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Discussion on manufacturing technology of steel box girder of cross-line bridge engineering in Xiamen Hele road

Zhengwei Feng¹, Longbin Lin^{1*}

¹Department of Civil Engineering, Xiamen University Tan Kah Kee College,
Zhangzhou, Fujian Province, 363105, China

*Corresponding author's e-mail: llb@xujc.com

Abstract. Taking cross-line bridge road engineering of Jimei district Hele road (Jinting north road -Jimei north road section) of Xiamen city as the background, the paper introduces the overall segmentation and hoisting sequence scheme of steel box girder, the division of plate element, the setting method of jig-frame, the production process of steel box girder, the beam section of steel box girder and the overall welding process. And then it analyzes the geometric dimension accuracy control of element, the penetration control of U-rib weld on the plate element and the quality control features of diaphragm plate, solves the preassembly line shape of steel box girder and the precision of the interface matching connection and other difficult manufacturing problems. It ensures the smooth progress of the project, and provides a reference for manufacture of the steel box girder of similar projects.

1. Project profile

With the development of urban space, Jimei district, as the four major districts outside the island, has become the key area for future development of Xiamen city. At the beginning of 2014, the Tianji connecting line of expressway, Jimei avenue and Xingjin road were transformed into urban expressway smoothly, realizing the whole journey without traffic lights. It compresses the journey time from the north station to the central part of the island from more than an hour to 25 minutes. At the same time, they are together with "old - fashioned main road" Xingqian road and Tongji road, forming the "skeleton" road network of Jimei highway.

Meanwhile, the backbone network of Jimei new city road also forms the "internal circulation" composed of the "three longitudinal roads" called Hele road, Hemei road, Heyue road, and the "three horizontal roads" called Haixiang avenue, Xinzhou road and Xinglinwan road. Currently, Haixiang avenue and Xinglinwan road have been built, and "three longitudinal roads" and "one horizontal road" will be built, and Haixiang avenue and Xinglinwan road will be renovated. In order to build the core area of Jimei new city and improve the road, transportation network, and Hele road project is of vital importance, and Hele road project shows a north-south direction, the south part and Jinting north road are on the same level, across the Shenhai highway to the north, and later on the same level with Jimei north road. The high-speed section across Shenhai is a continuous beam of steel structure, which is the key point of the south-north section of Guantong Hele road.

There is an east-west overpass bridge of He-le road, with a total width of 30m, the width of a single-width bridge deck is 14.5m, the spacing between the middle sections is 1.0m, and the span of the bridge deck is 40m+60m, with a total length of 100m. The deck transverse slope is 1.5%, and the transverse slope is adjusted by the support and the support pad stone. The steel box girder is 14.5m



wide and consists of a 2.5m cantilever beam + 9.5m box girder +2.5m cantilever beam with a height of 2.2m and a floor width of 9.54m. The cross-section is shown in figure 1.

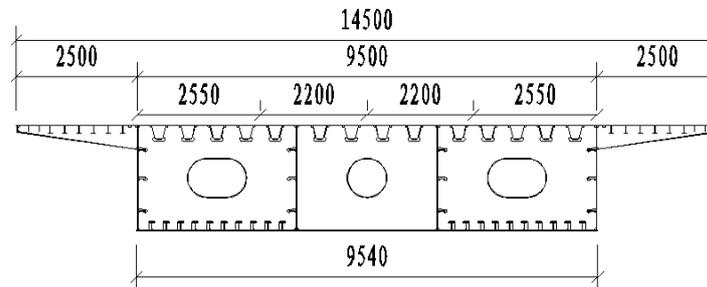


Figure 1. Cross section of steel box girder

The top plate, bottom plate and the web plate of the mainline bridge are all of orthogonal anisotropic plate structure. The vertical roof plate adopts U-shape reinforcing rib, the cantilever beam part and web plate adopts slab rib, and the bottom plate adopts T-stiffener. The diaphragm plate is set horizontally. The spacing between the diaphragm plates of the 40m and 60m main bridge sections is 2.0m, which is arranged alternately between 1 large beam and 2 small beams; the pier was spaced 1.5m and 0.75m apart.

