A construction process for hoisting, precise positioning and temporary fixation of a steel-concrete composite segment on a long-span steel-concrete hybrid girder

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Abstract: *A steel-concrete composite segment of a steel-concrete hybrid girder features a complex structure and generally encounters difficulties in positioning and temporary fixation. In view of this, this study explored the layout of survey control networks and put forward a method for observing deformation of a concrete box girder at the cantilever end at the steel-concrete composite segment based on Hanzhuang Grand Canal Bridge, Tai'erzhuang District, Zaozhuang City, Shandong Province, China. Moreover, a construction process for hoisting the steel-concrete composite segment was proposed and a temporary fixation device for the segment used with a hanging basket was developed. The key sequences of temporary fixation were researched, which could provide practical and technological reference for similar engineering.*

Keywords: *steel-concrete hybrid girder, steel-concrete composite segment, precise positioning, temporary fixation*

1. Introduction

A steel-concrete hybrid girder belongs to a form of hybrid bridges and is a structural system in which a steel girder and a concrete girder are connected into an integral beam by using joints at an appropriate longitudinal position. In the design of modern long-span cable-stayed bridges, suspension bridges, continuous beams and upper structures of continuous rigid frames, to reduce the dead weight of structures and increase the spanning capacity, a steel-concrete hybrid girder is adopted to increase the overall stiffness of structures and reasonably balance the dead weight of each span and the overall internal force. A steel-concrete composite segment is set between the steel girder and the concrete girder, so that steel and concrete become a coordinated whole to ensure smooth transmission of the internal force. Because the hybrid girder makes good use of characteristics of steel and concrete and gives full play to their advantages, the mechanical performance, spanning capacity, structural layout and economic benefits of the whole hybrid girder are superior to those of steel or concrete structure alone [1-6].

Owing to the whole steel-concrete hybrid girder is composed of a steel girder segment, a concrete girder segment and a steel-concrete composite segment between the two, the mechanical performance of a bridge span structure differs either from that of the steel girder or concrete girder. Therein, the steel-concrete composite segment is the key to ensuring their joint work, so how to ensure the construction quality of the steel-concrete composite segment is particularly important. At present, the construction processes of the steel-concrete composite segment of the long-span steel-concrete hybrid girder mainly include prefabrication of the steel-concrete composite segment, ship transportation to the bridge site, hoisting and fixation of the steel-concrete composite segment and pouring of concrete. The steel-concrete composite segment of the long-span steel-concrete hybrid girder has a complex structure. For this reason, how to ensure accurate positioning during hoisting of a steel box girder and temporary fixation before pouring of concrete is the key and difficult points in the construction of the steel-concrete composite segment of the long-span steel-concrete hybrid girder. If precise positioning method and construction process of fixation are considered not according to engineering characteristics, it is more likely to impair the construction quality, and even trigger accidents in serious cases, which brings an immeasurable loss to the project. At present, the relevant studies on the steel-concrete composite segment of the long-span steel-concrete hybrid girder mainly focus on the overall force analysis of the structure, but there is little research on key construction technologies, so it is urgent to carry out relevant studies based on practical engineering.

