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Overall Selection Design Based on the Mega Highway Bridge Project

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Abstract: In the continuous development of the modern highway and bridge engineering industry, the reasonable selection of mega highway bridges and their design is crucial. Based on this, this paper takes the actual bridge project as an example, and analyses the overall selection design of such highway bridges, including the basic overview of the project, the basic selection principle of mega highway bridge project structure and its design strategy, etc., to provide scientific reference for its selection design.

Keywords: Mega highway bridge; Selection principle; Selection design for railway crossing; Selection design for road crossing

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1. Introduction

In the process of selecting and designing the structure of the mega highway bridge project, the staff should first clarify the basic project situation. Then, based on this, the selection principles of such structures should be analyzed scientifically. Finally, taking into account the actual situation, reasonable measures should be taken to carry out the overall structure of the selection and design. So that the structure can be designed reasonably to meet the actual construction and application needs.

2. Project overview

The study is about the selection and design of the structure of a highway mega bridge project. The bridge is located on the highway in a standard two-way six-lane form, and its design speed is 120 km. the overall length of the mega highway bridge is about 3.4 km, and its line needs to cross the city main road, city and township river, embankment highway, West-East Gas Pipeline, township river, waterway, city railway, and so on. **Table 1** shows the cross-angle design of the mega highway bridge project and its crossroads and rivers along the route.

Table 1. The design of the mega highway bridge project and its crossing roads and rivers along the route

Serial number	Crossing roads/rivers	Designing cross angles
1	City Trunk Road No. 1	42°
2	City Trunk Road No. 2	134°
3	Urban Trunk Road No. 3	27°
4	Urban and Rural Level River	142°
5	Top of Dike Road	138°
6	West-East Gas Pipeline	38°
7	Township River	42°
8	Waterways	145°
9	Urban Railway	50°

This paper mainly analyzes the overall selection design of the mega highway bridge structure.

3. The basic selection principle of mega highway bridge engineering structure

In the process of selecting and designing the structure of the mega highway bridge project, the designer should combine the construction and application requirements of the actual project, and determine the basic structural selection principles through the comprehensive consideration, analysis, and evaluation of various factors according to the actual situation on the site.

According to the actual situation of the mega highway bridge project and its specific construction and application needs, when the structure is selected and designed, the basic selection principles include the following.

(1) The selection technology of the mega bridge structure should be sufficiently advanced, and the overall structure needs to be safe, reliable, durable, practical, and economically reasonable.

(2) Specific selection: The designer needs to be on the route of the linear index, smoothness, hydrogeological conditions, road traffic requirements, etc. to do a comprehensive consideration so that it is sufficient to have the conditions of adaptability [1].

(3) The upper part of the mainline bridge should use an assembly prefabricated structure with a standard span. For spans below 20 m, a prestressed hollow plate should be selected, while spans between 20 m to 40 m should be determined based on a variety of designs.

(4) When designing for crossings over highways, rivers, and waterways, designers should comprehensively consider the impact of the substructure on traffic, navigation, flooding, etc., and strive to align it with the direction of crossroads and rivers to minimize pier turbulence, cross-flow, and the effects of water barriers.

Adhering strictly to these design principles ensures that the overall design, construction, and application of the mega highway bridge structure are optimally protected and effectively minimize adverse impacts on surrounding infrastructure, achieving the most scientific and reasonable design outcome.

4. Overall selection and design strategy of mega highway bridge structure project

In the overall selection and design of a mega highway bridge structure project, the designer must create a reasonable design for each key bridge section based on the specific design and construction requirements, while considering the actual conditions of the project site. The bridge structure design focuses on three key areas: crossing railways, crossing rivers and waterways, and crossing roads. For these key areas, the designer should develop a variety of design options, conduct a comprehensive comparison and evaluation of these options, and scientifically determine the best choice. This approach ensures the quality of design selection for each critical point in the bridge project, thereby providing robust support for the overall design quality. The following is an analysis of the practical application of the overall selection and design strategy for the mega highway bridge project.

4.1. Selection and design scheme of the bridge across the railway

Site investigations reveal that the bridge crosses the railway at a roadbed height of approximately 7 m, with a crossing angle of 40° between the bridge line and the railway line. According to the overall design principles, the upper span and abutment arrangement must comply with the railway's clearance standards. Specifically, the clearance height of the upper span should not be less than 7.96 m, and the clearance at the top of the railway electrification pole should exceed 20 cm. For the underpass design, the clearance height should be at least 5.5 m. Considering various aspects such as bridge construction, pipeline integration, drainage, and future maintenance, the designer compared three options: a transverse upper span, a small box girder upper span, and an underpass railway [2].

Further analysis of the site conditions indicates that an underpass design would require a split-width passage, occupy significant space, and involve complex jacking construction due to the large crossing angle between the box structure and the railway. This would pose considerable construction challenges and risks, potentially disturbing the railway's roadbed and negatively affecting its quality and traffic flow. Additionally, the underpass would require a dedicated pumping station for rainwater, increasing long-term operation and maintenance costs. Therefore, the underpass option is not suitable for this bridge design.

If a small box girder upper span were used, the piers would need to be placed on the railway slope, increasing construction risks. The construction of the banner plate would also need to occur near the contact network, further elevating the overall construction risk. As a result, the small box girder upper span is also not suitable for this project.

A transverse T-beam structure, on the other hand, would have a smaller footprint, requiring construction only within the railway blockade area, thus minimizing disruption to railway traffic and ensuring higher construction safety. After considering all these factors, the designer decided to adopt a transverse T-beam structure with a 2 × 80 m specification, featuring staggered holes and split widths to span the railway. This design meets the required principles and accommodates the actual construction and operational needs.

