

Experimental behavior and analysis of prestressed concrete-filled steel tube (CFT) truss girders



Wenjin Huang^a, Zhichao Lai^{b,*}, Baochun Chen^c, Pengyu Yao^a

^a Fujian Agriculture and Forestry University, Department of Civil Engineering, Fuzhou, Fujian, China

^b Purdue University, Lyles School of Civil Engineering, West Lafayette, IN, United States

^c Fuzhou University, College of Civil Engineering, Fuzhou, China

ARTICLE INFO

Article history:

Received 9 May 2017

Revised 24 August 2017

Accepted 13 September 2017

Keywords:

Composite

Concrete-filled steel tube (CFT)

Truss girders

Prestress

Experimental test

Finite element analysis

ABSTRACT

Prestressed concrete-filled steel tube (CFT) truss girders usually consist of CFT chords, hollow steel tube braces, and high-strength prestressing strands. This paper investigates the behavior of prestressed CFT truss girders by conducting both experimental tests and finite element analyses. Experimental tests on five prestressed CFT truss girders are first conducted. The test parameters are the prestress level and shear span-to-depth ratio. Results from the experimental tests indicate that: (i) the initial flexural stiffness and flexural strength of prestressed CFT truss girders increase as the prestress level or shear-span-to-depth ratio increases, and (ii) the failure modes of prestressed CFT truss girders are influenced by the prestress level and shear span-to-depth ratio. Finite element models, which were developed previously by the authors for CFT truss girders, are then modified to predict the behavior of prestressed CFT truss girders. Comparisons with experimental load-deformation responses indicate that the developed finite element models can reasonably predict the behavior of prestressed CFT truss girders.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Concrete-filled steel tube (CFT) trusses are usually comprised of CFT chords and hollow steel tube braces. They have better behavior and strength than hollow steel tube trusses due to the presence of the concrete infill. The concrete infill prevents the steel tube in the top chord from buckling inward and restrains the steel tube in the bottom chord from pinching (inward contraction). The concrete infill also improves the strength of brace-to-chord joints and the overall flexural stiffness of the truss [1]. Moreover, the steel tube serves as formwork for placing the concrete, which facilitates and expedites construction while reducing labor costs [2–4]. As an innovative and efficient structural system, CFT trusses have been widely used around the world in various types of structures. For example, they have been used as main girders in continuous truss bridges (e.g., Xiangjiaba Bridge in Hubei, China, main span is 72.2 m, see Fig. 1a) and cable-stayed bridges (e.g., Zidong Bridge in Guangdong, China, main span is 140 m, see Fig. 1b); they have also been used as girders in roof systems [5].

In the last few decades, researchers have experimentally investigated the behavior and strength of CFT truss girders. These exper-

imental tests can be categorized into two groups depending on their scopes. Tests in the first group focus on investigating the behavior of brace-to-CFT chord joints with various types of configurations (e.g., X, Y, T, and K). Representative tests include those conducted by Park [6], Liu [7], Chen et al. [8], Chen and Huang [9], and Huang et al. [10] among others. The parameters of these tests include: (i) chord diameter-to-thickness ratio, (ii) brace diameter-to-thickness ratio, (iii) brace-to-chord diameter ratio, (iv) yield stress of the brace and chord wall, and (v) presence of concrete infill in the chords. The test results indicated that filling concrete in the chords significantly improved the stiffness and strength of the joints.

Tests in the second group focus on investigating the overall flexural behavior of CFT trusses, as summarized by the authors in a separate research [1]. The test parameters usually include: (i) shear span-to-depth ratio, (ii) angle between diagonal braces and chords, (iii) truss type (e.g., Pratt truss, Warren truss, and Warren-vertical truss), and (iv) concrete compressive strength. Warren-vertical truss means that vertical braces are used in the truss along with the diagonal braces, as shown in Fig. 2. These tests indicated that: (i) the behavior and strength of CFT trusses were significantly improved as compared to hollow steel tube trusses, (ii) Warren-vertical CFT truss had better performance than Pratt and Warren truss, (iii) the failure modes of CFT truss usually included tensile fracture of the bottom chord and joint shear failure, and (iv)

* Corresponding author.

E-mail addresses: wenjinhuang@fafu.edu.cn (W. Huang), laiz@purdue.edu (Z. Lai), baochunchen@fzu.edu.cn (B. Chen), yaopengy@126.com (P. Yao).

