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# Research on Construction Technology of Steel Structure Tie Rod Arch Bridge with Less Support

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***Abstract***

*In order to explore the installation method of the steel box tie-rod arch bridge across the canal, in order to meet the requirements of rapid installation under the condition of near the existing diagonal bridge. Based on qingshuihe Bridge of G50 Shanghai-Chongqing Expressway, the installation technology of steel box pole arch bridge is studied by combining theoretical analysis and field practice. This paper analyzes the construction problem of Qingshuihe Bridge and proposes an construction method of small supports and large sections. The oblique asymmetric beam arch is designed to avoid the influence on the channel headband. The installation process of bridge deck system is optimized, the bending moment of steel beam is effectively reduced, and the temporary span of beam beam installation is improved. The finite element analysis shows that the beam, arch ribs and other components are in good stress condition according to the asymmetric deformation of the boom force, and ensure the smooth installation of the beam and bridge deck.*

***Keywords***

*Steel box tie-rod arch bridge, less bracket installation, construction technology, force analysis*

## 1. Introduction

Arch bridge is a structural form with good bearing capacity and is widely used in river-crossing projects. According to different classification methods, the arch Bridges can be divided into many types, among which the steel structure tie-rod arch bridge is a common arch bridge form of large-span arch bridge in the plain area. The structure uses the horizontal tie rod between the arch feet to bear the horizontal force of the arch foot, which belongs to the arch bridge without physical strength system, especially suitable for the conditions such as crossing the canal in the plain area.

Many studies have been carried out on the construction methods of arch bridge at home and abroad. The main construction methods include the bracket assembly method, the construction method of beam and arch pushing, the overall jacking method of beam arch, the lifting method of tower cable, the construction method of tower cantilever, the overall floating displacement method, etc. (Li, 2019).

Among them, the bracket installation method is a common construction method of small and medium-sized span arch bridge. This construction method generally adopts the installation process of the first beam and then the arch. The span of this construction method bracket is generally small, which has a significant impact on the temporary passage under the bridge. The construction method of beam arch is a construction method that can better adapt to crossing the canal. This construction method is to connect the arch rib and the tie beam through temporary braces to form a space truss system. However, this construction method requires a lot of temporary setting, and has certain requirements for the assembly site.

Under the traditional construction conditions, how to carry out the rapid construction of steel structure tie rod arch bridge across the canal is a problem to be further studied. Based on the installation method of large-span steel structure tie arch bridge across this canal.

## 2. Relying on the Project Overview

### *2.1 Project Overview*

G50 Shanghai-Chongqing expressway Xuancheng-Wuhu section expressway reconstruction and expansion project is located in Xuanzhou District, Xuancheng City, and the end point is located in Wuhu main line station, with a total length of about 55.533 kilometers. With the increase of traffic volume, the road capacity is insufficient, it is necessary to rebuild and expand the existing roads and change the original two-way four-lane section to two-way eight-lane section. Among them, Qingshuihe Bridge is the key node project of the reconstruction and expansion project, which is located in Qingshui Town, Wuhu City. After the reconstruction and expansion, the bridge adopts the form of upstream and downstream separation. Among them, the right structure is built on the right side of the original bridge, and the left structure needs to be rebuilt from the old bridge in place after the demolition. The main bridge of the existing line is 30 + 952 + 30m prestressed concrete continuous beam bridge, and the axis of the bridge is in a state of 60.77°. The old bridge is arranged on the left and right sides, and the piers are arranged along the direction of the channel. Separated navigable holes are set under the bridge, and the upper and lower navigation pass through the two adjacent main spans respectively. And the site situation is shown in Figure 1.

**Figure 1. Construction Site of the Bridge**

After the reconstruction and expansion, the main bridge of Qingshuihe Bridge adopts a steel structure frame arch bridge with a span of 178m, one span crosses the Qingshui River channel, the north levee is 85m frame arch bridge, the south levee is crossed by (40 + 66 + 40) m steel box composite girder, and other approach bridge structures adopt 40m composite box girder and 30m precast concrete small box girder structure. The general layout of the main bridge across the river is shown in Figure 2. The external simply supported structure system is adopted. 27 pairs of boom rods are set in the whole bridge arch, and the boom spacing is 6m.