2. Project overview

Hanzhuang Grand Canal Bridge (Tai'erzhuang District, Zaozhuang City, Shandong Province, China) is a three-span continuous steel-concrete hybrid girder bridge with variable cross sections, as shown in Figs. 1 and 2. The three bridge spans are separately 85, 180, and 85 m wide, the total length of the mid-span steel box girder segment is 61.5 m, and the steel-concrete composite segment is 4.5 m in length. The top, bottom and web at the end of the steel box girder were made into double-walled plates in the form of a rear bearing plate with compartments, in which PBL shear plates and pins were set to form steel compartments. The steel chamber was filled with concrete, and the steel box girder was closely connected with the concrete box girder through the short prestressed tendons, both ends of which were anchored on the stiffness transition zone of the steel box girder and the diaphragm of the concrete girder. The steel chamber along the bridge was 1.25 m in length and the thicknesses of upper and lower plates of the steel compartments of the top plate in the steel-concrete composite segment were 26 and 25 mm, respectively. The upper and lower plates of the steel compartments of the lower plate were 25 and 24 mm in thickness. Round holes with a diameter of 80 mm were drilled on webs of the steel compartments, through which the transversely prestressed tendons passed. Besides, round holes with a diameter of 70 mm were also drilled on the webs to allow HRB400 reinforcement with the diameter of φ 25 mm to pass through, which was wrapped with concrete entering the round holes to form PBL shear connectors. The outer and inner webs of the steel compartments were 24 and 25 mm in thickness and the PBL shear plate with a vertical width of 225 mm was welded in the inner side of the web. Round holes with a diameter of 70 mm were drilled on the plate to enable HRB400 reinforcement with the diameter of φ 25 mm to pass through, which was wrapped with concrete entering the round holes to form PBL shear connectors. Shear pins with the diameter of φ 22 mm and height of 15 cm were set in the inner wall of the steel compartments.

There were four steel-concrete composite segments with the dimensions of 3.99 m * 12.75 m * 4.1 m on the whole bridge and the hoisting weight was 65 t. A floating crane was adopted for hoisting and after being lifted to the design position, the steel-concrete composite segments were temporarily fixed to the main girder by cooperating with the hanging basket and other devices.

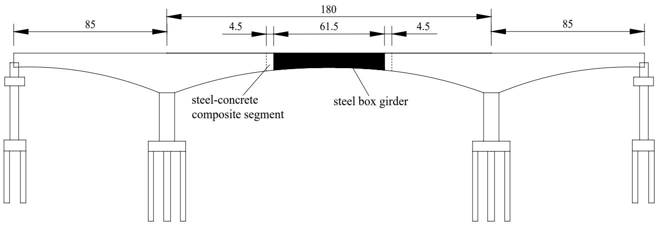

Figure 1: Plane view of Hanzhuang Grand Cannel Bridge (unit: m)

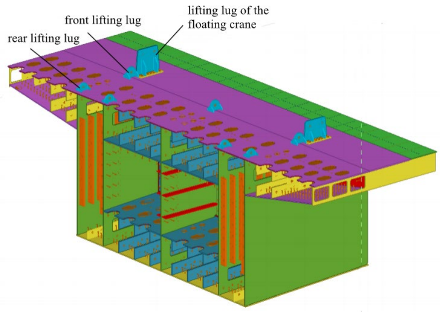

Figure 2: Three-dimensional diagram of a steel-concrete composite segment

3. Layout of survey control networks and deformation observation

3.1 Layout of Survey Control Networks

1) Selection of control points.

When hoisting the steel-concrete composite segment, it is necessary to ensure closure accuracy of the segment with the concrete box girder and consistent spatial postures of the two cantilever ends of the steel-concrete composite segment, so as to meet the accurate closure of the large-section steel box girder. Considering the slight deformation of the catilever ends of the steel-concrete composite segment in the cutting and transportation, control points should be set on the cross section 10 cm away from the cantilever ends and they are consistent with control points of the concrete box girder on the verticle view. The specific layout of the points is shown in Fig. 3.

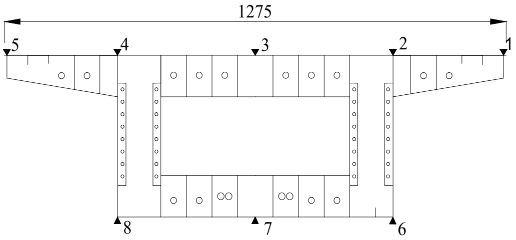

Figure 3: Layout of control points on the steel-concrete composite segment (unit: cm)

2) Control network settings.

According to actual situations of the construction site and positions of control points on the girder, the survey control networks adopt two control traverses (double traverses), namely, the control networks above and below the bridge. The densified control points were arranged along closed traverses and retested.