4.2. Cross-river and cross-channel bridge selection design program

Site visits for the mega highway bridge construction revealed that the bridge structure needs to cross three consecutive urban main roads, a river, and a waterway. The crossing angles between the bridge and the roads and waterways are relatively small, with significant changes before and after the crossings. The river's width at the site is approximately 120 m. During the specific design process, the designer must thoroughly collect all relevant information and coordinate with local water conservancy, and water and land transport departments during the pre-design phase. This coordination is crucial for making a scientific determination of various boundary conditions, including road clearance, water level design, embankment requirements, water obstruction rate, berm section, waterway clearance, flooding compensation, and collision avoidance requirements. Based on these considerations, the bridge structure selection and design program can be scientifically determined [3].

Since the bridge project crosses a Class VII channel, with a wide estuary and a small crossing angle with the river, the impact on water conservancy and flood control has become the primary constraint in the design selection process. Given this, the designer must first fully consider the requirements of the Class VII channel. Following field inspections and coordination with relevant authorities, the clearance requirement was determined to be 18 by 3.5 m. Considering the site conditions and various factors, the initial design proposed a structure comprising a combination of four 50 m T-beams and two 40 m assembled prestressed concrete box girders, with six spans to successfully cross the river and its embankments.

During the design process, after consulting with flood assessment experts, the designer increased the bridge span to accommodate flood discharge needs, as the river is a key channel for local flood relief. With significant elevation on both sides of the river and minimal embankment, placing bridge abutments within the river was deemed unsuitable, and the water resistance ratio of the abutments was controlled within a range of 5% to 7%. Based on these considerations, the designer, following expert recommendations, proposed two design options: a variable cross-section suspended prestressed concrete box girder and a steel box girder, tailored to the specific structural requirements of the bridge's superstructure and substructure.

For the variable cross-section suspended prestressed concrete box girder, the designer, following expert recommendations, placed the piers at the normal water level line. The span of the main bridge was designed to be 115 m, and the main piers were designed as solid piers [4]. For the steel box girder, the designer reduced the weight of the superstructure based on the actual conditions and designed the substructure with elliptical variable cross-section abutments oriented in the direction of the water flow. The span of the main bridge was designed to be 55 m, with the projected width of the abutment in the direction of the water flow set at 2.1 m. After comprehensive consideration of factors such as cycle time, maintenance difficulty, and the entire lifecycle, the designer decided to adopt the steel box girder design scheme, incorporating special water compensation measures based on flood and navigation assessments.

Additionally, two options were proposed for the steel box girder structure: one with a lower part designed as a double-column pier structure and the other with an elliptical variable cross-section pier structure in the downstream direction. Upon evaluating construction difficulty, structural stress, economy, aesthetics, and other factors, the designer found that the elliptical variable cross-section pier structure offered simpler construction, better structural performance, lower costs, and superior aesthetic integration. Therefore, the designer chose the elliptical pier design scheme [5].

4.3. Across-the-road bridge selection design program

Since the mega highway bridge needs to cross multiple city main roads at small crossing angles, the designer must carefully analyze and design the crossing road scheme. Field investigations reveal that the crossing angles are as follows: approximately 42° with City Trunk Road No. 1, 135° with the river at pile number 443.7 m, 38° with the West-East Gas Pipeline at pile number 132.1 m, and around 145° with the navigation channel and embankment road at pile number 427.8 m. This indicates significant variation in crossing angles along the bridge [6]. Given these conditions, the designer developed three options for crossing the roads: a positive incline bridge design, an oblique incline bridge design, and a reverse incline bridge design [7]. After evaluating construction difficulty, impact on the surroundings, economic factors, and aesthetics, the diagonal bridge option (i.e., split-width staggered holes) was selected as the recommended design.

Additionally, the designer considered the impact of the West-East Gas Pipeline (WEP). To accommodate operational and maintenance needs, the design ensures a minimum horizontal clearance of 5 m or more between the bridge abutments and the pipeline [8].

4.4. Overall bridge selection design program

After developing, selecting, and determining the design schemes of each bridge section, the designer has formulated a comprehensive design for the key nodes of the mega highway bridge project. The overall design scheme is as follows.

(1) For bridge sections without major control factors but with secondary control factors, the designer has opted for a combined box girder structure with a 30 m specification. A single diagonal connection will facilitate the transition of the box girder, forming the foundation of the mega highway bridge project. This selection represents the optimal design scheme for the bridge.

(2) The total length of the bridge structure is approximately 3.4 km. The superstructure primarily consists of transverse T-girder structures, steel box girder structures, prestressed assembled concrete continuous box girder structures, and prestressed cast-in-place continuous concrete box girder structures [9].

(3) The lower abutment structure includes solid abutments, elliptical variable section abutments, gantry abutments, and column abutments.

(4) The bridge abutment utilizes ribbed plate platforms and seat plate platforms, with drilled piles serving as the foundation [10].

5. Conclusion

In summary, when selecting and designing a mega bridge structure in highway engineering, the designer must first clarify the basic project profile, including the design and application requirements of the mega bridge and the actual conditions of the construction site. This helps in identifying key factors and establishing fundamental selection and design principles. Based on this foundation, the designer can then perform a comprehensive selection and design process for the mega bridge structure, ensuring it aligns with site conditions and meets the project's design, construction, and application needs. This approach effectively ensures the rationality of the overall structural design, maximizes structural advantages, minimizes adverse impacts on surrounding infrastructure, and supports the successful construction, application, and development of the mega bridge project.

Disclosure statement

The author declares no conflict of interest.

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