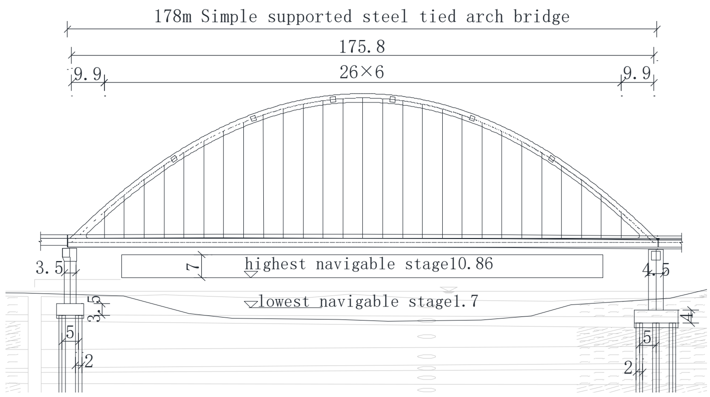


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**Figure 2. Overall Layout of the Main Bridge of Qingshuihe Bridge**

*2.2 Bridge Structure Form*

The main bridge of Qingshuihe Bridge is a single-span bearing steel structure tie-pole arch bridge. The arch ribs are vertical arch ribs, the arch axis is secondary parabola, the sagittal span ratio is 1 / 4, the arch ribs are equally sectional steel box arch ribs, the section height is 2.6m, and the two transverse arch ribs are connected by 6 to horizontal wind support. The standard section of the bridge deck of the bridge is shown in Figure 3. The transverse layout of a single bridge is 2m (anchor cable area) + 0.5m (anti-collision guardrail) + 19.25m (running lane) + 0.5m (anti-collision guardrail) + 2m (anchor cable area), and the full width of the single bridge deck is 24.25m. The steel beams on both sides adopt box section with section size of 2.0×2.6m. The bridge deck system adopts the orthogonal heterosexual steel bridge panel structure, the steel beam is connected with the steel beam through bolting, and four inverted T-shaped small vertical beams are set between the beams to strengthen the bridge deck system.

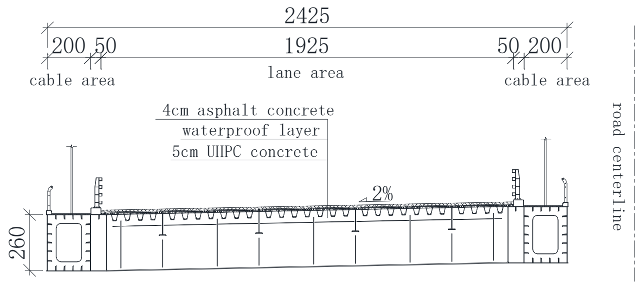


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**Figure 3. A Schematic Diagram of the Main Bridge Cross-Section**

*2.3 Installation and Construction Problems*

The Qingshui River crossed by the main bridge of Qingshui River Bridge is an important part of the Wushen Canal. The shipping under the bridge is busy, so the impact on the existing navigation should be minimized in the construction process. At the same time, because the bridge and the channel are in an oblique state, the piers of the old bridge are arranged with wrong holes, and it is difficult for the temporary construction support to avoid the channel. Under these restrictions, the construction method to complete the component installation efficiently is the key issue of bridge construction. Considering the requirements of construction period, economy and safety, the bridge construction adopts a construction method of less support construction. By optimizing the construction process, the load of temporary support is reduced and the span of temporary support is increased. Through the left and right arch ribs and beam asymmetric segments and asymmetric support, the way to avoid oblique navigation.

## 3. Less Bracket Installation and Construction Technology

*3.1 Support Arrangement Scheme*

In the construction process of the bridge, in order to reduce the influence of the temporary support on the existing channel, the layout of the bracket is straight along the direction of the channel and the old bridge pier to ensure that the clearance of the channel is not occupied. Specifically, taking the right bridge as an example, the spacing of the left beam is (10.585+22+52+52+30+10.215) m, and the spacing of the right beam is (10.139+35+52+52+17+10.661) m. Such bracket arrangement requires that the left and right side tie beams and arch ribs adopt different segment lengths during the installation process, with the maximum horizontal segment length of 52m. This arrangement optimizes the installation mode of the bracket, effectively reduces the spacing and footprint of the bracket, and meets the requirements of construction safety and space utilization.

