System Conversion of Space Cable for Self-anchored Suspension Bridge

Riliang Zhang

Liuzhou OVM Machinery Co., Ltd. Liuzhou, Guangxi, 545006, China

Corresponding author: ovmzrl@163.com

Abstract

The construction method of space cable system conversion of self-anchored suspension bridge is briefly described, and the system conversion of space cable is realized through the rotatable cable clamps and adjustable suspenders of space structure. Taking the Tianjin Fumin Bridge as an example, based on the rotatable cable clamp and the suspender of space structure, the concrete implementation mode and the tension method of the space cable system conversion are discussed. The space cable is transformed from the plane cable plane to the space cable plane system, and the tension construction is completed. It will provide some references for space cable structure suspension bridge construction in China.

Keywords

System conversion; Space cable; Rotatable cable clamp; Suspension cable.

1. Introduction

Because of its magnificent momentum and beautiful appearance, suspension bridges are called queens in bridges, and are developing rapidly all over the world. In the late 1980s, the construction of suspension bridge in the world reached its heyday, and there were 17 suspension bridges with span of more than 1000 m. In China, since twenty-first Century, due to the need of economic development, the construction of cities and roads and bridges is builded very rapid, and many suspension bridges have been built, such as Xiamen Haicang Bridge, Jiangsu Runyang Bridge, Jiangyin Changjiang Highway Bridge, Wuhan Yangluo Changjiang Highway Bridge, and other large suspension bridges in the world. In recent years, the continuous development and innovation of bridge structure type, a kind of space cable suspension bridge with novel structure and beautiful appearance has been applied in China. The suspension bridge adopts the space cable structure, the main cable line is the space structure, the projection of the main cable line are all parabola. In the system conversion of the construction erection, the main cable has the vertical, horizontal and longitudinal three direction changes, and the cable clamp is changed into the three direction. The first single tower space cable surface self-anchored suspension bridge, Tianjin Fumin Bridge, has completed the cable system installation and achieved a successful system conversion through the careful design and professional construction by Liuzhou OVM Machinery Co., Ltd.

Tianjin Fumin Bridge is the first self-anchored suspension bridge with single tower space cable structure in China. It is one of the main contents of the comprehensive development project of Haihe River in Tianjin, China. The main bridge is made up of two span, and its span is mainly 157.081m + 86.4 m. The main bridge side span anchorage is designed to be prestressed concrete gravity anchorage to overcome the uplift force produced by the main cable. The main span is designed as a self-anchored anchorage structure, that is, the main cable anchor is anchored to the two sides of the main beam, and the side main cable is anchored to the ground anchor, forming a stable mechanism system. The main span of the main cable adopts three-dimensional spatial alignment, and parabolas are used in elevation

and plane. The side span adopts a group of parallel cables without vertical suspender (Fig. 1). The system conversion of the cable system is the excessive process of the main span of the main cable from the natural plane cable to the space cable plane. In view of the mechanical and construction requirements of the space cable structure of Tianjin Fumin Bridge, the main cable, cable clamp and suspender cable are analyzed in this paper. On the basis of the cable structure of the original suspension bridge, the innovation is made to meet the requirements of the bridge.

