Journal of Constructional Steel Research 72 (2012) 267–275

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Investigation on the horizontal mechanical behavior of steel-concrete composite cable-pylon anchorage

Qing-Tian Su, Guo-Tao Yang *, Fei Qin, Chong Wu

Department of Bridge Engineering, Tongji University, Shanghai 200092, China

ARTICLE INFO

Article history:
Received 21 July 2011
Accepted 10 January 2012
Available online 30 January 2012

Keywords:
Cable-stayed bridge
Composite cable-pylon anchorage
Composite structure
Concrete cracking

ABSTRACT

The configuration and mechanical behavior of steel-concrete composite cable-pylon anchorage in cable-stayed bridges are very complex. Considerable local deformation of composite cable-pylon anchorage zone could occur under the horizontal component of the inclined cable force. It is difficult and unfeasible to analyze the horizontal mechanical behavior of the composite cable-pylon anchorage by the traditional analytical theory of composite structures. In this paper, full-scale model tests were carried out according to an actual project to analyze the horizontal mechanical behavior of composite cable-pylon anchorage. Stress distribution patterns of the main members and the failure modes were obtained. Structural response of the anchorage was analyzed by spatial solid and shell finite element model. By analyzing and simplifying the configuration and details of the structure, the expression for calculating the horizontal force burdened by the main members of composite cable-pylon was derived based on the deformation compatibility principle. The equation for calculating internal forces of the main members in the composite cable-pylon anchorage was also obtained. It is shown that the proposed simplified method agree well with the experimental result and finite element method result.

1. Introduction

As a new type of anchorage structure, the steel-concrete composite cable-pylon, as shown in Fig. 1, is mainly used in the long-span cable-stayed bridge nowadays [1]. The composite cable-pylon anchorage system consists of two parts, the concrete wall and the steel anchor box. The steel anchor box is arranged inside the concrete wall and connected to the concrete wall with the shear connectors. Due to its excellent mechanical performance, composite cable-pylon anchorage was adopted in several long-span cable-stayed bridges, such as Normandy Bridge in France, Rion-Antirion Bridge in Greece, and Sutong Bridge, Shanghai Yangtze River Bridge, No. 3 Huanghe River Bridge and Edong Bridge in China.

The vertical mechanical behavior of the steel-concrete composite pylon is similar to that of common composite members, such as the concrete filled steel tube and the concrete encased steel-concrete composite columns [2,3]. The mechanical response of the composite pylon due to global and local effects can be analyzed and calculated based on the theories of columns [4–6]. However, there are non-neglected huge local forces due to the horizontal components of the forces of the inclined cables, which would cause high local stress and large local deformations on the concrete wall and the steel anchor box. Three key issues are related to in the analysis of the mechanical response of the steel-concrete composite cable-pylon anchorage, (1) local response of the support plate and the adjacent web plate of the steel anchor box due to the eccentric patch loading by the anchor heads of the stay-cables; (2) composite behavior between the concrete and the steel anchor box, or in other words the effective region of the steel anchor box to be taken account of in the composite behavior of the concrete wall; (3) response of the concrete wall due to the transverse force and the existence of the round holes for the stay-cables.

As for issue (1), extensive investigations have been conducted on the web plates of the steel beams [7–11], and there is no substantial difference between the web plates of beam and the support plates of the steel anchor box of the cable-pylon anchorage. With regard to issue (3), local cracking is prone to occur in concrete wall caused by the horizontal component of the cable forces, which becomes one of the most important issues that govern the design of the composite cable-pylon anchorage [12]. Previous researches were mainly focused on the concrete slab with cutouts [13,14], the concrete walls of cooling towers [15,16], and the walls of dams [17].

Many studies could be found on the load transmitting mechanism of the anchorage zones of concrete girder bridges with the method of numerical simulation and the method of model tests [18]. However, there is no relative study on issue (2) and the interaction behaviors between the three issues. Therefore, the percentage of the horizontal components of the forces carried by the concrete wall and the web plates of the steel anchor box can not be numerically determined.

* Corresponding author. Tel.: +86 21 65983116x2602; fax: +86 21 65983450.
E-mail address: 2010expo@tongji.edu.cn (G.-T. Yang).

