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Research Article

Design and Construction Strategy of Arched Continuous Rigid-frame Bridge

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Abstract: With the current rapid development of urbanization in China, people's living standards have been greatly improved. In the context of such a development background, the requirements for road traffic are getting more stringent, especially for bridge projects. The arched continuous rigid-frame bridge was developed under this social background. The advantage of the bridge lies in the design of a bridge model that integrates various functions such as transportation, landscape, and sightseeing. Based on the above, this paper first refers to the case to analyze the design and construction strategy of the arched continuous rigid-frame bridge, in hope of providing a valuable reference for relevant personnel.

Keywords: Arch; Continuous steel structure; Bridge design; Construction

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1 Introduction

The use of arched continuous rigid-frame bridges in bridge design and construction can display the ecological, sightseeing and artistic features of the area where the bridge is located, which serves to build a landscape-like bridge. In the actual design and construction, economics, safety and aesthetics are taken as the principles, which are in line with the requirements for bridge construction in the current urban development. Based on the case study, this paper discusses the design and construction strategy of the arched continuous rigid frame bridge in detail, which has practical research significance.

2 Project Overview —— Taking XX Project as an Example

The area where the bridge construction of the XX project in a certain city is located is in the key project that connects the major road networks in the city. According to the analysis and research on multiple plans, it was finally decided that the construction plan of an arched continuous rigid-frame bridge with a main span of 21m + 30m + 21m be adopted for the project. The length and width of the entire bridge project are 78.16m and 30m respectively, and the entire project was designed in left and right sections. The following is a discussion on the design and construction strategy of the arched continuous rigid-frame bridge based on this project.

3 Overall Structure Design of Arched Continuous Rigid-frame Bridge

3.1 Superstructure

For the superstructure design of the project, pre-stressed concrete continuous box girder was mainly used. The structure of the main girder section is a variable cross-section single-box multi-chamber structure for construction. The purpose is to achieve a relatively low structural height while gaining a very large structural rigidity. The sectional height of the bridge was varied according to the calculation principle of the circular curve equation. A beam of equal height was set in the middle of the bridge with a length of 4 m; The heights of the pier-top beam and the mid-span beam in the V-shaped part of the main beam are 170 cm and 120 cm respectively; the requirements for the width of the top-plate, the width of the bottom-plate and the cantilever are 15 m, 10.6m and 2.2 m respectively; the requirements for the thickness of the top-plate and bottom-plate and the width of the girder web are 20cm, 20cm and 40cm respectively; for the top of the beam section, the thickness of the bottom-plate gradually changed from the previous 20cm to 40cm, and the girder web changed from the previous 40 cm to 80 cm. A total of 4 cross-beams with a thickness of 100cm were designed for the entire bridge project, which are mainly used to transmit forces between the superstructure and substructure of the bridge[1]; the side-span, mid-span, and side-to-mid span ratios of the bridge are 21m, 30m, and 0.7 respectively. The side-span design is relatively large. The main consideration is to use the long side-span to balance the horizontal force on the pile top and reduce the positive bending moment of the mid-span simultaneously.

3.2 Substructure

Firstly, when designing the bridge pier part, as the bridge pier of this project is designed with V-shaped piers, the design of the V-braces on both sides mainly adopts the design of variable cross-section rectangular plates, and the arc line is mainly used in the design of the changing curve part. The thickness of the plate is required to be between 0.6m - 0.8m, and the width of the plate is 10.6m. In addition, the V-braces on both sides of the V-shaped pier are in a consolidated state with the beam body and the cap, and C50 reinforced concrete structure is mainly used for its construction. For the cap part, the specification of the rectangular section is 12m×1.8m ×1.5m, the foundation is constructed with bored piles, and the pile diameter is 1.2m.

Secondly, in the design of the abutment part, the heights of the abutments on both sides are designed to be 4.5m and 3.5m respectively, and the height of the platform cap is 1.2m. In addition, the slope protection on both sides of the abutment and the upper-span landscape belt are linked, and the design and requirements for the foundation and pile diameter are the same as the above-mentioned bridge pier design[2].

Thirdly, the design of other parts of the bridge is mainly on the bridge deck, which uses 8cm cast-in-place concrete and 9cm asphalt concrete for paving operations. For the expansion joints, D-80 expansion joints are mainly adopted.