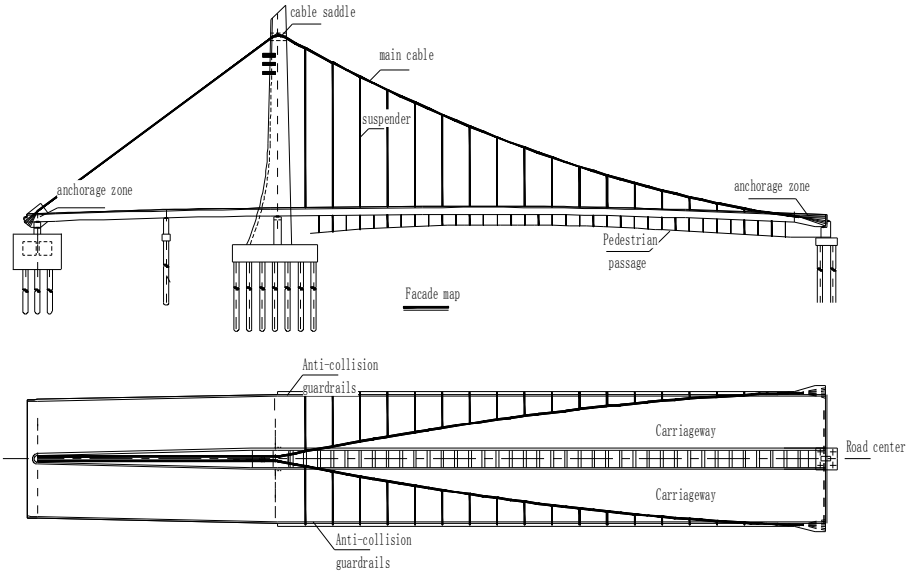

Fig.1 Front and Plane Layout of Cable System

2. The structure of the main cable

The main cable of Tianjin Fumin Bridge consists of 2 main cables, and is prepared by the prefabricated parallel wire strand (PPWS) method. Each main cable consists of 37 strand prefabricated parallel wire rope strands, each cable contains 127 galvanized steel wire with a diameter of 5.2 mm, and the theoretical diameter of the cable is 393.64 mm after the cables are compacted. The design tension of a single main cable is 4000 tons, and the safety factor K is 4. One head of the main cable uses a hot cast anchor, anchored to the side span anchors through a pull rod and a cable-share connector, and the other with a conventional cold cast anchor on both sides of the main beam (Fig 2).

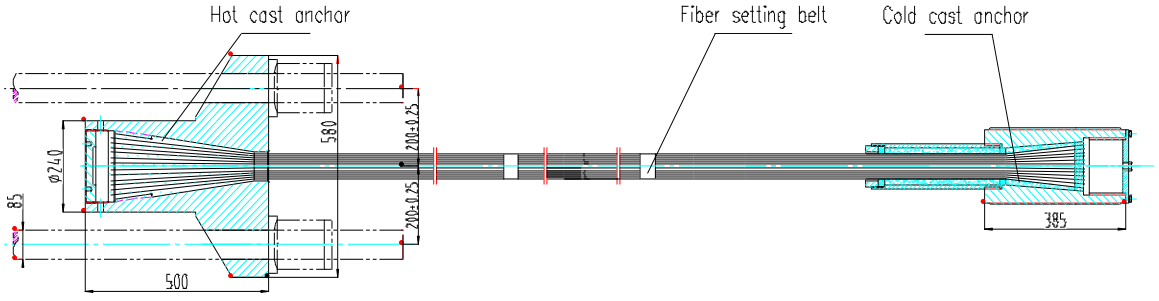

Fig 2 The structure of the main cable(mm)

The method of heterogeneous casting is adopted for the first time in the main cable of TianJin Fumin Bridge. The application of cold cast anchor on the main cable, it is very difficult to carry out the super tension after the cable stock on the upper plate. By comparing the cold cast anchor is pushed test and the super tensile test, the pushing technology is used instead of the cold cast anchor over tension.

3. The rotatable cable clamp

For the space cable structure suspension bridge, the main cable in the construction is vertical, horizontal and longitudinal in three dimensions, and there is no precedent for reference. It is conceived that a pre deflection angle is seted to the cable in the unloaded cable, and the three directions transformation system of the main cable can be converted by auxiliary tension. If the calculated pre deflection angle is inaccurate or there is a large error in the installation, it is difficult to convert the main cable to a certain angle. When the system converts to the second tension, the main cable is unfavourable. There is also torque for cable clamp, and affects the performance. In view of the requirements of the suspension bridge of the space cable structure, a new type of rotatable cable clamp is adopted for the main span cable of the TianJin Fumin Bridge, that is, the is composed of the inner cable clamp and the outer cable clamp, while the side span cable clamp uses the traditional cable clamp to set the shape.

The new type of rotatable cable clamp is characterized by the requirement that the suspension bridge which is suitable for the space cable structure to rotate during the construction process. The new type of rotatable cable clamp is composed of cable clamp body, rotating part, ear plate and high-strength bolts. The cable clamp body and rotating part are all cast steel structure (Fig. 3). The middle part of the cable clamp body is an outer circle, and the rotating part can rotate freely on it. Because of the structure improvement, the structure of the cable clamp is changed, and the tension of the suspender cable is reasonably converted to meet the change of the cable clamp of the cable structure of the space cable structure, and the construction becomes simple and feasible.

In order to verify the performance of the rotatable cable clamp, the cable clamp with the largest design force and the largest installation angle was tested in the bridge. The test contents are: slide resistance test and mechanical performance of cable clamp, mechanical performance of cable clamp rotating part and size matching between cable clamp rotating part and cable clamp body. The test results show that the design of the rotatable cable clamp is reasonable, the mechanical performance is reliable, and the performance is feasible.