0143-974X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jcsr.2012.01.004

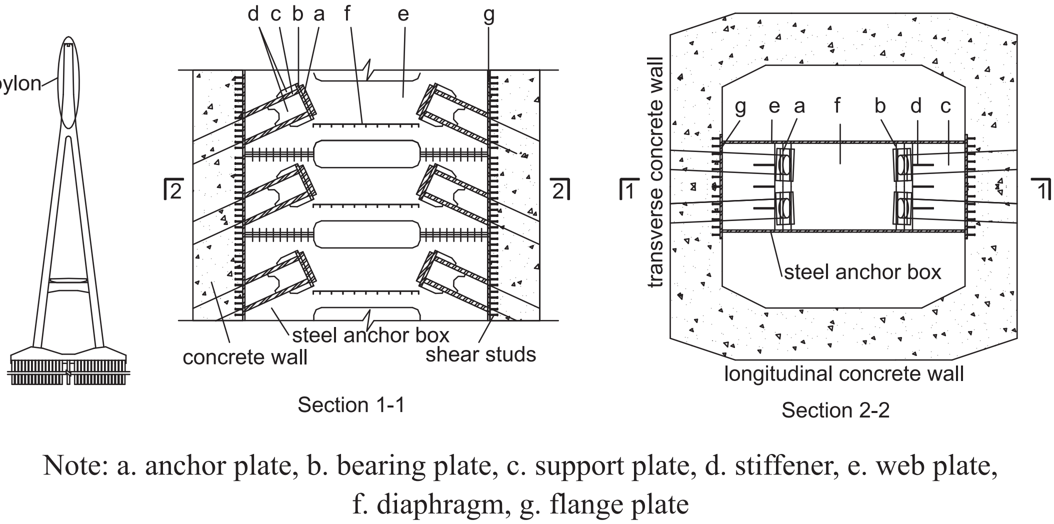

Fig. 1. Details of steel-concrete composite cable-pylon anchorage.

In this paper, both model test and theoretical analysis were adopted to investigate the horizontal mechanical behavior of the composite cable-pylon anchorage. In the test model and analytical model, only the horizontal component of the cable force was considered to eliminate the influence of the vertical components of the cable forces on the boundary condition and interaction between the two directions.

2. Full-scale segment model

The steel-concrete composite cable-pylon anchorage consists of two components: concrete wall and steel anchor box. The steel anchor box is composed by anchor plates, bearing plates, support plates, stiffeners, web plates, diaphragms and flange plates, as shown in Fig. 1. The anchor box is located inside the closed concrete wall and connected to the concrete with shear connectors. In actual bridge pylon, many steel anchor boxes are arranged linearly inside the pylon, so stress distribution in the web plates of the steel anchor box and in the concrete wall under the horizontal component of inclined cable force is comparatively uniform along the vertical direction. Thus a segment of the pylon could be adopted to study the horizontal mechanical behavior of composite cable-pylon anchorage, and the force could be simplified to be horizontal to eliminate the influence of vertical component of the cable force, as shown in Fig. 2. Due to modification of the direction of the cable force in the segment model, support plates of the steel anchor box and the stiffeners welded to it are oriented to be horizontal as well. In the design of the full-scale segment model, the mechanical behavior of concrete wall, middle area of web plates and most other components of steel anchor-box are conform to the original structure, and only the connection region between the web plate and support plate is of little difference.

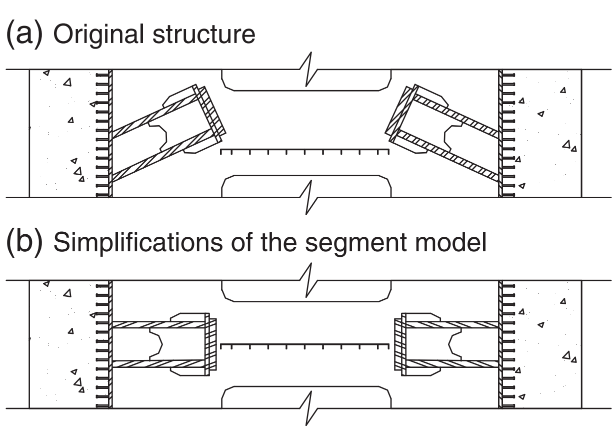

Fig. 2. Design of full-scale segment model.

3. Model test

3.1. Test program

To investigate the horizontal mechanism of the steel-concrete composite cable-pylon anchorage, a full-scale model test was conducted and the test model is shown in Fig. 3. The dimension of test model is 8.00 m × 8.40 m × 2.30 m. The thickness of the concrete wall, the flange plate, stiffener, and other plates in steel anchor box are 900 mm, 30 mm, 25 mm and 40 mm respectively. The reinforcing bars are not illustrated in figure of the test model. Two jacks with capacity of 650 t were set on each side of anchor plates, as shown in Figs. 3 and 4. A spreader beam was designed to transfer the force of jacks to the anchor plates.

Mechanical properties of materials were obtained on the same day of the test (42 d). The detail properties of the concrete and the steel are listed in Tables 1 and 2.

3.2. Test results and discussions

The cable force was taken from the Third Yellow River Bridge in Jinan, which is a single pylon cable stayed bridge with the span of 60 m + 60 m + 160 m + 386 m. The maximum horizontal cable force is 5339 kN and it is the horizontal component of the maximum cable force 6370 kN under ultimate limit state. The combination of ultimate limit state is done according to General Code for Design of Highway Bridges and Culverts, China (JTG60-2004). In the test of the model, when the applied load reached 0.9 times P, first crack of the concrete wall appeared near the right cable hole on outside surface of transverse concrete wall. When the applied load reached P, there were several cracks distributing above and below the cable hole on the outside of the concrete wall and the maximum crack width was 0.15 mm. With the increase of the applied load, many new cracks were found on the concrete wall and the crack width