The main structural steel plate of the box girder is Q345C, the thickness of the roof plate is 22, 14 and 16mm, of which the pier top section is 22mm, the 40m span is 14mm, and the 60m span is 16mm. The thickness of the bottom plate is 22, 16 and 8mm, the top section of the pier and 60m bottom plate is 22mm, the bottom plate of 40m is 16mm, and the bottom sealing plate of the middle chamber is 8mm. The thickness of the web plate is 16mm. The diaphragm plate is 10, 12, 14, 20, 28, 32mm, the small beam diaphragm plate is 10mm, the large beam diaphragm plate is 12, 14, 20mm, the support plate is 28, 32mm, the whole bridge uses all-welded construction.

In order to meet the transportation and hoisting requirements, the single-width steel box girder of the main bridge is divided into 27 sections, 3 sections of the pier top section, 8 sections of the main box girder, 16 pieces of the flange cantilever beam, and the maximum size of a single-width section is about 27m long, 5.1m wide and 2.2m high. The heaviest single room is 80 tons, and the steel used for the whole bridge is about 1,550 tons.

2. Overall plan of steel box girder manufacture

2.1. The overall section of steel box girder and hoisting sequence

According to the structural form and transport conditions of the steel box girder, the single-width box girder is divided into 27 sections. The hoisting sequence of sections is as follows: firstly, steel girder is hoisted at the section of the pier, then steel box girder is hoisted at the middle section, then 40m span is hoisted, and then 60m span is hoisted. When the steel box girder is hoisted across the middle section, the steel box girder on the side of the road shall be hoisted uniformly from east to west.

2.2. Element partition and baseline layout

According to the structural characteristics of different sizes of each section of the steel box girder, each section of the girder is divided into several elements, including the top plate element, the bottom plate element, the web plate element, the transverse plate element and the cantilever beam element, and the axle axis is taken as the longitudinal datum line.

2.3. Production process of steel box girder

In order to control the welding deformation of box structure, guarantee the overall quality of products, and speed up the manufacturing process, steel box girder manufacturing adopts the mode of "plate element→beam section assembly→pre-assembly→bridge site welding", that is, the production

element, integral assembly of beam section, site pre-assembly, and finally the bridge site is connected into a whole [1].

The steel plate carries on the rolling and pretreatment, according to the division of the steel box girder elements to perform blanking, correction and machining of parts. Then the assembly, welding, weld inspection and repair of parts (unit and unit assembly) shall be carried out to complete the roof element, floor element, web element, transverse plate element, cantilever beam plate element, roof element assembly and floor element assembly, and assemble the whole body by the reverse method [2]. Construction of bridge site includes: beam section erection adjustment, seam side adjustment, circular seam welding and inspection, welding and inspection of embedded patch, and final coating. After assembly, perform step welding, then remove the rust, paint and store.

3. Structural features analysis and manufacturing focus

The key of making steel box girder is the control of component geometric dimensioning & tolerancing, welding quality and anti-corrosion treatment. According to the structural features, stress state, assembly and installation requirements of steel box girders of overpass bridge of the Hele road, the following key processes should be controlled in manufacturing.

3.1. Geometric dimensioning & tolerancing control of unit

Unit is the basic component of the steel box girder. Its size, spacing of U-shaped ribs, and precision of U-shaped ribs are the basis for ensuring the overall assembly precision of the box girder. The following measures should be taken in production:

- In the aspect of plate unit processing, the plate roller should be flattened before blanking to eliminate the rolling stresses; the shape size, tolerance and groove dimensions of the U-shaped rib should be manufactured and processed according to the corresponding technical requirements and tested according to the corresponding standards.
- In terms of controlling welding deformation, the reverse deformation amount is set by using the reverse deformable tire frame, and the CO₂ gas protection automatic welding process with linear energy is adopted to weld under constraint conditions.

