HOSTED BY
ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/jtte
Journal of Traffic and Transportation Engineering (English Edition)

Original Research Paper

Application study on the first cable-stayed bridge with CFRP cables in China

CrossMark

Kuihua Mei [a,*], *Yajuan Li* [b], *Zhitao Lu* [c,d]

[a] *School of Highway, Chang'an University, Xi'an 710064, China*
[b] *CCCC First Highway Consultants Co., Ltd., Xi'an 710075, China*
[c] *School of Civil Engineering, Southeast University, Nanjing 210096, China*
[d] *Chinese Academy of Engineering, Beijing 100088, China*

ARTICLE INFO

Article history:
Available online 6 June 2015

Keywords:
Cable-stayed bridge
Finite element method
CFRP cable
Bond-type anchorage

ABSTRACT

In order to push forward the development of CFRP cable-stayed bridge and accumulate experiences, the study on the application of the first cable-stayed bridge with CFRP cables in China was carried out. The design essentials of main components of the bridge were introduced and its integral performances, including static properties, dynamic properties and seismic response were analyzed using finite element method. A new bond-type anchorage was developed and the processes of fabricating and installing CFRP cables were elaborated. Based on the results of construction simulation, a tension scheme for bridge was propound. During constructing, the stresses and displacement of girder and pylon, as well as the forces and stresses of cables, were tested. The results indicate that all sections of the bridge could meet the requirements of the ultimate bearing capacity and normal service; the performance of the anchorage is good and the stresses in each cable system are similar; the tested values accord well with the calculated values. Further, creep deformation of the resin in anchorages under service load is not obvious. All these results demonstrate that the first application of CFRP cables in the cable-stayed bridge in China is successful.

1. Introduction

Being as the external prestressing tendon, steel stay cables are prone to corrosion and fatigue. Further, due to the relatively higher self-weight of steel cable, it is increasingly difficult to erect steel stay cables for the current trend of such bridges with super-long spans. To overcome these problems, it is necessary to find a new type of material in lieu of steel. Carbon fiber reinforced polymer (CFRP) has many excellent properties, such as light weight, high tensile strength, corrosion resistance, excellent fatigue strength, and thus it is widely used in the field of civil engineering currently. It is especially

* *Corresponding author*. Tel./fax: +86 29 82336336.
E-mail addresses: meikuihua@163.com (K. Mei), 939227042@qq.com (Y. Li), luzhitao@seu.edu.cn (Z. Lu).
Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2015.05.004

suitable for using as stay cables of cable-stayed bridges. If CFRP cables are adopted, the problems of corrosion and fatigue of conventional steel cables can be radically solved. Most significantly, the self-weight of cables will be reduced, so the span ability of the bridge can be improved and the dimensions of substructure can be decreased. As early as 1987, senior experts put forwarded theoretic feasibility for constructing an 8400-meter-long CFRP bridge at the narrowest location of the Strait of Gibraltar (Li, 1990). Since then, the researches on CFRP cable-stayed bridges were carried out in many countries. Some researchers analyzed the static and dynamic characteristics of a long-span cable-stayed bridge with CFRP cables (Mei, 2007; Mei and Lu, 2004, 2006; Mei et al., 2007a, 2007b; Wang and Wu, 2010; Xie et al., 2014; Xiong et al., 2012), and others analyzed the nonlinear vibration and seismic response of cable-stayed bridge with CFRP cables (Fang et al., 2012; Zhang and Xie, 2009; Zhang and Ying, 2007; Zhou et al., 2011). Since then, three footbridges with full CFRP cables and two highway-bridges with partial CFRP cables were built in Switzerland, Denmark, Japan, United States, China, respectively (Mei, 2005; Scalea et al., 2000; Swiatecki, 1998; Winkler and Klein, 1998).

