Analysis of Construction Technology for Long-Span Beam-Arch Composite Steel Bridges in Municipal Road and Bridge Projects

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Abstract: Municipal road and bridge engineering is one of the most crucial components of China's municipal engineering. The selection and application of construction technology are vital during municipal engineering construction, necessitating the development of a targeted and comprehensive construction technology system for municipal road and bridge projects. Currently, the application scope of long-span concrete continuous beam construction technology is continuously expanding, forming a construction technology system for long-span beam-arch structures. Particularly for composite steel bridges, their application in municipal road and bridge engineering significantly enhances the structural stability and service life of projects, meeting the specific requirements of modern road and bridge construction in China. Based on this, starting from the analysis of long-span beam-arch structure bridge construction, this paper specifically explores the key application points of long-span beam-arch composite steel bridge construction technology in municipal road and bridge projects, hoping to provide valuable experience for future municipal road and bridge engineering construction.

1. Introduction

Under the current social background, China's socio-economic level and modernization development are continuously improving. During the construction of municipal road and bridge engineering projects, the project scale is becoming larger, involving more construction phases. To effectively guarantee the construction quality, benefits, and subsequent service life of municipal road and bridge projects, targeted construction technology plans and a perfected construction technology system should be established. Currently, long-span beam-arch steel bridge construction technology is widely used in China's municipal road engineering projects, and its application scope is still expanding. It improves the comprehensive structural stability of municipal road projects and aligns with the modernization and sustainable development needs of China's road and bridge construction sector. However, long-span beam-arch steel bridge construction technology involves significant technical difficulties, primarily manifested in high technical standard requirements and high demands on the professional quality of construction technicians. Based on the current application of long-span beam-arch steel construction technology in China, it mainly adopts two structures: steel truss structure or steel box girder composite structure.

For steel truss structures, they are typically used in smaller-scale road and bridge engineering projects. They not only allow effective control over project structural stability and overall construction quality but also represent a new architectural form that can control construction costs. For steel box girder composite structures, their application in municipal road and bridge construction demonstrates unique advantages, ensuring structural stability and seismic resistance. They are usually suitable for bridge projects with spans greater than 300m but less than 500m, meeting the specific requirements of modern municipal road and bridge construction in China.

2. Analysis of Construction Difficulties in Long-Span Beam-Arch Composite Steel Bridges

2.1 Difficulty in Controlling the Stiffness of the Bridge Main Girder

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During the construction of long-span beam-arch composite steel bridges, although the construction technology has unique advantages, numerous challenges are still encountered. For instance, some bridge main girder structures may have poor stiffness and are prone to having low deck slab heights. This situation is related to the upper structure of the bridge adopting a steel-concrete composite section form. For this type of structure, there is a possibility of structural slippage during the subsequent service life of the bridge, affecting the overall stability of the bridge structure[1]. Therefore, during the construction of long-span beam-arch composite steel bridge projects, to ensure the stability and safety of such structures and avoid negative impacts on people's lives and property during service, careful attention must be paid to the main girder alignment construction work. The control and management of the main girder's structural stiffness must be intensified to ensure it meets engineering standards, thereby reducing the possibility of structural slippage during the bridge's service life.

2.2 Difficulty in Controlling the Longitudinal Curvature of Steel Cross Girders

The application of long-span beam-arch composite steel bridge construction technology often involves the longitudinal construction of steel cross girders. To ensure the quality of bridge engineering construction, controlling the longitudinal curvature of steel cross girders must be one of the important tasks during construction. Generally, if the longitudinal curvature of steel cross girders in a long-span bridge is excessive, it can easily lead to local structural fractures or even collapse during subsequent construction and service, resulting in serious engineering accidents and irreparable losses[2]. Therefore, during the construction of long-span bridge projects, to effectively control the aforementioned difficulties, attention should be paid to strengthening on-site monitoring, supervising and managing multiple construction phases, and formulating targeted on-site construction safety management plans. Particularly, it is crucial to determine whether the longitudinal curvature of the steel cross girders meets the specific requirements of the engineering construction, ensuring subsequent construction phases proceed only after standards are met.

3. Exploration of Key Points of Long-Span Beam-Arch Composite Steel Bridge Construction Technology in Municipal Road and Bridge Engineering

The quality and safety of municipal road and bridge engineering directly impact China's urban development and overall social modernization. Therefore, during the construction of municipal road and bridge projects, the construction technology system should be continuously optimized. Especially under the current background of continuously improving technology levels for long-span composite steel bridge construction, this technology should be utilized to enhance the construction level of municipal road and bridge projects, providing impetus for the sustainable development of China's municipal road and bridge engineering sector.

3.1 Key Points of Steel Girder Structure Construction Technology

Steel girder structures are already widely used in China's municipal road and bridge engineering construction. Particularly for municipal bridge single projects, the optimization and application of steel girder structures have significantly improved bridge structural stability. Currently, the steel girder structures for bridge single projects mainly include double-tower single-span prestressed concrete continuous steel rigid frame bridges and multi-tower simply-supported truss stiffened girder arch bridges. Each of these two types has its advantages. For the double-tower single-span prestressed concrete continuous steel rigid frame bridge, there are no connection nodes between the tower pier and the main cable. Moreover, the tower height is usually higher than the deck elevation, with the main girder ends fixed by steel cables to two members parallel to the design line center. This ensures structural stability without significantly increasing construction costs, showing obvious advantages in bridge single projects[3]. In the future, research efforts should focus on the aforementioned steel girder construction technology to further enhance the overall stability of steel girder structures, thereby ensuring the comprehensive quality and benefits of municipal road and bridge engineering projects.

