concrete and Perfobond Leiste rib, double composite truss bridge proved to be a fairly suitable solution in negative moment area. Perfobond Leiste shear connector (PBL) is widely implemented in the composite structure for its outstanding fatigue resistance. In this pilot bridge, Perfobond Leister ribs (PBR) were installed in the truss girder's joints, which played double roles as shear connector and stiffener. An erection method and overall bridge structural analysis were then presented. Typical joints in the pilot bridge were selected to analyze the effect of PBR. Investigation of the effect of PBR in concrete-filled tubular joints was elaborated. Comparison has revealed that concrete-filled tubular joints with PBR have much higher constraint capability than joints without PBR. For rectangular tubular truss, the punching shear force of the concrete filled joint with PBR is approximately 43% larger than that of the joint without PBR. Fatigue performance of the joint installed with PBR was improved, which was found through analysis of the stress concentration factor of joint. The PBR installed in the joints mitigated the stress concentration factor in the chord face. Therefore, the advantages of this new type of bridge are demonstrated, including the convenience of construction using rectangular truss, innovative concept of structural design and better global and local performances.

1. Introduction

The composite tubular truss bridge has been built in western countries for 20 years since the closure of well-known pilot project Nantenbach Railroad Bridge in 1993 (Brozzetti, 2000; Hanswille, 2008). The main span of Nantenbach Railroad Bridge is 208 m with two side spans of 83.2 m excluding approach bridge (Fig. 1(a)). The cross section of superstructure

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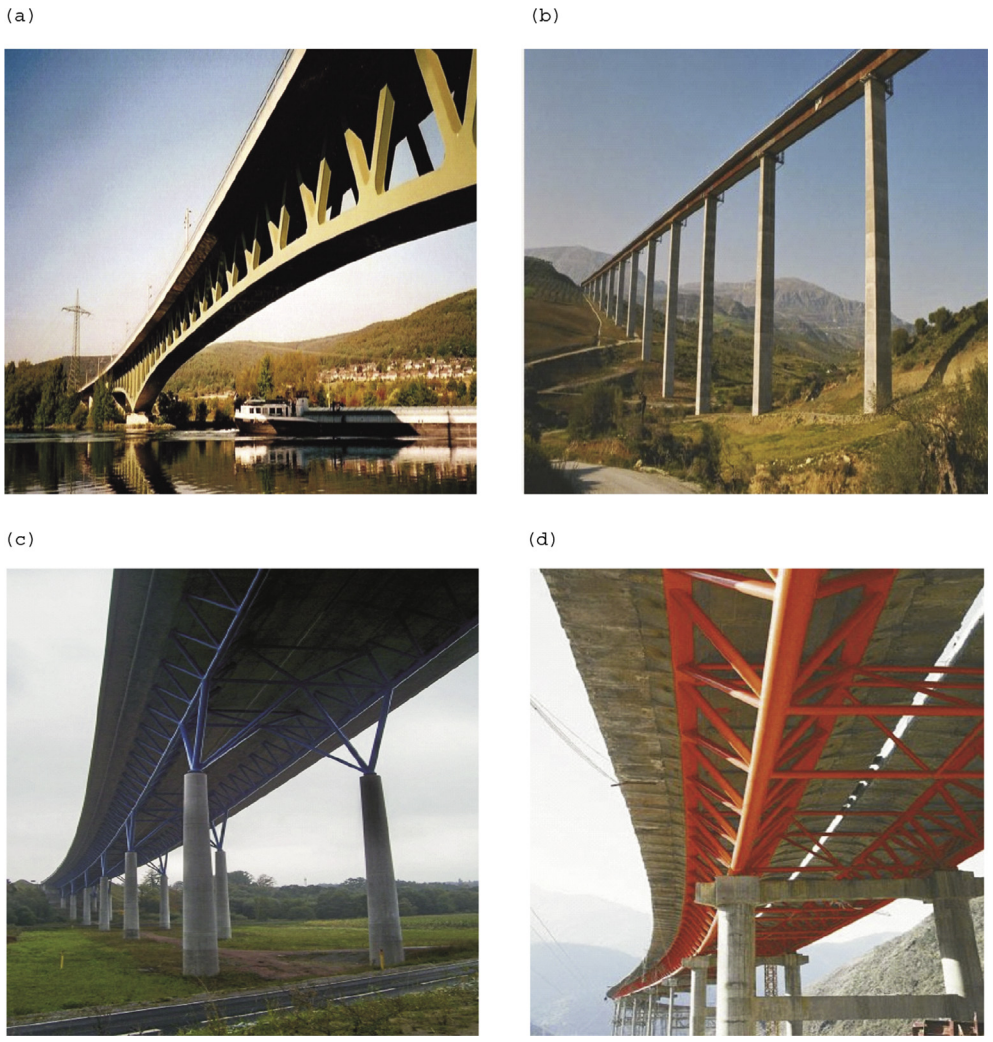

Fig. 1 – Typical composite bridges. (a) Nantenbach Railroad Bridge (Germany). (b) Arroyo Las Piedras Viaduct (Spain). (c) St. Kilian Viaduct (Germany). (d) Ganhaizi Bridge (China).

consists of two main rectangular truss frames spacing 6 m in transverse direction. The bottom chord is filled with concrete at piers to improve its stiffness. Top concrete slab and bottom composite sections form a double-composite structural type which has an outstanding performance in heavy and fatigue loading while train speeds over (Schwarz et al., 1992). This double-composite concept is adopted in Arroyo Las Piedras Viaduct, part of high speed railway line in Spain (Mato et al., 2007) (Fig. 1(b)).

At the mean time, circular hollow tube is an alternative choice in composite tubular truss bridge design. Typical applications such as St. Kilian Viaduct and Ganhaizi Bridge are shown in Fig. 1(c) and (d) respectively (Dorrer, 2007; Wang et al., 2011). St. Kilian Viaduct is a continuous bridge with maximum span of 61.5 m. The cross section is a three-chord system - a main circular truss tube (Φ610 mm) with a height of 5 m and two web truss tubes (Φ298.5 mm). The joints of bottom chord are cast iron. Ganhaizi Bridge is located in Ya'an, which is an area with a high risk of earthquake in China. The weight of composite truss bridge is significantly lighter than reinforced concrete bridge, which makes a best solution for high seismic risk zone. However, since the curvature of the circular truss tube should be under restrict control during fabricating and welding (Liu et al., 2010), the manufacture quality of rectangular truss is more easily guarantied than the circular truss. The cost and simplicity of circular truss are less competitive than that of rectangular truss.

Substantial experiments (Liu et al., 2010; Packer, 1995; Sakai et al., 2004) and analysis of tubular structure indicate that the joints' strength and fatigue performance are governing factors in design (Hou et al., 2013; Liu et al., 2009; Machacek and Cudejko, 2009; Schumacher et al., 2009; Shi et al., 2012; Wang et al., 2013). In this paper, perfobond ribs (PBR) have been settled in chord joints for better performance than the hollow tubes. Based on the knowledge of double-composite action and special configuration of joints, the author proposed a new type of composite bridge fitting for the span range of 30–80 m, which is made of rectangular truss chord with concrete-filling and prestressed concrete slab. The bottom concrete-filled chord combining with the prestressed concrete slab forms a double-composite system.