Nomenclature

A_c	cross-section area of the concrete infill	P_u	maximum applied vertical load
A_p	cross-section area of each prestressing strand	a	shear span
A_s	cross-section area of the chord wall	i_p	prestress level, see Eq. (1)
D	diameter of chords	n	number of prestressing strands
D_b	diameter of braces	t	chord wall thickness
E_c	concrete elastic modulus	t_b	brace wall thickness
E_s	steel elastic modulus	f_{cu}	concrete cube compressive strength
El_e	initial flexural stiffness of prestressed CFT truss girders	$f_{cu,k}$	nominal 28-day concrete cube compressive strength
F_p	proportional limit, $F_p = 0.8F_y$	$\varepsilon_{c,0.7}$	compressive strain of the top chord at the midspan when the applied load equals to $0.7P_u$, see Eq. (2)
F_{py}	yield stress of the prestressing strands	$\varepsilon_{t,0.7}$	tensile strain of the top chord at the midspan when the applied load equals to $0.7P_u$, see Eq. (2)
F_u	steel tensile strength	ε_q^{pl}	equivalent plastic strain
F_y	steel yield stress	ξ	confinement factor, see Eq. (4.3)
H	height of prestressed CFT truss girders	ϕ	curvature
L	span of prestressed CFT truss girders	σ_{con}	desired prestress value
$M_{0.7}$	moment at the midspan when the applied load equals to $0.7P_u$, see Eq. (2)		
M_u	flexural strength of prestressed CFT truss girders		

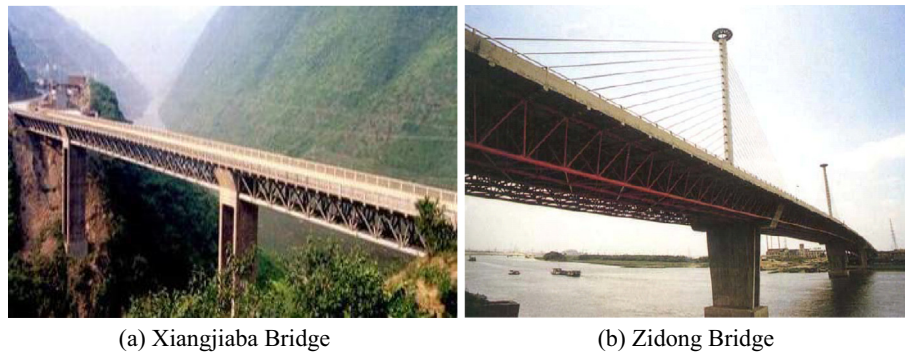


Fig. 1. Typical applications of CFT truss girders in bridges.

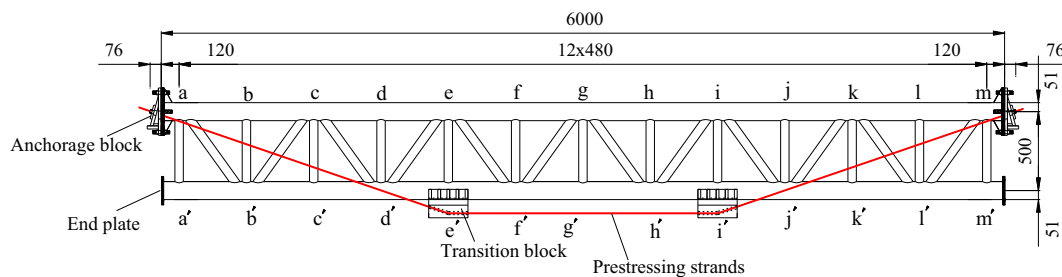


Fig. 2. Elevation view of the prestressed truss girder (unit: mm).

concrete compressive strength had negligible effects on the failure mode of CFT truss girders. Based on these experimental investigations, researchers such as Han et al. [11] have proposed design equations for estimating the flexural strength of CFT truss girders.

In practice, CFT truss girders are sometimes prestressed (post-tensioned) using high-strength strands to: (i) offset negative bending moments at the supports, (ii) reduce deflections due to self-weight during constructions, (iii) increase the flexural stiffness, or (iv) allow the use of shallower sections (i.e., with smaller cross-section height). The resulting structural system is referred to as prestressed CFT truss girders.

Currently, there is lack of knowledge regarding the behavior of prestressed CFT truss girders. This paper addresses the knowledge gap by conducting both experimental tests and finite element analyses. Experimental tests on five prestressed CFT truss girders are first conducted. The test parameters include the prestress level

and shear span-to-depth ratio. Finite element models, which have been developed and benchmarked earlier by the authors for CFT truss girders [12], are then modified to predict the behavior of prestressed CFT truss girders.

2. Experimental program

2.1. Test specimens

Five prestressed CFT truss girders subjected to three-point loading were tested in this research. The specimens were designed based on the CFT truss girders used in the Ganhaizi Bridge in Sichuan, China. This 1811 m long bridge has concrete decks, CFT truss girders, and shear studs that are used to develop composite actions between the decks and girders. It is important to note that the three-point loading scheme used in this research is different from

Download English Version:

<https://daneshyari.com/en/article/4919718>

Download Persian Version:

<https://daneshyari.com/article/4919718>

[Daneshyari.com](https://daneshyari.com)