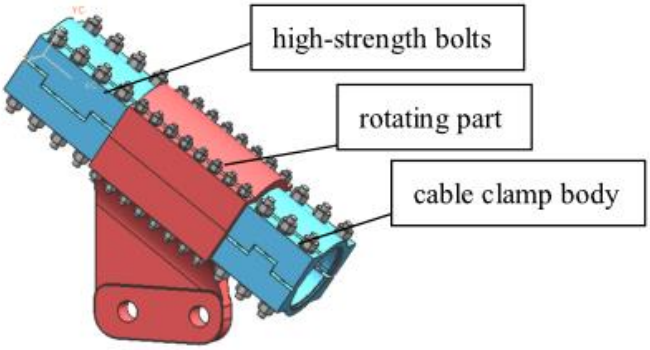

Fig. 3 The new type of rotatable cable clamp

4. The structure of space suspender cable

During the construction of the cable system from the free cable state to the bridge state, the clamps can be carried out with the main cable to achieve the three direction change, with the rotatable cable clamp, the adjustment of the tension of the suspender cable and the line of the main cable. Obviously, the traditional suspender cables used in suspension bridges are technically unable to meet the technical development requirements of suspension bridges of space cable systems. The use of auxiliary tensioning equipment will waste materials, improve the bridge cost and construction cost. The clamp with space structure can adapt to the suspension bridge with space cable structure, so that the clamp

can move and space suspender cable extend or shorten a certain length, and at the same time, it can turn a larger angle. The Tianjin Fumin Bridge uses a space clamp with a double space suspender cable (Fig.4), including the upper anchorage, the space suspender cable body, and the lower anchorage device. The upper anchorage and pin connected to the rotatable cable clamp are connected by the thread. The anchorage device for the lower of the structure of space suspender cable includes the lower anchorage, the threaded rod, the connecting sleeve, and the spherical connecting rod. The base and the rotary pair located between the spherical connecting rod and the base. The bottom end face of the base is fixedly connected with the box beam through bolts. The anchors of the upper and lower ends of the space suspender cables are all use cold cast, and the space suspender cable is 91 -Φ5 wire galvanized parallel steel cable.

5. System conversion and tensioning installation

The suspender of the space cable structure and the rotatable cable clamp meet the system conversion requirements of the space cable system. When the system is converted, a flat load beam A can be set at the top of the lower anchorage, and another flat load beam B is set at the step of the connecting rod. The two flat load beam A and the flat load beam B are connected through a tension bar, and lifting jacks are tensioned at the top of the flat load beam A (Fig. 5), as long as the connecting sleeve is adjusted to the threaded rod and the connecting rod. Different locations can achieve the purpose of adjusting the cable tension and main cable alignment. This kind of structure has relatively simple connection and large adjustment, and is suitable for installation of the suspender of space cable structure.

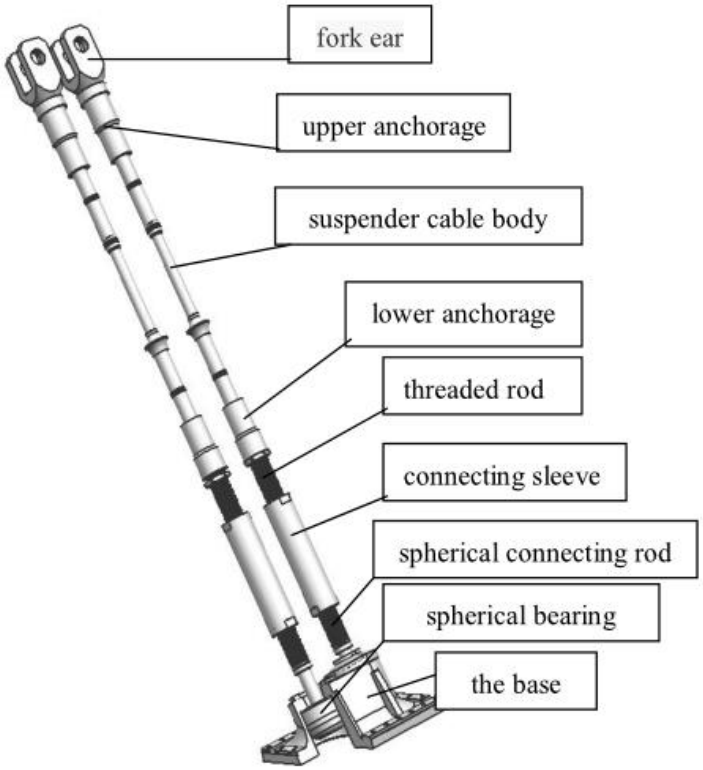

Fig.4 Schematic diagram of space suspender cable structure

In the design of suspenders, The Tianjin Fumin Bridge fully takes into account the operability of the installation and replacement of suspender, and adopts the structure of double suspender. Before the system is converted, the suspender is assembled from the connecting sleeve to the fork ear section, and the pin is connected to the cable clamp ear plate through a fork ear. When the system is converted, the