3.2. Weld penetration control of U-rib

For the welding of U-rib and roof plate, the fusion depth should be no less than 0.75 times of the thickness of U-rib. In order to meet the design requirements, the following main measures are adopted in production:

- Single-V groove is opened on welding side, and the size and angle deviation of the edge are strictly controlled.
- Using ship position welding which is easy to guarantee the fusion depth, and the special reverse deformation tire frame is designed.
- Adopt CO₂ gas shielded automatic welding to reduce the influence of welder operation skill level on welding quality.
- Perform welding in accordance with specified welding sequence and process parameters, with emphasis on monitoring the length of the groove, welding current and walking speed.

3.3. Quality control of diaphragm plate

The diaphragm plate in the steel box girder can be divided into 4 forms: small beam, large beam, supporting plate and end sealing plate diaphragm, which are all cut by numerical control and assembled on the platform. The diaphragm plate is the inner tube of box beam, whose precision directly affects the section size of the beam section, and adopts the following technological measures to control the geometric accuracy:

- The roller is used to eliminate the rolling stress before blanking the steel plate, so as to reduce the welding deformation of the following parts.

- After the CNC blanking of the diaphragm plate at the support, the horizontal and vertical base line is delimited on the platform. Assemble the stiffening rib according to the wire, finish the welding, and cut the groove after correction.
- Platform-rigid constraint welding is adopted to reduce the work of deformation and correction.

4. Welding process of steel box girder

4.1. Bracket set

4.1.1. Welding positioner placement

Considering the site conditions, two sets of 160x24m total tire racks were set in the site for controlling the assembly efficiency, and the east and west steel box girders were put together.

4.1.2. The design of pre-assembled tire frame of beam section

According to the structural characteristics of the bridge, the girder segment is designed to assemble the tire frame. The length of the single-width tire frame is about 100m, 9.5m wide, and the height of the tire frame is 1.5m. The tire shape is determined by taking the roof shape as the base level, and the position of the diaphragm is supported by the supporting plate to control the line type [3].

The longitudinal datum point is set at both ends of the tire frame. The horizontal reference point separating from the tire frame is set under each beam. During the beam section assembly, the placer is used as the base level of support and the diaphragm plate is used as the inner tube to control the dimensional accuracy of mouth. Through the longitudinal and transverse reference point control units and the placement of the unit assembly, the welding is carried out under the constraint of the horse plate [4]. The assembly jig-frame is shown in figure 2.

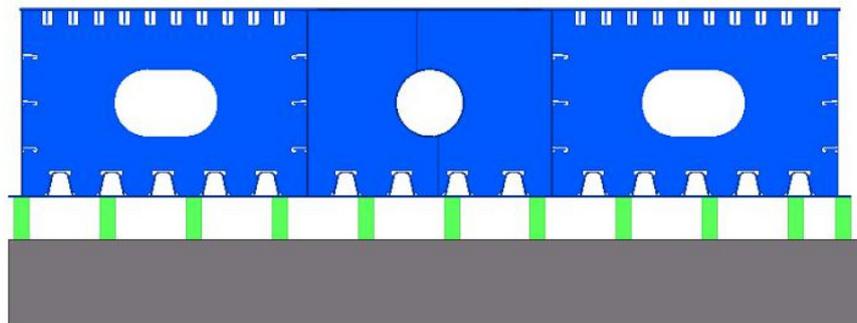


Figure 2. Beam section assembly welding, and pre-assembly jig-frame diagram

4.2. Complete welding of steel box girder

4.2.1. Technological process of beam section

In the assembly process of the beam section, the tire frame is used to control the overall longitudinal profile of the box beam, and the transverse diaphragm is used to control the size of the box mouth, and the longitudinal and transverse baseline control board units are in place. After the assembly welding of all girder sections on the tire shelf is completed, remove the horse plate, turn over, weld and repair, and transfer the painting process after passing the inspection.

4.2.2. Welding process of beam section

- Roof assembly: the top plate is assembled symmetrically on both sides with the center line of the bridge. After each top plate unit is positioned according to the longitudinal and transverse datum lines, the horse plate and tire frame are adopted to secure, and then the side roof unit is assembled symmetrically.

