Research on Lifting Techniques of Large Segments of steel box girder of Chongqi Bridge

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Abstract: Techniques of lifting large segments of steel box girder by floating crane is used in construction of Chongqi Bridge. Considering the hydrological environment on the site, characteristics of steel box girders and performance parameters of floating crane, the selection of floating crane is carried out. To ensure hoisting work achieve function and safety, a new type of lifting device named Self-balance lifting device is designed, and the lifting-points design is optimized to make the reaction of all lifting-points of large segments equal. In the erection process of large segments, the security risk control is analyzed to ensure the steel box girders and lifting equipments safety.

Introduction

Chongqi Bridge, as a part of the Hushan Expressway (Shanghai-Xi’an), starts from Chongming island in Shanghai, ends at Qidong in Jiangsu. It is a continuous steel box girder bridge with 6 spans of 102m +4×185m +102m. The cross-section of the main girder is separated to two single-box, each single-box is 16.1m wide. The girder height varies from 4.8m at the mid-span to 9m at the pier top. According to the different working situation, different thickness of steel plate is adopted in different segments of the steel box girder. General arrangement of Chongqi Bridge is shown in fig.1; Cross section is referred to fig.2.

Fig. 1 General arrangement of Chongqi bridge   Fig. 2 Cross section of steel box girders

General construction method

At the sites of Chongqi Bridge, the riverbed is flat, and the water is deep enough for large floating crane working. As Chongqi Bridge is located near Yangtze River estuary, there is strong wind in the whole year, and sometimes even typhoons. To reduce the on-site welding work, speed up the erection progress of the box girder, hence greatly reduce the bridge construction risk, a method of large segments of steel box girder erected integrally by floating crane is adopted.
When small segments (design segments) of the steel box girder are fabricated in the factory, they are welded into large segments with different length as 146.8m, 185m and 55.6m. These large segments of steel box girder are then shipped to bridge-building sites, where they are erected by large floating crane from north to south, from upstream to downstream. Among these large segments, the 146.8m and 185m segments are lifted by two floating cranes, while the 55.6m segments are lifted only by one floating crane.

As the bridge construction environment is severe, it is very important for ensuring the safety of the whole erection process of such long and heavy segments of steel box girder, thus an in-depth study about lifting techniques of large segments of steel box girder by floating crane should be taken on.

**Selection of floating crane**

Before doing the selection of the floating cranes, a broad investigation should be taken, which including environment condition on-site such as the water depth, riverbed conditions, and also the parameters of the lifting weight, height and width of all large segments, and the performance parameters of floating crane available. Among these large segments, the maximum lifting weight are about 2700t, the maximum height, length and width are 46m, 185m and 16.1m respectively. One crane will not be sufficient for so great lifting weight demand, therefore, method of dual lifting by two cranes is adopted to meet the loading capacity, also considering economic value, two floating cranes, one is Zhenfu No.5 (maximum lifting weight 2200t), the other is Zhenfu No.6 (maximum lifting weight 1600t) are finally adopted.

The method of large segments beam erection by two large floating cranes has been successfully applied, but seldom at home. According to sci-tech novelty retrieval it has been used in the construction the approach of the Hangzhou Bay Bridge, in which the maximum lifting weight is only 2300t and length 70m, nor many used in foreign countries. In the hoisting stage of large segments beam, it is very important to ensure synchronization and cooperation of the two floating cranes.

Before decision for the floating crane being finally made, the lifting weight, height and width of floating crane should be verified carefully.

1) Verification of lifting weight.

Take 185m large segments into account, the total lifting weight can be written out as:

\[
G = G_0 + G_1 + G_2 + G_3 + G_4 + G_5 \leq W_n.
\]

Which G represents total lifting weight, G0 represents self weight of box girder, G1 represents temporary reinforcement weight, including weight of lifting lugs, brackets, juncture of between box girder and strengthen weight of bearing, G2 represents weight of lifting appliance, including two hanger frame, block and tackle, pull board system, G3 represents sling weight, G4 represents wind load, G5 represents other load, including paint, platform, dryer and so on, Wn represents rated load of floating crane (when two floating crane are used, n=0.8). As the large segments are steel box girder with variable height, the lifting weight of the two floating cranes is not the same when dual lifting.

As a result, the total weight of 185m large segments is 2700t, and the lifting load surplus of zhenfu No.5 and zhenfu No.6 are respectively 382t and 99.7t, which shows that the combination using of 1600t+2200t floating crane meet the requirements of large segments beam lifting.

2) Verification of the lifting height.

Take the surface elevation as +0m, the lifting height of floating crane is shown in Fig. 3. Which \( \triangle H_0 \) represents elevation difference between the bottom of the box girder and bearing surface (1.5m) , H0 represents elevation difference between the bottom of the box girder and water surface.
(35.5m), H1 represents the maximum height of box girder (including box girder lug) (9.88m), H2 represents sling height 1 (30.0m), H3 represents sling height 2 (8.0m), H represents hoisting height of box girder (H = H0 + H1 + H2 + H3 = 83.4 m), Ha represents the maximum lifting height of floating crane (elevation difference between lifting hook and water surface).

