Technology for long cable erection of a thousand-meter scale cable-stayed bridge

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Abstract: In the background of the construction of Sutong Yangtze River Bridge (short as Sutong Bridge), the cable construction method and techniques of a thousand-meter scale cable-stayed bridge are introduced. Some key construction techniques, such as outspreading cable on deck, installing cable at pylon, pulling and fixing cable at the attachment with decks and cable PE sheath protection are discussed.

Key words: a thousand-meter scale cable-stayed bridge long cable; outspreading cable; the final scheme of construction technique for long cables; long cable construction

1 Introduction

In order to consummate state highway sketch, a number of cable-stayed bridges over rivers and bays are starting to be constructed, with their spans become more and more great. Thus, cables which are primary-load bearing member of cable-stayed bridges become longer and heavier. The construction of super-long cable is a key procedure in the construction of cable-stayed bridges. The selection of construction techniques directly relates to the success of cable-stayed bridges' constriction. This paper introduces cable construction techniques applied in Sutong Yangtze River Bridge (short as Sutong Bridge), in order to provide some references to cable construction of cable-stayed bridges in future.

Before Sutong Bridge was open to traffic, experience of cable construction of cable-stayed bridges whose spans are below 700 m has been accumulated due to the construction of several long span cable bridges. But, how to construct cables of a thousand-meter scale cable-stayed bridge has no reference world-wide.

The key cable construction techniques include outspreading cable on bridge decks, installing cable at pylon, towing and anchoring cable at the attachment with decks.

2 The general engineering situation

As the longest span cable-stayed bridge in world, Sutong Bridge is a seven-span bridge with double pylons and double cable planes. The spans are 100 m, 100 m, 300 m, 1 088 m, 300 m, 100 m and 100 m, respectively. The pylons are of inverse "Y" shape, and 330.4 m high. Its decks are 41 m wide and 4 m high. The cables are laid as spacial double fan-shape plane. There are 34 double of parallel steel wire cables at both sides of the pylon, and the bridge has total 272 cables, and the longest cable is 580 m long and 59 t weight (Fig. 1).

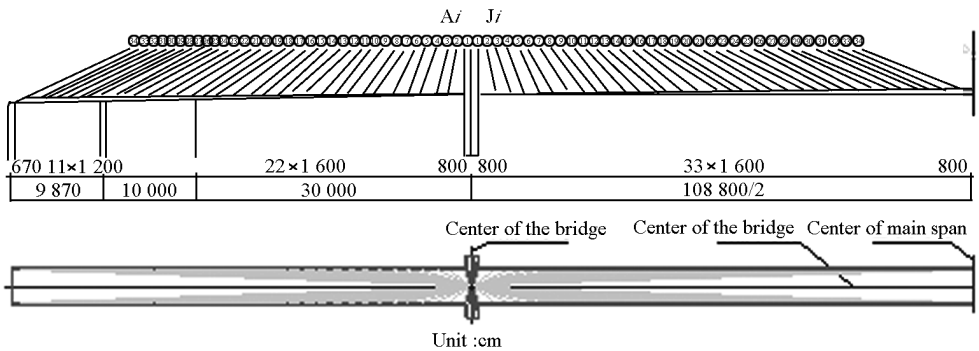

Fig. 1 General layout of cables

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The high strength parallel wires cables with dual antiseptic systems are introduced in construction of Sutong Bridge, the size of steel wire is PES7. There are eight specs of cables in Sutong Bridge, which are PES7-139, PES7-151, PES7-187, PES7-199, PES7-223, PES7-241, PES7-283 and PES7-313, respectively. The space between two adjacent cables is 16 m at the center span and lateral spans, and is 12 m at accessorial spans which are far from pylons.

3 Scheme of construction technique for long cables

The cable construction scheme of Sutong Bridge took the successful experience of Tatara Bridge in Japan as reference. According to itself characteristics of Sutong Bridge, some adjustments and optimizations were made, and the final scheme of construction technique for long cables is as below.

Long cable was hang to decks by a scraper on bridge deck, and then was placed at a vertical unreeling machine; cable anchorage head at the attachment with deck was pulled by hoisting machine on deck, MD3600 tower crane hoisted cable from the middle point of cable to assist its outspreading on deck; installation of cable at pylon was carried out by the gate frame and hoisting machine; cable anchorage head at the attachment with deck was pulled into cable sleeve by hoisting machine on deck and continuous jack using the combining soft-pulling and hard-pulling. At last, cable was tensioned at deck[1], and adjustment of cable forces was accomplished at pylon.

To satisfy space requirement for cable pulling and tension, part or all of fairings were installed after finishing cable construction at one block.

