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Durability and Maintenance of the Shantou Bay Suspension Bridge, China

Durabilité et maintenance du pont suspendu de la baie de Shantou, Chine

Dauerhaftigkeit und Unterhalt der Hängebrücke über die Shantou Bay, China

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SUMMARY

The Shantou Bay Bridge is under construction in China with a prestressed concrete box girder as its stiffened deck. The reason for using a prestressed concrete girder instead of the traditional steel type is mainly to improve durability of bridge deck against corrosion in the marine environment and to ease maintenance by eliminating the need for painting. But the self-weight of the whole bridge increases greatly, as does the cross-sectional area of two main cables. The stability of the bridge under wind pressure will be improved by the increased self-weight.

RÉSUMÉ

Le pont suspendu de la baie de Shantou est en construction en Chine. Le maître de l'ouvrage a donné la préférence à un tablier en poutre-caisson en béton précontraint, pour garantir une plus longue durabilité grâce à une meilleure résistance à la corrosion dans un environnement marin et à une maintenance plus facile en éliminant les renouvellements de peintures protectrices. Mais il a fallu accepter un poids propre nettement supérieur pour l'ensemble du pont et, en conséquence, de plus grosses sections des deux câbles porteurs principaux. Toutefois, cet important poids mort du pont agit favorablement sur la stabilité au vent de l'ouvrage.

ZUSAMMENFASSUNG

Die Shantou-Bay-Brücke ist zur Zeit in China im Bau. Für den Fahrbahnträger wurde Spannbeton dem traditionellen Stahl als Werkstoff vorgezogen, um eine höhere Dauerhaftigkeit gegenüber Korrosion durch die Seeluft zu erreichen und unterhaltsaufwendige Anstriche einzusparen. Aber das Eigengewicht der gesamten Brücke und damit der Querschnitt der beiden Hauptseile werden deutliche grösser. Das höhere Eigengewicht wirkt sich günstig auf die Windstabilität der Brücke aus.

1. GENERAL DESCRIPTION OF THE BRIDGE

Shantou Bay Bridge is located at the coast city Shantou of Guangdong Province in south China. Its main part was designed as a 3-span suspension bridge with span-length of 154 + 452 + 154 metres (Fig. 1).

The distance between two parallel main cables is 25.2 metres apart, it will give a bridge deck width of 24.2 metres and carry six lanes of motorway with two sidewalks. Each main cable will be made of 110 strands of 91 ϕ5 mm steel wires with cable diametre about 550 mm to 560 mm, and erected by PPWS method. The span/sag ratio of main cable in main span is 10, and in side spans is 29.6.

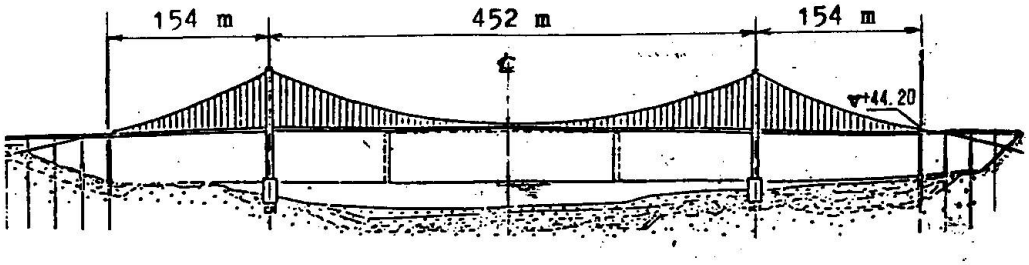

Fig.1 Profile of Shantou Bay Bridge

The concrete towers are of portal type with two intermediate horizontal beams (Fig.2). The total height of tower columns H = 95.10 m, and the top of tower is about 50 metres higher than the bridge deck level. The cross-section of hollow concrete tower columns are cast in "D" type, of which the straight wall is placed inside of the column, and the curved outside, thus to improve wind load condition. Besides this, the centre line of straight wall of tower column was designed to be coincided with the centre line of main cable. The outskirt dimensions of "D" type column are 6 m longitudinally and 3.5 m transversely, all in constant values (unvariable).

