Original Research Article

Construction technology of top push method for erecting large span steel box beams of railway bridges

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Abstract: In response to the problems of high construction difficulty, high precision requirements, and significant impact on surrounding traffic in the process of erecting large-span steel box girders for railway bridges, this paper proposes a construction technology based on the walking multi-point synchronous pushing method. This technology gradually pushes the steel box girder forward by installing a pushing device on the bridge pier, solving the problem of traditional lifting methods being unable to meet the requirements of large-span steel box girder erection. The research results indicate that this method can not only effectively control construction accuracy and reduce the impact on surrounding traffic, but also significantly improve construction efficiency and safety. By reasonably setting up temporary piers and steel guide beams, the stability of the steel box girder during the pushing process has been further enhanced. The research results can be applied to similar large-span steel box girder erection projects, providing valuable technical references for future railway bridge construction.

Keywords: Railway bridge; Large-span steel box girder; Top push method installation; Construction technique

1. Preface

In recent years, with the rapid development of railway construction in China, the demand for large-span railway bridges has been increasing. Due to its advantages such as light weight, strong crossing capacity, and fast construction speed, large-span steel box girders have become one of the important bridge types in railway bridge construction. However, the installation of large-span steel box girders faces challenges such as high construction difficulty, high safety risks, and strict technical requirements. How to efficiently, safely, and economically complete the installation of large-span steel box girders has become a key issue that urgently needs to be addressed in the field of railway bridge construction. As an advanced bridge construction method, the top push method has the advantages of fast construction speed, minimal impact on traffic, and high construction safety. It has shown great potential for application in the installation of large-span steel box girders. In recent years, with the continuous progress of top pushing equipment, construction technology, and monitoring technology, the application scope of top pushing method in large-span steel box girder erection has been continuously expanded, and significant achievements have been made. The purpose of this study is to systematically summarize the construction technology of large-span steel box girder top push method, analyze its key technical difficulties and solutions, and explore the application of top push method in large-span steel box girder erection by combining specific engineering cases. This study will provide theoretical guidance and technical support for the top push method of large-span steel box girder erection, and promote the sustainable development of railway bridge construction technology in China.

2. Project overview

A cable-stayed bridge is located on an important railway trunk line in China, with a total length of 420 meters, including an upper span length of 220 meters and a bridge deck width of 34.5 meters. It adopts a double tower double cable plane cable-stayed bridge structure, with a mixed main beam design, pre-stressed concrete box girders on both sides, and steel box girders on the middle span. The bridge structure is complex and the construction difficulty is high, especially for the installation of mid span steel box girders, which requires high construction technology. The two side spans of the bridge are made of prestressed concrete box girders with a length of 109.4m, which mainly bear the side span load of the bridge and ensure the overall stability of the bridge; The mid span adopts a steel box girder with a length of 197.2m, which is the core part of the entire bridge. Steel concrete joint sections are set at the intersection of the two ends of the steel box girder and the prestressed concrete box girder to ensure that the beams made of two different materials can be effectively connected and subjected to common forces. The steel box girder is divided into 58 standard sections, each with a length of 3.4m and a total mass of 3984 tons. Two steel-concrete composite sections, each with a length of 2m, are set up to connect the steel box girder with the prestressed concrete box girder. The main difficulty in the construction of this bridge lies in the installation of the mid span steel box girder. Due to the large length of the mid span, traditional lifting methods are difficult to meet the construction requirements. Therefore, the top pushing method is adopted for the installation of the steel box girder. The top pushing method gradually pushes the steel box girder forward by setting up a top pushing device on the bridge pier, and finally completes the installation of the entire mid span. This method can not only effectively control the construction accuracy, but also reduce the impact on surrounding traffic, and has high construction efficiency. By analyzing the overview of the cable-stayed bridge project, it can be seen that the top push method has significant advantages in the installation of large-span steel box girders, which can effectively solve technical problems in construction and ensure the smooth progress of the project.

3. Installation plan

In the process of erecting steel box girders on railways, the walking multi-point synchronous jacking method is adopted, with a jacking mass of 9.4 tons per meter and a total length of 255 meters. This method ensures the safety and efficiency of construction by setting up leading beams and temporary supports. In order to achieve this goal, the construction team arranged corresponding top pushing equipment on the construction site. The steel box girder was welded section by section in the factory, and the overall steel box girder was lifted and pushed forward using the top pushing equipment. During the pushing process, the steel box girder was gradually lowered onto the temporary pier steel pad beam. The top pushing equipment used a walking multi-point synchronous top pushing technology to comprehensively enhance the stability and safety of the steel box girder during the pushing process. In each top pushing cycle, after the top pushing cylinder shrinks to the bottom, the next cycle continues until the steel box girder reaches the design position. During this process, the leading beam and temporary support pier play a crucial role in supporting and guiding, improving the stability and accuracy of the steel box girder during the pushing process. Through this step-by-step multi-point synchronous pushing method, the construction team successfully completed the installation task of the steel box girder crossing the electrified railway at Ningbo East Station, which not only improved construction efficiency but also ensured safety during the construction process, providing valuable experience for similar projects.