3.2 Deformation Observation of the Concrete Box Girder at the Cantilever End

1) Selection of observation points on the box girder.

Before hoisting the steel-concrete composite segment, deformation of end faces of the cantilever concrete box girder was observed to master changes of two end faces under different temperatures and time points, so as to provide supports for determining parameters of spatial postures of the steel-concrete composite segment in hoisting. Three points (1, 2 and 3) were symmetrically set on the top end face of the box girders of two mid-span No. 17 blocks, as shown in the figure 4 below. Considering the accuracy and convenience of measurement, the observation points were set 10 cm away from the end face.

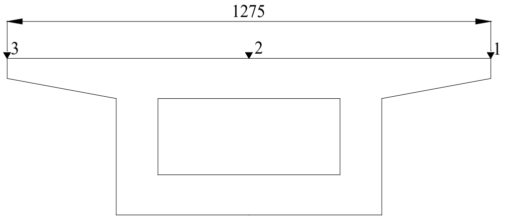

Figure 4: Layout of observation points for deformation of the concrete box girder (unit: cm)

2) Deformation observation of the concrete box girder at the cantilever end.

Before hoisting the steel-concrete composite segment, six observation points on the end face of the cantilever concrete box girders were continuously observed for 12 h. A lot of collected data were analyzed to determine control parameters. The data were collected every 2 h and the atmospheric temperature was measured by utilizing a temperature controller.

3) Comparison of actual measurement with design and simulation analysis.

Through the observation in the morning, noon and evening, the changes of spatial position of the cantilever beam were analyzed at different temperatures, and the changes in spacing between the two ends were inversely calculated according to coordinates of three pairs of symmetrical points on the cantilever beam for each observation. Elevation was mainly used to measure the changes of the height difference of symmetrical points.

4. Construction process of hoisting and temporary fixation of the steel-concrete composite segment

4.1 Hoisting Process

Considering the environment and efficiency of the construction site, the floating crane was used to hoist structures in this project. The steel-concrete composite segment has four sections, which should be hoisted for four times in the construction. The hoisting should be performed in a sequence according to the needs of on-site construction, but one half should be constructed after the completion of the other half. Fig. 5 shows the steel-concrete composite segment being lifted by the floating crane.

Figure 5: Lifting of the steel-concrete composite segment by the floating crane

The process is shown as follows:

1) Docking of the floating crane. To complete hoisting of each component in each segment, the floating crane needed to be anchored and docked. The floating crane needed to occupy the main channel (the occupation time should be controlled within four hours each time), and it was necessary to communicate with the maritime department in time to provide temporary traffic control and safety measures for the channel. It required to ensure that the hoisting process was safe and controllable.

2) The first steel-concrete composite segment was hoisted with the lifting wight of 65 t. The segment was temporarily fixed through spot welding.

3) The floating crane was docked at the side of a larger chainage, and the requirements were same as those of the first hoisting.

4) The second steel-concrete composite segment was hoisted with a lifting weight of 65 t and then temporarily fixed by means such as spot welding.

5) The other half of the steel-concrete composite segment was hoisted and fixed in the same way.

4.2 Temporary Fixation of The Steel-Concrete Composite Segment

1) Temporary fixation devices

The steel-concrete composite segment was hoisted by the floating crane to the elevation of the cantilever end of the concrete girder. After that, it was necessary to adjust spatial postures of the segment before its final fixation with the main concrete girder to ensure accurate positioning of the steel-concrete composite segment and reach the designed camber and elevation, which took a long time. Therefore, the steel-concrete composite segment was temporarily hoisted and fixed with the hanging basket and an auxiliary device at the rear lifting point which replaced the floating crane, to allow the floating crane to leave the site as soon as possible and shorten the closure time of the waterway, as displayed in Figs. 6 and 7.