3.3 Structural Calculation of Arched Continuous Rigid-frame Bridge

3.3.1 Structural Internal Force

For the construction of arched continuous steel bridge structures, as the mechanism is mainly the formation of a steel structure system after the consolidation of piers and beams, the entire process from the formation of the steel structure system to the structure bearing pressure is mainly divided according to the three construction phases and operation phases. The division of the construction phase is as follows: the construction phase of the pouring of bridge piers, side-spans and mid-span box girder (which does not include the 2m mid-span closing-segment part)[3]; stretching the pre-stress of the main girder (including the construction of the supporting parts and the construction phase of the main girder 2 m closing-segment through pouring and stretching the pre-stress); the main girder and pier supports are removed, and the construction phase of the system is transformed. For the operation stage, factors such as the constant load force on the bridge, the pre-stressing force, the load generated during the driving of cars, the temperature rise (or drop) of the entire bridge by 35 ℃ , and the shrinkage of the concrete are mainly considered. Perform calculations and analyze the combined internal forces and stresses under the working conditions in each construction phase to adjust the bridge segment sizes and pre-stressed steel strands accordingly. Through the above processes, it can be ensured that the forces and stresses in each construction phase can be maintained within safe and controllable ranges.

3.3.2 Pre-stressed Steel Strands

Regarding the XX project, the pre-stressed layout design was carried out according to the calculation results. The main girder is designed according to the pre-stressed A-type components, and the V-shaped pier of the bridge can be designed with ordinary reinforced concrete components. The pre-stressed steel strands are arranged in the main beam, and the diameter specifications of the steel strands, the area of the steel strands, and the standard tensile strength are Φ15.2mm, $139mm^2$, and 1860MPa respectively; it is recommended that the tension control stress mainly be $0.75f_{pk}$, elastic modulus $E_p = 1.95\times10^5$MPa.

In order to effectively reduce the impact of the pre-stressed secondary internal force, the longitudinal pre-stressed steel strands of the main girder can be arranged in the following steps: for the side span of the bridge, the top of the V-shaped pier and the bottom of the mid-span, a relatively short positive-bending moment strand is used for layout, with its single-end in tension state and anchored in the transverse beam; the girder web bundle can be arranged in segments, with its two ends in tension. The layout of the steel bundle is shown in Figure 1:

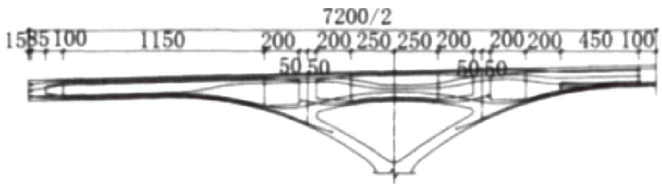

Figure 1. The Arrangement of Steel Beams

4 Construction Strategy of Arched Continuous Rigid-frame Bridge

Regarding the construction of the arched continuous rigid-frame bridge, as the nature of the project belongs to a high-order hyperstatic system, taking effective measures to reduce the secondary internal force is the key point in the design and construction of the entire bridge project. Based on the above, for the main structural part of the bridge project, the construction is mainly carried out by the cast-in-place method with full-floor brackets. The specific construction steps are as follows: First, in the entire bridge construction, the first step is to carry out construction work on the cast-in-place piles and the platform part; secondly, carry out the pouring construction of the joint between the V-brace part on both sides of the V-shaped pier and the main beam[4]; thirdly, carry out pouring on the side-span, V-pier top and mid-span box girder. During the pouring process, a post-cast segment of 1m should be reserved for the top of the V-pier, and a closing-segment of 2m should be reserved for the middle of the mid-span; fourthly, the 1m post-pouring segment of the V-shaped pier is poured first, and then the girder web steel beams, the side-span bottom-plate beams and the V-pier top- and bottom-plate beams are stretched, and finally the mid-span closing-segment is poured; fifthly, the closing-segment steel beams are stretched, and then the 50cm post-pouring belts on the left and right sides of the bridge are poured. Through the above processes, the bridge deck is built into an entirety, and finally other systems and auxiliary facilities on the bridge deck are constructed.

In the construction steps above, it is necessary to install a 1m post-pouring belt on the top of the V-shaped pier, and the main reason for pouring the closing-segment after the completion of the steel strand tensioning process is because that the shrinkage, creep and secondary internal stress caused by pre-stressing during construction can be reduced when the above-mentioned construction stages are split up, which will maximize the scientific rationality of the structural force, and the scientific application of pre-stressing can effectively ensure the quality of bridge construction.

5 Conclusion

In summary, in the process of modern bridge construction, on the one hand, it is necessary to meet the functional requirements for transportation in the city; on the other hand, it must also meet the contemporary aesthetic requirements for bridge construction and build bridges that integrate functions and aesthetics based on construction quality to contribute to the process of urbanization.

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