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Composite box girder with corrugated steel webs and trusses – A new type of bridge structure

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ABSTRACT

Composite box girders with corrugated steel webs and trusses is a new type of advanced bridge structure proposed recently. This kind of structure consists of a top concrete slab, corrugated steel webs and two bottom concrete-filled steel tubes connected by trusses. The resistance to torsion and overturning of this kind of structure is larger than that of composite bridges with a single concrete-filled steel tube. This kind of structure is able to satisfy the requirement of rapid construction, environment protection and cost effectiveness. Two composite box girder bridges with corrugated steel webs and trusses have been or are being constructed in China. This paper presents the design of these two bridges in detail, which will provide valuable engineering experience for the further promotion of this kind of new bridge structure. Experimental research has been carried out to study the flexural behavior and the flexural capacity of this kind of new bridge structure. The test results show that when the test beam is at the elastic stage, the cross-section can be viewed as a plane section if only the strains of the concrete top slab and the bottom steel tubes are considered. The test beam shows good ductility throughout the whole loading process.

1. Introduction

The concrete box girder is one of the most commonly used structure forms for bridges because of its large flexural and torsional stiffnesses. However, with the increase of span length, the self-weight of a concrete box girder may increase rapidly, which restricts its use in long-span bridges [1]. One of the most promising ways to reduce the self-weight of bridges is to adopt steel–concrete composite structures. Nowadays, there are mainly three types of steel–concrete composite bridge structures: composite bridges with steel beams and top concrete slab, composite bridges with steel webs (or steel trusses) and top and bottom concrete slabs, and composite bridges with top concrete slab, steel trusses and bottom concrete-filled steel tube (Fig. 1(a)).

Among all the above mentioned types of composite bridges, the number of composite bridges with top concrete slab and bottom trusses is the smallest. This is because this kind of structure contains a lot of truss joints, and the fatigue and the stress concentration at such joints may lead to the failure at these locations before the global failure of the whole structure happens. That means the flexural capability of the bridge may not be fully utilized. To solve this problem, engineers proposed the composite bridge with Corrugated Steel Webs (CSWs) and Concrete-Filled Steel Tube (CFST, Fig. 1(b)), where the trusses are replaced by corrugated steel webs so that the number of joints can be greatly reduced. The Maupré Bridge [2] constructed in 1988 in France is the first bridge of this kind. Chen and Gao [3] has shown that such an improvement increases the ultimate flexural capacity of the bridge by nearly 80%. Meanwhile, the adoption of corrugated steel webs significantly improves the mechanical performance of the structure (e.g. [4,5]). This has been shown in the comprehensive studies on the mechanical performance of composite girders with CSWs and top and bottom concrete slabs, including the flexural behavior (e.g. [6–9]), the shearing behavior (e.g.[10–12]), the torsional behavior (e.g. [13,14]), the dynamic properties (e.g. [15,16]) and so on.

However, there are still some limitations in the composite bridge with CSWs and CFST (Fig. 1(b)). First, as the cross-section is triangular, the torsional stiffness and the resistance to overturning is relatively small. Second, the space for some construction procedures such as the welding between the corrugated steel webs and the steel tubes is limited. To further improve this kind of structure, the composite box girder with CSWs and trusses is proposed. Fig. 2 shows a typical cross-section of this kind of structure. The most important feature is that the single concrete-filled steel tube in Fig. 1(b) is replaced by two bottom steel

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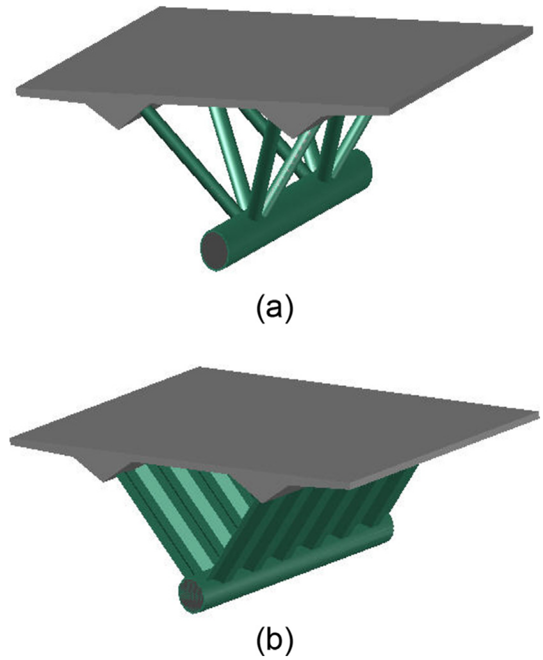

Fig. 1. Typical cross-section of (a) composite bridges with top concrete slab, trusses and bottom CFST; (b) composite bridges with CSWs and CFST.

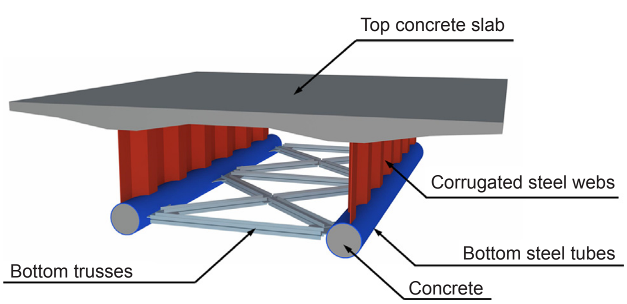

Fig. 2. Typical cross-section of composite box girders with CSWs and trusses.

tubes filled with concrete and connected by trusses, which may enhance the capability to resist torsion and overturning. The space for construction and maintenance within a bridge cross- section is also enlarged.

This paper aims to introduce to the public the composite box girder with CSWs and trusses, which is a new kind of composite bridge structure. In the following sections, a footbridge and a viaduct in China will be first presented in detail. Afterwards, the flexural behavior of this kind of bridge will be experimentally studied. The stress and strain characteristics and the failure mode under flexural loading will be summarized to provide a scientific basis for the application of this kind of bridge structure.

2. Engineering examples

2.1. A Footbridge in Hebei Province, China

The first composite box girder with CSWs and trusses that has been constructed is a footbridge located in Hebei Province, China, as shown in Fig. 3. It is a two-span simply supported girder bridge passing across the Beijing-Hong Kong-Macau Highway. This footbridge was designed by Shenzhen Municipal Design & Research Institute Co., Ltd.

The structural designs of the two spans of the footbridge are basically the same. Fig. 4(a)–(c) demonstrate the structural design of one of the spans of this footbridge. The net length of each span is 29.54 m. The depth of the girder is 1.60 m. The width of the top concrete slab is 3.30 m. The slope along the longitudinal direction of the bridge is 2.0%. At the bottom of the footbridge are two bottom steel tubes connected by horizontal trusses consisting of transversal and diagonal braces. The distance between the centers of the two bottom steel tubes is 1.50 m. Vertical trusses are also set up every 6.40 m along the longitudinal direction to enhance the integrity of the footbridge.

The typical cross-sections of the footbridge are shown in Fig. 4(d). The footbridge is a single-box structure. The thickness of the top concrete slab is 0.15 m at the edge and at the center of the cross-section, and 0.30 m at the intersection with corrugated steel webs. Both the horizontal and the vertical trusses are made of steel tubes. The diameters of the tubes at the horizontal and the vertical trusses are 168 and 146 mm, respectively. The thickness of these steel tubes is 6 mm. The diameter and the thickness of the bottom steel tubes are 500 and 24 mm, respectively. All steel tubes are made of Chinese standard

Fig. 3. A footbridge at Hebei Province, China.