4 Primary construction method

The construction of long cable includes hanging cable to deck, outspreading cable on deck, installing cable at pylon, pulling and fixing cable at the attachment with decks, and tensioning and adjusting cable force at last[2].

4.1 Hanging cable to deck

Cables were transported by ship through Yangtze River. According to the scheme of construction technique for long cables, the cable plant shipped cables to the sites near pylons and dropped anchor after cable checking and accepting. Then cables were hang to deck together with steel plate by the gate-frame scraper, and were placed at the vertical unreeling machine[3].

4.2 Outspreading cables on deck and install cables at pylon

4.2.1 Method of outspreading and installing cables

For their great weight and length of cables applied in Sutong Bridge, cables were outspreaded by the hoisting machine on deck associated with the tower crane. And its install at pylons were accomplished by the hoisting machine, associated with the gate frame on the pylon. The procedure of cable-outspreading and cable-installing at pylons is as below:

Cable and vertical unreeling machine were pulled to center of the box-girder by the hoisting machine → cable anchorage head at the attachment with deck was debussed and laid at the vehicle unreeling machine at deck → cable anchorage head was connected to steel wire ropes of the hoisting machine → cable anchorage head at the attachment with deck was pulled to the front of the deck by the hoisting machine → cable was hoisted at the middle point till full outspreading by tower crane → cable clips were installed, and then connected cable clips to the hauling system → cable anchorage head was hoisted into cable sleeve by hoisting machine on top of pylon → cable was pulled and fixed by hoisting machine on the top of pylon.

4.2.2 Key techniques

1) Outspreading cables on deck. For their great weight, the vertical unreeling machine and cable plate should be fixed at the No.3 girder near shore in order to avoid cables were attainted by steel box-girder during the process of outspreading cables.

The vehicles were rebuilt to support and convey cables. After the rebuilding, the height of the vehicles was shorten and the space between vehicles was declined, in order to protect outspreading route straight, which is advantageous for protecting cables. The outspreading of cables is shown as Fig.2.

Fig.2 Outspreading cables of Sutong Bridge

2) Install cable at pylon. The key point of installing long cable at pylons was how to hang cable anchor-

age to the anchor padding plate at pylon and fix it without damaging cable. Cable was hung from two points in order to avoid breakage by bending. But due to large force at the main hanging point, cable clip was apt to gliding from cable, which causes damage of cable.

The hanging force of J34 cable of Sutong Bridge at pylons was about 23 t, and the frictional coefficient between cable clip and PE protection sheathing is about 0.1 (there's no relative data domestically, this is test datum), thus the clamping force must greater than 230 t in order to avoid gliding. For brittle PE sheathing, increase of cable clip length was chosen to avoid impairing cable. But the construction would become more difficult.

In order to reduce the risk of construction, PE compression test and tension test were carried out to choose the length, inner diameter and type of rubber blanket, and to acknowledge some key force indexes such as the clamping force, drawing force and the applied torsion moment of bolts (Fig. 3). Sandblasting should be done in advance (Fig. 4). The bolts were installed one by one in steps by hand dog to guarantee no slippage at the interface of cable and clip, and to reduce construction difficulty.

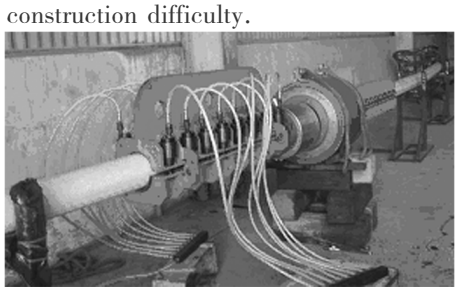


Fig. 3 The compressive test of cable PE sheaves

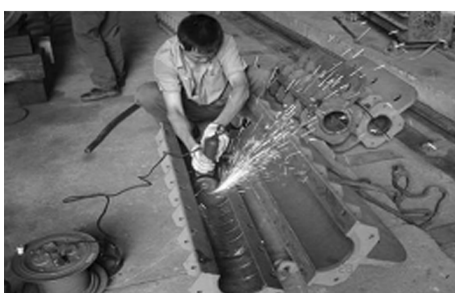


Fig. 4 Sandblasting inner surface of cable clip

4.3 Towing, anchoring and tensioning cable at deck

4.3.1 Scheme of towing, anchoring and tensioning cable

The combining of soft-pulling and hard-pulling was chosen in construction of Sutong Bridge. Tension was applied at deck. The construction procedure was as below:

The pulling clips were installed at cable anchorage head at the attachment with deck, and connect it to the pulley block of the hoisting machine→cable anchorage head at the attachment with deck was pulled to site where derrick cranes were→the devices of combining soft-pull and hard-pulling such as tension bar and steel wire ropes were installed at cable anchorage head→tension bar was soft-pulled to cable sheave by the jack →adjusting tension bar and anchorage head to make them concentric to cable sheave by angular adjusting scaffolding→tension bar was soft-pulled out of the anchor padding plate by the jack and fixed specially→cable anchorage head at the attachment with deck was hard-pulled out of the anchor padding plate and fixed →turning on the oil pump and starting to tension cable symmetrically and synchronously.