- Location of the partition plate: mark assembly position line, position and fix. According to the design requirements, the middle web should follow the bridge position position plumb and horizontal plane, so attention should be paid to the direction of the diaphragm when positioning the diaphragm.
- Web and diaphragm assembly: the assembly of web and diaphragm is carried out alternately, and the location accuracy and verticality of diaphragm are controlled by positioning jig and jacking tool in the assembly process, so that the spacing between diaphragm and web meets the standard requirements [5].
- Cantilever beam unit welding: after the oblique web unit assembly welding, draw the cantilever beam unit assembly position line, and weld the cantilever beam stiffening rib according to the line assembly.
- Floor unit assembly: first assemble the floor unit at the center line of the shaft, then assemble the side floor unit, and then assemble the side floor unit with the transverse baseline of the web and the longitudinal reference control line, and then assemble the other bottom unit assembly from the middle to both sides symmetrically, and finally install and seal [6].
- After the overall inspection of the steel box girder section is qualified, the longitudinal and transverse baselines of the steel box girder are corrected, the position of the spot-welded horse plate is repaired, and relative difference of the interfaces of the two adjacent box sections are rechecked, and they are repaired when out of tolerance.

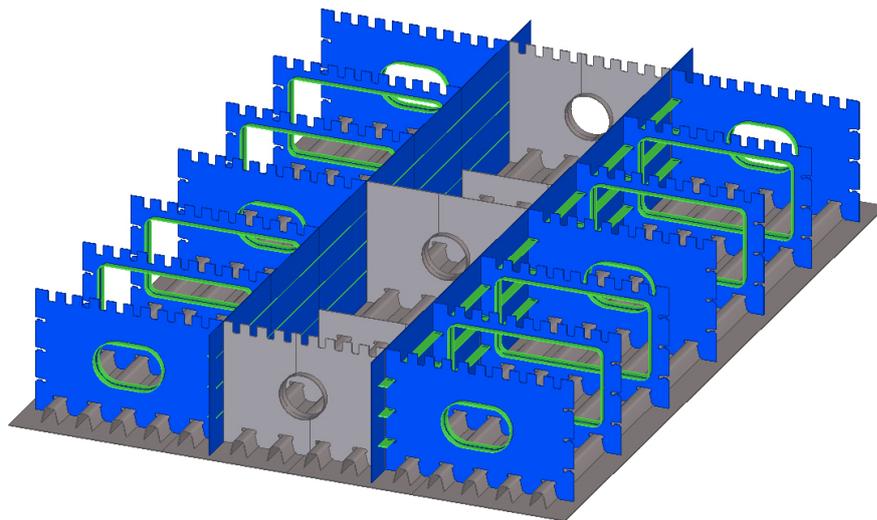


Figure 3. Assembly diagram of the middle web and side partition unit

4.3. Pre-assembly line shape and interface match connection accuracy control

Preassembly line (arch degree, side bend) and matching connection precision of box mouth will be the key to ensure smooth hoisting of beam section, integral line shape of bridge and welding quality of circular joints.

The length and straightness are controlled by horizontal and vertical datum line, and the arch degree is controlled by frame support. Control of matching connection precision is implemented by using the whole preassembly method. In order to reduce the difficulty of bridging the wrong side adjustment of the bridge level interface, 200mm welding seam is reserved at the junction of the box mouth, and the bottom is drilled and filled to 1/3 of the plate thickness.

5. Conclusion

The Hele road project in Xiamen city is shown as north-south direction, among which the Shenhai high-speed section is a continuous steel structure beam, which is the key point of the south and north section of the Hele road. In this paper, the steel box girder overall manufacturing and assembly sequence, analysis several key techniques in the process of manufacturing, steel box girder integral

compound process, the assembly precision and welding quality put forward the corresponding quality control points, further reducing the construction risk, guarantee the smooth engineering progress, and have certain reference significance for similar engineering construction Figures.

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