3.2 Key Points of Steel Box Girder Construction Technology

In modern municipal road and bridge engineering construction, steel box girder construction technology has become one of the most important technical components in long-span steel bridge engineering construction. To ensure the quality of steel box girder construction and the overall stability of the bridge structure, the following technical points should be clarified:

3.2.1 Structural Modeling Points

BIM (Building Information Modeling) 3D modeling technology, based on information technology, is already applied in China's municipal road and bridge engineering construction. During steel box girder construction, 3D modeling technology should be actively utilized to effectively optimize the engineering construction management model. It is necessary first to determine the specific dimensions of the steel box girder components and their spatial positions during construction. After determining these parameters, the actual construction environment should be simulated, considering potential proruption situations (contingencies) in different construction phases, conducting targeted finite element analysis calculations, and subsequently building a BIM 3D model[4]. The construction of the BIM 3D model enables the visualization of various on-site construction phases, facilitating macro-level supervision and control by construction managers.

3.2.2 Welding Operation Points

Welding operations are involved during steel box girder construction, and their execution directly affects the stability of the steel box girder structure, thereby influencing the final engineering construction quality. Therefore, technical supervision and control of welding operations are essential. This should start from several stages: material preparation (preparing and heating welding rods), cutting weld seams, cooling to room temperature, etc. However, for steel materials of different models and specifications, the requirements for welding processes also vary. To ensure the welding stability at joints and the bearing capacity of the bridge, the surrounding temperature changes must be strictly controlled during welding operations to maintain a suitable temperature[5]. Simultaneously, assembly welding is also involved during construction, which places high demands on the professional quality of welding technicians. For some long-span bridges, multiple phases are involved in the welding process, and there are numerous assembly welding tasks. Some installation personnel might be prone to missed welds or wrong welds during operation. Therefore, on-site management should be strengthened, strictly following the specific sequence requirements of the construction drawings for welding operations. Additionally, controlling the ambient temperature should be done carefully to reduce the possibility of freeze-thaw cracks in the steel, ensuring the comprehensive quality of steel box girder welding operations[6].

3.3 Key Points of Support System Construction Technology

For long-span beam-arch composite steel bridges in municipal road and bridge engineering, the support system construction is one of the important components. The support system mainly consists of continuous steel structures composed of steel pipe piles, precast beam elements, etc. This steel structure system plays a vital supporting role and is key to ensuring the stability of the road and bridge structure. Therefore, the construction technology plan for the support system needs to be reasonably designed. Based on the current construction situation of long-span municipal road engineering in China, the support system construction primarily utilizes two frame structures: the main frame and the secondary frame, which complement each other to form an integrated structure[7]. For road and bridge engineering, the support system can counteract external loads, achieve shock absorption effects, and effectively reduce the possibility of issues like foundation settlement and structural collapse.

During specific support system construction, the construction plan should be formulated considering the construction of large-scale engineering facilities like surrounding buildings and bridges, leveraging the support system's role in preventing concrete cracking and deformation. This ensures the stability and safety of the long-span steel bridge structure. Under special environmental

conditions such as high temperature, low temperature, and high air humidity, the stability of long-span road and bridge structures can be affected. For example, diseases like deck slab cracks may occur, severely impacting the load-bearing capacity of the road and bridge structure. Therefore, during the construction of the support system for long-span bridges, the loads within the bridge span structure should be shared, i.e., reinforcing the abutments and piers to improve their load-bearing capacity, which can also enhance the overall strength of the bridge steel skeleton[8]. However, for some municipal road and bridge projects, the steel materials used and the formed steel skeleton structure might experience gradually declining mechanical properties or even severe structural damage due to external weathering (wind, frost, rain, snow), ultimately leading to the scrapping of some components or the entire structure of the steel bridge. Therefore, during the initial selection of steel materials, the rust resistance of the steel must be strictly required, thereby reducing the impact of external climatic factors on the main steel structure of the bridge during its service life. This is also key to ensuring the stability and service life of long-span bridge structures[9].

4. Conclusion

In summary, the current modernization level of China's municipal engineering is continuously improving, providing solid momentum for urbanization and integrated urban-rural development. In the future, during the construction of municipal road and bridge engineering projects, to ensure project quality and comprehensive benefits, traditional road and bridge construction technologies should be actively innovated to form a more targeted and complete construction technology system. Currently, long-span bridge projects are increasingly common under China's modernization background, demonstrating advantages such as strong structural stability and long service life. During the construction of municipal road and bridge projects, long-span beam-arch composite steel bridge construction technology should be actively introduced. Considering factors such as the specific project scale, functional attributes, and surrounding climatic environmental conditions, the composite steel structure should be reasonably designed to ensure the load-bearing capacity of the main structure meets the standards required for municipal road and bridge engineering. Specifically, the key points of long-span beam-arch composite steel bridge construction technology in municipal road and bridge engineering should be clarified, mainly manifested in steel girder structure construction technology, steel box girder construction technology, support system construction technology, and other aspects. Through in-depth analysis of the aforementioned construction technologies, more ideas can be provided for the construction of long-span composite steel municipal road and bridge projects, ensuring the quality and efficiency of subsequent municipal engineering construction.

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