4.3.2 Key techniques

The key technique of towing and fixing cable at deck was to determine towing forces at all steps[4], and to choose towing devices according to towing force. For example of J34 cable of Sutong Bridge, its towing force and displacement curve is shown as Fig. 5.

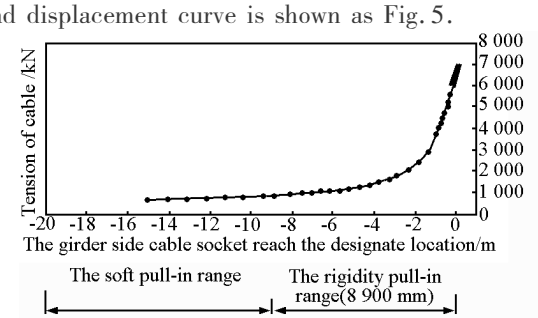


Fig. 5 The pulling force and displacement at deck of cable No. 34

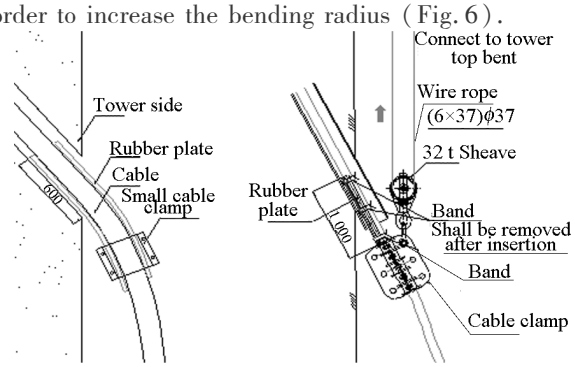
40 bundle of steel twisted wires were needed if only soft-pulling adopted for towing and anchoring J34 cable, which cannot be taken into reality; and a length of 26 m tension bar was required if only hard-pulling adopted, which bending breakage easily takes place. So these two methods were both infeasible for Sutong Bridge.

The cable towing and fixing of Sutong Bridge was accomplished by combining soft-pulling and hard-pulling, which could utilize both advantages of soft-pulling and hard-pulling. Due to the adoption of hard-pulling, tension force of soft-pulling falls, which result in reduction of steel twisted wires and make it easy to control. At same time, the adoption of soft-pulling could also shorten the length of hard-pulling.

4.4 Protection cables by PE sheath

The main function of PE sheath is to protect cable

from eroding during service time. The quality of PE sheath directly affects the service life of cables, even the life of cable-stayed bridge. The contact of PE sheath and hard material during tension would cause cables impaired. If cable bending radius is not great enough, cable damage also occurs. Thus, 100 mm thick rubber blankets should be laid at sites where cable meets hard matter. For long cables, after installation at pylon, before being tensioned at deck, it was difficult to satisfy the minimum bending radius limit. If no protection, cables' PE sheath would be attainted. To settle this problem, rubber blankets should be laid at contact sites, at the same time, cables should be hang in the air by hanging tool on the top of pylon in order to increase the bending radius (Fig. 6).



Unit: mm

Fig. 6 Measures for protect bending radius of cables

5 Conclusion

The cable construction of Sutong Bridge can be used for references of successful experience of long-span cable-stayed bridge worldwide. An improving cable outspreading method was applied to guarantee the outspreading routine straight, which was advantageous to protect cable. The tension of long cable was accomplished by combining soft-pulling and hard-pulling, which could utilize both advantages of soft-pulling and hard-pulling that lower tension force of soft-pulling and shorter length of hard-pulling, thus the risk and degree of difficulty of construction were reduced.

The main bridge of Sutong Bridge was open to traffic at June 10, 2007. The success of construction proved that its cable construction scheme was rational, which provided experience for new construction of the same type bridges.

References

[1] Jin Zenghong. Introduction on the construction technology of the Akashi Kaikyo Bridge in Japan[J]. Foreign Highway, 1999, 19(4):8-13. (in Chinese)

[2] Chen Mingxian. The construction technology of the cable-stayed bridge[R]. Beijing: China Communications Press, 2004. (in Chinese)

[3] The First Highway Engineering Company of the Ministry of Communications of China. Handbook of highway construction-bridge bridge II[R]. Beijing: China Communications Press, 2003. (in Chinese)

[4] Liu Shilin. Cable-stayed Bridge[M]. Beijing: China Communications Press, 2002.

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