connecting sleeve of the suspender is connected with a spherical connecting rod after a lifting jack is pulled to a certain position,

and the original tension device is unloaded after the connection of the sleeve to a certain degree, and another tensioning of the suspender is carried out. When the second time tension cables are adjusted, the double suspender is seted on the synchronously lifting jack, to achieve the purpose of adjusting the main cable alignment and the tension of the suspender.

One of the most important technical difficulties in the system conversion of space cable structure suspension bridge is the alignment of catwalk. The catwalk of Tianjin Fumin Bridge is the same as the main cable line. After the system is converted, the main cable forms a spatial alignment, requiring that the catwalk follow the same change, so as to ensure the smooth operation of the later stage. In order to make the line shape of the catwalk consistent with the line of the main cable, the auxiliary tool is used to hang the catwalk directly onto the cable clamp body of the rotatable cable clamp on the main cable and fixed with the cable clamp bolts. When the system is converted, the catwalk is moved along the main cable through the tension and adjustment of the space suspender. The alignment is basically the same as that of the main cable (Fig. 6).

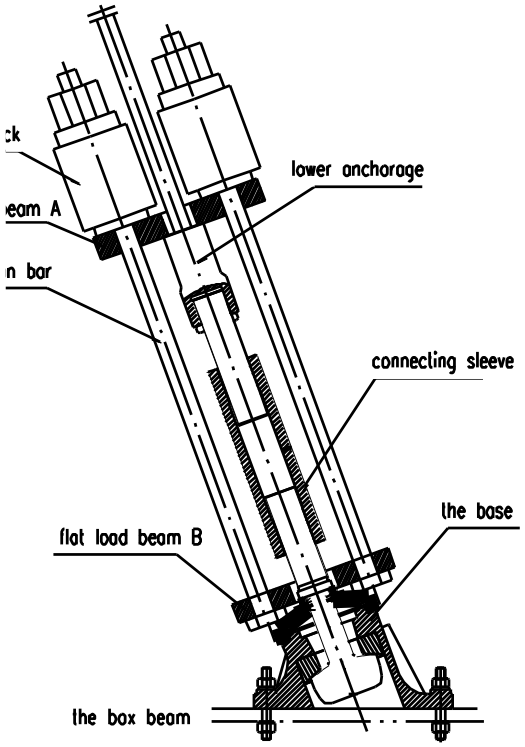

Fig. 5 Schematic diagram of space suspender tensioning installation

Fig. 6 alignment adjustment of catwalk

6. Summary

Tianjin Fumin Bridge is the first suspension bridge with single tower space cable structure in China. With the successful completion of the bridge, it is of great significance to the development of bridges in the future. more and more suspension bridges with space cable structures will be design and build。

In the process of system conversion, the suspension bridge of the cable cable structure requires that the suspender can adapt to the change of the line shape of the main cable, and the cable clamp is consistent with the axis of the suspender, avoiding the additional bending moment and torque when the cable clamp is not consistent with the axis of the suspender.

By adjusting the space structure of the suspender, it can adjust the tension of the suspender and the alignment of the main cable.

The key of the suspension bridge system conversion of the space cable structure is the construction method based on the space suspender and the rotatable cable clamp, which has important reference significance for the subsequent construction of the suspension bridge of the space cable structure.

References

[1] LEI Junqing, ZHENG Minzhu, XU Gongyi, Design of Suspension Bridge[M], People's transportation press,2002

[2] JTG/TD65-05-2015, Design Specification for Highway Suspension Bridge[S], Ministry of transport and communication of the People's Republic of China,2015

[3] HAN Zhenyong,PENG Chunyang, et al. Utility model patent:A rotatable suspension bridge cable clamp[P], Patent number:ZL 2006 2 0098950.3, 2007.10.17

[4] ZHANG Riliang, PENG Chunyang, HUANG Jiazhen, Study on the Performance of the Rotatable Cable Clamp of Tianjin Fumin Bridge[J], Prestress Technology, pp.24-29. 2007.

[5] JT/T 449-2001, Suspension Bridge of Highway[S], Ministry of Communications of the People's Republic of China, 2001