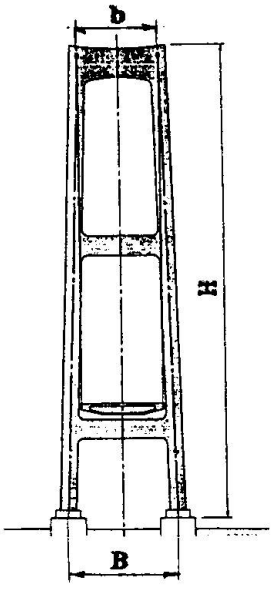

Fig.2 Portal Tower

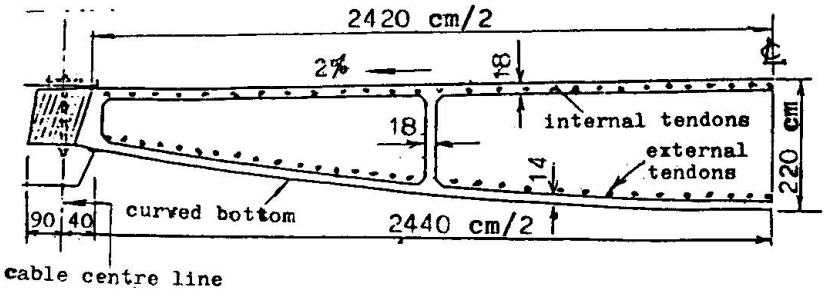

Fig.3 Half Cross-section of PC Box Girder

The PC stiffenef box girder is used for the main suspension bridge. Fig.3 is the half cross-section of this PC stiffened box girder. It is of streamlined shape with R = 7688 mm curved bottom plate. It is just something like a cross-section of the wing of an airplane if we put it upside-down. The 3-cell concrete box girder has two intermediate vertical webs with 18 cm in thickness. The thickness of upper and bottom plate is 18 cm and 14 cm respectively. The girder depth is 2.20 metres at the centre line of the bridge. The PC box girder is supported by the vertical hangers made of steel ropes with longitudinal spacings in 6 metres apart.

2. WHY PC BOX GIRDER IS USED AS STIFFENED BRIDGE DECK

Generally speaking, in order to reduce the self-weight of suspended construction of a suspension bridge, as well as its main cables and all the bridge parts such as cable saddles, cable bands, cable anchors, vertical hangers,etc, traditionally the steel girder (box or truss) will be used, especially for long span-length bridges. But for Shantou Bay Bridge, considering the durability and maintenance problems, PC box girder was finally selected to substitute traditional steel construction.

Shantou Bay Bridge is now under construction to link the mainland and Ma Yu Island in Shantou Bay. The suspension bridge is just over the sea. The marine condition is very unfavourable for steel girder, because it will be easy to make corrosion by heavy salt particles in the air surrounding the bridge superstructure. Therefore, using PC box girder can lengthen the lifespan of stiffened bridge deck by higher capacity of resisting corrosion than steel girder. Simultaneously, it can avoid periodical paint renovating which will be necessary for steel girder, and thus to ease the maintenance work of the bridge deck which must be done in high sky and inside the steel box girder with narrow space and high temperature & humidity.

3.DISADVANTAGES CARRIED BY PC BOX GIRDER

The very special feature of Shantou Bay Suspension Bridge to use PC box girder as stiffened deck for the sake of extending life span and easing maintenance will carry some significant disadvantages.

The major disadvantage is to increase the self-weight of the whole bridge.The unit weight of PC box girder is about 320 kN/m instead of 130 kN/m if steel box girder would be used. Therefore, the cross-sectional area and selfweight of two main cables also increase much more. Comparison with other suspension bridge of similar span-length and bridge width shows the unit weight of main cable will be increased about 80%. Other bridge parts such as vertical hangers (its longitudinal spacings of 6 metres is about only half of those used in suspension bridges with steel girder, so the amount of it is about double), cable bands (amount and size), cable saddles and anchorage materials etc. are also correspondingly increased.

The difficult of erecting PC box girder is the second disadvantage. Each girder section 5.7 metres in length and 170 tons of weight will be erected one by one to hang it to connect with the lower ends of a pair of vertical hangers. After a series of girder sections has been hung up, the 30 cm wide wet joints between the girder sections will be then cast-in-situ with some necessary fixing apparatus. There are altogether 121 girder sections, so the erection work will be heavier than to erect steel girder sections with about 12 metres in length and 150-160 tons of weight.

The third disadvantage is higher cost and longer construction period of bridge, because of that more cable work and girder erection must be done.

The fourth disadvantage is that, the self-weight of whole bridge increased by using PC box girder will be unfavourable to resist seismic response during earthquake. So, the substructure must be strengthened to meet the requirement of earthquake design.

4. ADVANTAGES COME WITH DISADVANTAGES

Although some disadvantages mentioned above will be carried by using PC box girder to substitute traditional steel girder, but some advantages reversely will come along with disadvantages.

First, the wind resisting capacity of the suspension bridge will be much more increased by the contribution of heavier self-weight of the whole bridge. Any

wind induced vibrations will be much more moderated. The vibration amplitude will be smaller and frequency will be higher.

Another advantage perhaps would be shown after long time service of the bridge. Generally speaking, the main cables and their anchorages of a suspension bridge are not easy to renovate or strengthen, but the relatively minor members such as hangers and stiffened girder are easy to change or renovate if it would be necessary to be done. Using PC box girder is firstly a key factor to extending the life span of the suspended bridge deck. If the PC box would be damaged after its designed service time, or would be renovated from PC box girder to steel one by some unexpected accidents or widened by increased heavier traffic condition within its service period, it would be then possible to utilize the reserved excessive strength of main cables and their anchorage capacity for a new steel stiffened box girder which is much more lighter in weight than PC box girder.

5. CONCLUSION

Because of the temperature at bridge site is always higher than 0° C within a whole year, no snow or ice will appear, thus no salt-spreading damage problem on concrete deck will occur to PC box girder. Therefore, using PC box girder for a suspension bridge to extending its life span and ease deck maintenance will be available. Of course, the cost of the bridge will be more expensive by using PC box girder as its stiffened deck.