4. Construction safety technology for steel box girder erection

According to the requirements of the railway steel box girder top pushing installation plan, this bridge is equipped with 8 temporary piers to ensure the stability of the steel box girder during the top pushing process. The arrangement and structural design of temporary piers are key links in the top-down construction method, directly affecting the smooth progress of construction. The staff need to arrange six temporary piers between the 2 # and 3 # main piers, numbered L1 #~L6 # piers. These temporary piers can effectively share the load of the steel box girder during the top-down process, allowing for a smooth transition of the steel box girder during the pushing process. Two separate bearing platforms are horizontally arranged at the bottom of temporary piers L1 #~L6 #, with a size of 4.6 m × 4.6 m × 2.0 m. Four 1 m diameter bored piles are symmetrically arranged at the bottom of each bearing platform to provide sufficient bearing capacity. Between the 0 # side pier and the 2 # main pier, L7 # pier and L8 # pier are arranged, with L7 # pier set on the 1 # pier abutment and L8 # pier set on the small mileage side of the 2 # main pier. L7 # pier is directly set on the 1 # pier abutment using steel pipe columns, which not only simplifies the construction process but also enhances the stability of the temporary pier. By reasonably arranging temporary piers and adopting scientific structural design, the construction plan of the steel box girder jacking method for this bridge can effectively ensure construction safety, ensure the smooth progress of the steel box girder during the jacking process, and ultimately achieve the smooth closure of the bridge.

The main function of temporary piers is to support steel box girders and provide necessary support during the pushing process. According to the construction plan, temporary piers are divided into L1 # to L8 #, each with different functions. The main function of L1 # temporary pier is to support and fix the end of the steel box girder. There is no top pushing equipment installed on the pier top. After the top pushing is completed, during the construction of the steel-concrete joint section, steel pipe supports will be arranged on the separation platform of L1 # temporary pier to support and fix the end of the steel box girder, enhancing the stability of the steel box girder during the construction process. Four steel pipe piers are arranged on each pier of temporary piers L2 # to L8 #, with steel pipe connections between the piers. A steel box girder top pushing platform is arranged on the piers, which not only provides sufficient support but also allows the steel box girder to move smoothly during the top pushing process. Each temporary pier's jacking platform is equipped with necessary jacking equipment, such as jacks and guiding devices, to precisely control the steel box girder during the jacking process. By setting up reasonable temporary piers, construction risks can be effectively reduced, construction efficiency can be improved, and the smooth progress of large-span steel box girder top push method installation can be promoted.

5. Steel guide beam setting

In the construction of steel box girder jacking, due to the limitations of railway tracks, the steel box girder will exhibit two stress states: simply supported and cantilever. In order to ensure safety during the construction process, workers set up steel guide beams at the front end of the steel box girder, aiming to share the load of the steel box girder in the cantilever state, reduce the deflection of the front end of the steel box girder, and avoid structural instability problems caused by excessive cantilever length. The design and installation of steel guide beams are important steps in the top-down construction method. According to the engineering requirements, the length of the steel guide beam is 46m and the width is 10m, divided into 6 sections. The guide beam and steel box girder are connected by welding, with high-strength bolts connecting the upper flange plate and web plate, and groove welding connecting the lower flange plate. The total mass of the steel guide beam is 85 tons. After modeling and calculation, when the guide beam reaches the L3 # pier and is in the maximum cantilever state, the deflection at the front end of the guide beam is -153.8mm. In order to ensure construction safety, the deflection at the front end of the guide beam was increased by 146.2mm during design, resulting in a total deflection of -7.6mm, to ensure the stability of the guide beam in the maximum cantilever state. By reasonably setting up steel guide beams and optimizing their structural design, the deflection and stress of steel box girders during the pushing process can be effectively reduced, enhancing the safety and stability of the construction process[5].

6. Temporary pier structure verification

When the steel box girder is pushed and slid 239.1m, the tail of the steel box girder leaves the L8 # temporary pier. During the pushing process, the L2 # to L6 # temporary piers jointly bear the load. At this time, the L2 # temporary pier bears the maximum vertical reaction force, reaching 7186 kN. In order to ensure construction safety, it is necessary to conduct a detailed calculation of the bearing capacity of temporary piers. Firstly, the stress distribution of each temporary pier is calculated based on the self weight of the steel box girder, the top thrust, and the layout of the temporary piers. L2 # temporary pier, as the main bearing pier, has the highest stress and requires key verification. The verification content includes the vertical bearing capacity, lateral stability, and foundation overturning resistance of the temporary pier. Detailed calculation of the stress state of temporary pier L2 # is carried out through structural mechanics analysis and finite element simulation. The results show that when L2 # temporary pier is subjected to a vertical reaction force of 7186 kN, its vertical bearing capacity, lateral stability, and foundation overturning resistance all meet the design requirements. The structural design of the temporary pier is reasonable and can safely bear the load during the pushing process of the steel box girder[6].

7. Summary

In summary, this article proposes a construction plan based on the walking multi-point synchronous top pushing method through a detailed study of the installation technology of large-span steel box girders for railway bridges. This plan effectively solves the technical difficulties in the installation of large-span steel box girders by setting up temporary piers and steel guide beams reasonably, ensuring the safety and efficiency of construction. The research results indicate that the top push method has significant advantages in the installation of large-span steel box girders. It can not only improve construction efficiency, but also reduce the impact on surrounding traffic, and has a wide range of application prospects. In the future, with the continuous development of railway bridge construction, this technology is expected to be applied in more large-span bridge projects, providing strong technical support for China's railway bridge construction.

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