The support design adopts the beam-arch integration scheme, and the beam support and the arch rib support share the foundation structure. This innovative design effectively reduces the number of supports, improves the construction efficiency, and ensures the stability of the structure. After the installation of the beam beam, the bearing capacity of the bracket system is further strengthened by forming the arch rib bracket at the top of the beam support. The overall support structure is supported by a steel pipe pile foundation with a diameter of 1m to ensure the stability of the support. The double joint HN 560 beam is arranged as the bearing member of the beam to share the load. The arch rib support is composed of steel pipe support of 425mm and the double joint I45 I-steel is installed on the top. This structural method further improves the overall stability of the support system. Each pillar forms a stable structural system through reliable connection, which ensures the bearing performance and construction efficiency of the support, especially in the case of temporary load and large wind force in the construction process, to ensure the safety and reliability of the support.

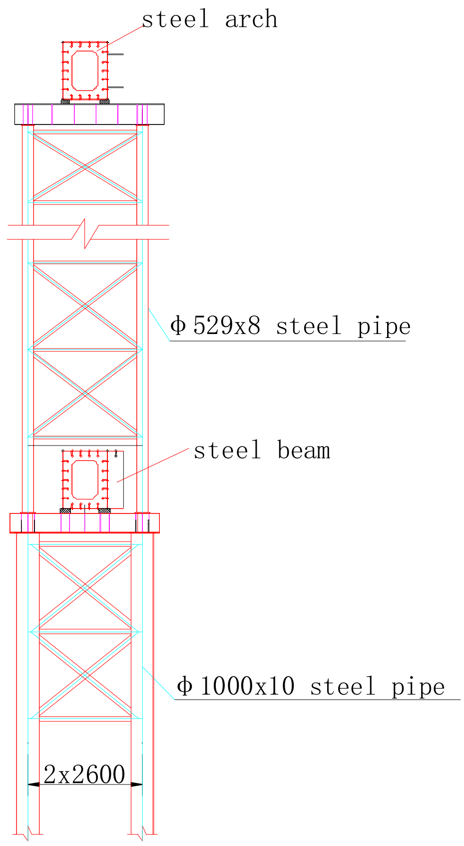


**Figure 4. Schematic Diagram of the Cross-Section of the Steel Pipe Column**

### *3.2 Optimization of the Installation Process*

In order to solve the problem of limited bending bearing capacity of steel beam, the construction process is optimized. First complete the beam bracket erection, and install the end beam and steel beam segments; then install two sets of standard beams and bridge deck, to form a preliminary overall frame; then lift the prefabricated arch rib bracket in place, and connect with the beam bracket, lift the arch rib segments and install the wind support. After the installation of the arch ribs, install and tension the boom and transfer the beam load to the boom, then remove the remaining beams and bridge deck and complete the deck paving and ancillary facilities by adjusting the cable force of the boom. After the optimized process makes the steel beam only bear its own weight in the construction, and the boom directly bears the load of the bridge deck after installation, which effectively reduces the load of the temporary support and improves the construction efficiency and safety.

*3.3 Construction Technology of Installation of Components*

In the installation and construction process of components, the maximum span of the support is 52m, and the maximum lifting weight of the corresponding steel beam and arch rib is 158t and 150.7t, respectively. The 500t floating lifting equipment is used to meet the installation requirements of large weight components. The hoisting is carried out in accordance with the principle of "from the middle to the arch foot", advancing from the middle of the bridge to the two sides of the arch foot. At the same time, the wind support is installed in real time to ensure the stability of the components and the overall wind resistance.

The hoisting of the steel beam should be coordinated with the installation of the end beam to form a partial frame structure to provide preliminary support. The hoisting of arch rib segments strictly follows the predetermined order and positioning scheme, and adjusts the lifting attitude and cable force through real-time monitoring to avoid partial overload or component inclination. In the stage of tensioning of the boom, the component stage tension mode is adopted, the pretension is accurately applied according to the design parameters, and the tension change is monitored in real time through the sensor, so as to control the tension on both sides synchronously, so as to reduce the cumulative deformation difference of the tie beam. Optimization of tensioning strategy reduced the deformation difference from the initial maximum 25mm to 5mm, successfully eliminate the uncoordinated deformation on both sides of the beam, ensure the smooth of the deck and beam in the installation, the overall process to realize the precise connection and reasonable distribution of load, for the construction quality and structural stability.