However, CFRP tendons are anisotropic and more sensitive to transverse pressure and notch effects compared to steel tendons. Thus, traditional anchors used for steel tendons, such as steel wedges, are not appropriate to use CFRP tendons, and traditional methods of fabricating and installing are not appropriate for CFRP cables. Therefore, it is necessary to develop an anchorage system that does not damage the CFRP tendons and explore new methods for fabricating and installing CFRP cables. Various anchorage systems for CFRP tendons have been developed and investigated over the last two decades (ACI, 2004; Jung et al., 2013; Schmidt et al., 2012). Based on the anchorage principle used, they can be classified into two types: bond-type anchorages and mechanical anchorage. The performance of bond-type systems depends mainly on the surface characteristics and bonded length of the tendon, the properties of bonding matrix, and the geometry of steel sleeve (Benmokrane et al., 1997, 2000; Fang et al., 2013; Mei et al., 2005; Noisternig, 2000; Schmidt et al., 2010; Zhang and Benmokrane, 2002; Zhang et al., 2001, 2006).

Although various pull-out tests of FRP tendon anchorages with cementitious material have been conducted to simulate ground anchorages in rock, there are relatively few studies reporting about CFRP tendon anchorages with a resin for cable-stayed bridge. The information for practical application of CFRP cables is much less. The intention of this paper is to introduce the design and construction of the first CFRP cable-stayed bridge in China.

2. Overview of the first CFRP cable-stayed bridge in China

The first CFRP cable-stayed bridge in China is located in the main campus of Jiangsu University. It is a pedestrian bridge with one pylon, double cable planes and a length of 48.4 m (main span is 30 m and side span is 18.4 m). The piers, pylon and girder of the bridge are consolidated together. The stay-cables are made of CFRP tendons, while the girder and the pylon consist of reinforced concrete structures. The concrete grade is C40, and the compressive and tensile strengths of concrete are 26.8, 2.4 MPa, respectively. The width of the bridge is 6.8 m, including 5-meter-wide footway. Four pairs of CFRP cables are set on each span. Abutments are supported on the enlargement base, while piers are supported on the foundation of digging piles, as shown in Fig. 1.

3. Design and research

3.1. *Design of structural components*

Comparing to aramid fiber reinforced polymer (AFRP) and glass fiber reinforced polymer (GFRP), CFRP has preferable performances, so CFRP tendons were adopted in bridge. Only the commercially available leadline rods were used in this project. These rods are composed of pitch-based carbon fibers and epoxy resin. The contents of fiber and resin are 65% and 35% by volume, respectively. The rods have an indented surface to provide interlock and stress transfer, and a nominal diameter of 7.9 mm. The physical and mechanical properties are summarized in Table 1, where values in parentheses are characteristic (minimum guaranteed) quantities provided by the manufacturer.

Depended on cables forces of this bridge, three types of stayed cables were used. For the cable consisting of 6 leadline rods, it was designated “6D8”, and for the cables consisting of 11 rods and 16 rods, they were designated “11D8” and “16D8”, respectively. The arrangement of different types of cables was

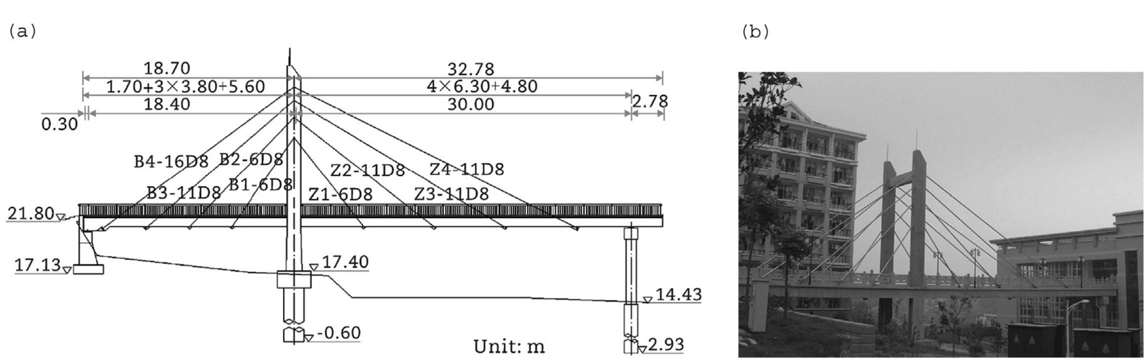

Fig. 1 – First cable-stayed bridge in China. (a) Overall layout. (b) Appearance of the bridge.