As a result, the lifting height surplus of zhenfu No.6 is: \( \Delta H = Ha - H = 24.6 \) m, and of zhenfu No.5 is: \( \Delta H = Ha - H = 2.1 \) m, that is, the lifting height meet the height requirements.

3) Verification of the lifting width.

By calculation, if the floating crane and the transporting girder ship moors on both sides of the bridge pier respectively, the distance between the hook and the hoisting position is only about 15m, which is less than 16.1m (width of the box girder), therefore, the floating crane and the transporting girder ship should moor on one side of the bridge pier. Anchor of the floating crane is shown in Fig.4.

**Design of lifting device and lifting points of steel box girder**

**Selection of the lifting device:** In the dual lifting process, it is not easy to ensure traveling synchronization of the two floating cranes, also the reaction of all lifting-points will not be equal if traditional lifting device adopted, thus it will cause security problems in the erection process of large segments, so analysis and comparison about all the lifting device should be taken on, and special lifting device for this project should be designed if necessary. Generally speaking, there are two form of lifting device:

1) truss type lifting device: The usual form of lifting device we adopt domestic, in which there are multi lifting points on the lower chord, thus the weight of the box girder is distributed evenly on the lower chord of the lifting equipments. As is used in Qingdao Gulf Bridge construction (Fig. 5);

2) Plane-compression-bar type lifting device: Which lowered the height of the structure, and decreased the lifting weight, as is used in Sutong Bridge construction (Fig. 6);

As for truss type lifting device, it does not satisfy the requirement of floating crane for the lifting weight and lifting height, while for plane-compression-bar type lifting device, it is only suitable for short segments. For both the two type of lifting device, it is very difficult to make the reaction of all lifting points be equal, thus neither of these two lifting device meet the hoisting requirements in Chongqi Bridge construction.

To ensure the hoisting working of large box girders operating smoothly and safely, considering the performance parameters of floating crane and the structure characteristics of the large segments of the box girder, a new type of lifting device named self-balance lifting device was designed, as is used in Chongqi Bridge construction (Fig. 7).
Self-balance lifting device (Fig. 8), including sling, lifting frame, pulley blocks, lifting lugs, pulling plate and so on, in that a pulley blocks is used between lifting frame and lifting lugs, the sling can slide freely which makes all the lifting point force equal, and a small amount of longitudinal angle can be adjusted when needed.

**Fig. 5 Truss type lifting device**  
**Fig. 6 Plane-compression-chord type lifting device**

**Fig. 7 Self-balance lifting device**  
**Fig. 8 Construction of self-balance lifting device**

**Optimum Design of lifting-points:** Considering structure characteristics of the large segments of box girder, the design of the lifting-points number and position is optimized. 32 lifting-points are set in No 1~ No 5 beam segments which are dual lifted by two floating cranes, while 16 lifting points are set in No 6 beam segments which are lifted by only one floating crane. Each lifting point has one lifting lugs, the lifting lugs are welded with the webs through the roof of the box girder.

A solid finite element numerical model of the large segments of steel box girder is established by using Ansys software to analysis the stress state of the box girders in the lifting process. The finite element result shows that the maximum stress of box girders is 99.6MPa, which is at the intersect of the lifting lugs and the roof of the box girders, as the box girder is made of Q345D, the box girder structure is in the safe condition in the hoisting process.

**Safety risk control of erection of large segment steel box girder**

As the large segments of box girder being so long and heavy, erected integrally by floating crane first at home under so many adverse conditions, the security risk control analysis is crucial to a successful erection of the large segments of steel box girder. The general security risk control is proposed as follows:

1) Traveling synchronism of two floating crane. In the lifting process, two floating cranes are connected by cables, the floating crane traveling must obey the unified command of specially-assigned person. Once deviation of the two floating crane being found, it must be corrected in time.
2) Lifting synchronism of steel box girder by two floating crane. In the lifting process, monitoring lifting load and head, to ensure lifting load and head are in the range of the allowable value.

3) Safety of lifting device and large segments of box girder. Lifting work of large segments beam should be carried out in daytime, and wind less than No 6. Before doing the lifting work, check all the main structure to be sure they are in safety conditions. Lifting and dropping work of large segments beam should be slowly and gently, and the box girder should be kept horizontal. Keeping an eye on the force of the sling, make sure all the force of the sling is equal. Monitoring the stress of the box girder to be sure they are in safety conditions.

**Conclusion**

The erection of the whole steel box girders of Chongqi Bridge was successfully completed within six months (from 2010.10 to 2011.3), with the method of large segments of steel box girder erected integrally by floating crane. As at earlier stage by taking sufficient and in-depth research of the lifting techniques by floating crane, the whole erection process of large segments beam was in safety conditions, and in the completion state the shape and stress of the main girder satisfy the requirements of design.

**Reference**


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