## 4. Force Analysis during the Installation Process

*4.1 Analysis Method and Analysis Model*

In order to deeply analyze the force of components in the construction process and ensure the construction safety, a comprehensive model of bridge construction is established by using the finite element software Midas Civil. The model uses the beam unit to simulate the mechanical characteristics of the steel beam and the steel arch ribs, the truss unit to simulate the tension distribution of the boom, and the plate unit represents the mechanical behavior of the bridge deck, which fully reflects the whole process of construction steps and system transformation. In the process of model construction, the key conditions in the construction stage are set in detail, including the installation and welding of steel beam, section lifting of arch ribs and wind support installation, boom tension and load transfer, etc. Taking qingshuihe Bridge as an example, during the installation of the steel beam, the deformation difference of the section installation and the influence of these deformation on the installation of the bridge deck are analyzed. The calculation results show that the vertical deformation difference of the boom beam is significantly reduced from 25mm to less than 5mm, which verifies the effectiveness of the boom tension strategy and its regulating effect on asymmetric deformation. The application of the finite element model not only provides a scientific basis for the optimization of the construction process, but also provides an important reference for the mechanical monitoring and structural adjustment in the actual construction process, ensuring the stability and safety of each component in the construction. Through this analysis method, the construction process can be predicted more accurately. The possible mechanical problems can provide theoretical support for real-time monitoring and adjustment in the construction process

*4.2 Process Force Analysis*

The finite element analysis results show that the stress state of the steel arch ribs and steel beams during the construction process is always kept within the safety range of the design, showing the reliability and effectiveness of the construction technology of less supports. The stress of the steel arch rib gradually increases with the gradual application of the construction load, and finally reaches 108.1MPa under the state of the bridge, which fully meets the design standards and safety requirements, indicating that it has sufficient structural bearing capacity and safety margin. In the process of system transformation, due to the gradual change of construction load, the stress of the steel beam shows a certain fluctuation, but there is no overload or stress concentration, which ensures the stability of the structure. In the vertical deformation analysis, the maximum vertical deformation difference reached 25mm due to the asymmetric section installation of the left and right beams in the initial stage of construction. With the gradual tension of the boom and the precise adjustment of the cable force, the deformation difference of the tie beam is significantly reduced, and finally controlled within 5mm. This improvement not only eliminates the potential risk of uneven deformation, but also ensures the smooth installation of the bridge deck and beams. The analysis results fully verify the safety and feasibility of the construction method of the less support. Through accurate load transfer and deformation control, the structural stability of the structure and the accurate installation of the components in the construction process are successfully realized, and the less support technology is in the large-span steel structure tie arch bridge. The wide application provides a solid technical support.

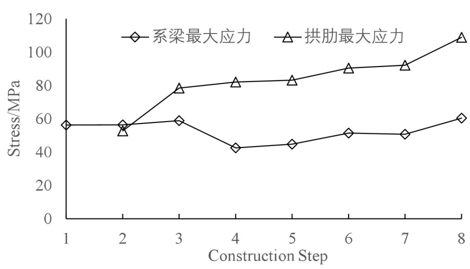


**Figure 7. Maximum Stress of the Steel Structure during the Construction Process**

## 5. Conclusion

Relying on the construction practice of qingshui river bridge, this research to install less support steel structure pole arch bridge construction technology has carried on the thorough discussion, and draw the following conclusion: first, the proposed less support large segment installation construction method effectively reduce the influence on the existing channel, optimize the construction environment, especially in the busy shipping area. Secondly, the integrated support structure of the asymmetric beam and arch is designed, and by optimizing the construction process, the temporary bearing capacity of the tie beam and the arch rib is significantly improved, so as to ensure the stability and safety in the construction process. Finally, the finite element analysis shows that the force and deformation of the components are under control, which further verifies the effectiveness of the method in ensuring the construction safety and quality. This research provides a new technical path for the construction of steel structure tie-rod arch bridge, and also provides valuable experience for the implementation of similar engineering projects.

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