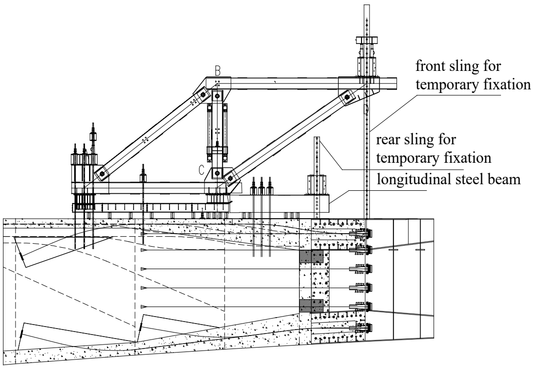

Figure 6: Schematic diagram of the hanging basket and temporary hoisting and fixation devices

Figure 7: Site photos of the hanging basket and temporary hoisting and fixation device

As shown in Figs. 6 and 7, after hoisting the steel-concrete composite segment in place, the original hanging basket could only fix the front lifting point of the steel structure in the steel-concrete composite segment and the lifting lug was set on the deck web. The hanging basket applied the hoisting force to the steel-concrete composite segment through the lifting lug. The steel-concrete composite segment was temporarily hoisted and fixed with the auxiliary longitudinal steel beam at the rear lifting point in a force transfer mode by setting the lifting lug on the web of the steel-concrete composite segment. The lifting lug was connected with the steel belt, through which the weight was then distributed to the jacks and beams on both sides by the carrying pole beam on the top of the steel belt. The cross beam was placed on four longitudinal steel beams with the longitudinal length of 3 m, and the suspended concrete segment was 1 m long. Cushion blocks were set at the bottom of the longitudinal steel beam to ensure clear mechanical behaviors.

2) Temporary fixation process

① The steel plate was embedded in the concrete girder segment in advance to be used as a guide plate for hoisting.

② After the steel-concrete composite segment was hoisted in place and initially positioned, the embedded steel plate was welded with the steel-concrete composite segment.

③ The steel-concrete composite segment was accurately measured by measuring devices, such as total station and was adjusted via coordination of the floating crane and guide beam.

④ After adjusting the steel-concrete composite segment in place, a coupling beam was installed and fixed.

⑤ The coupling beam was fixed with the rear-pivot lifting lug of the steel-concrete composite segment through hinge pins.

⑥ The hanging basket was adjusted according to the front pivot point of the steel-concrete composite segment.

⑦ The hanging basket was fixed with the rear-pivot lifting lug of the steel-concrete composite segment through hinge pins.

⑧ The floating crane slowly released the hook to transfer the bearing force to the hanging basket.

The process was closely monitored till it is completely unhooked.

5. Conclusions

1) Considering slight deformation of the cantilever ends of the steel-concrete composite segment in the cutting and transportation, the control points should be set on the section 10 cm away from the cantilever ends and consistent with those of the concrete box girder on the vertical view.

2) The survey control networks adopted two control traverses (double traverses), namely, the control networks above and below the bridge. The densified control points were arranged along closed traverses and retested.

3) Before hoisting the steel-concrete composite segment, the deformation of the end face of the cantilever concrete box girder was monitored to master the changes of the two end faces under different temperatures and time points. This provides supports for determining parameters of spatial postures of the steel-concrete composite segment.

4) Considering the environment and efficiency of the construction site, the floating crane was used to hoist by the steel-concrete composite segment in this project. The steel-concrete composite segment had four sections in total, so the hoisting required to be performed for four times in a sequence according to site construction. The construction of the one half should be carried out after the completion of the other half.

5) During fine adjustment, the verticality, elevation and plane positions of control points at the ends for closure of the steel-concrete composite segment and large-segment steel box girder were mainly controlled.

6) In order to make the floating crane leave the site as soon as possible and shorten the closure time of the waterway, the hanging basket and the auxiliary device connected with the rear lifting point were used to replace the floating crane for the temporary hoisting and fixation of the steel-concrete composite segment.

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