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A Review on the Foundation Design and Construction Technology of Highway Bridges

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Abstract: ***The construction design of highway bridge infrastructure is an integral part of highway bridge design and the main structure for load and load transfer. Therefore, the construction quality directly affects the overall quality and safety of highway bridges. The construction party shall develop a detailed construction technical plan based on the design drawings and the characteristics of various foundations and substructures of highway and bridge engineering. At the same time, the construction party should accurately grasp the technical aspects, construction difficulties, and key points of each stage of construction, improve the planning and standardization level of construction operations, comprehensively improve the quality and investment of highway bridge infrastructure construction, and ensure the safety and stability of the entire structure of highway bridges.***

Keywords: highway bridges; Basic design; construction technique.

1. INTRODUCTION

Due to the fact that highway bridges are important public projects, they not only play an important role in highway transportation, but also serve as an important component of urban transportation development. Therefore, the construction of highway bridges in the 21st century cannot be ignored. To build a good highway bridge, a lot of effort must be invested in the construction process of the project itself to match the overall quality. During the preliminary construction and construction process of the project, attention should be paid to the operation period to ensure that the overall design of the project meets practical needs. Therefore, this article mainly conducts in-depth analysis and research on technical issues in the design and construction of highway bridge foundations, and on this basis, hopes to provide corresponding reference value to colleagues in the same industry.

2. OVERVIEW OF HIGHWAY BRIDGES

At present, socio-economic development has led to a gradual increase in traffic flow. With the continuous growth of vehicle ownership, newly built highway bridges need to ensure high traffic capacity and maintain a relatively stable state even after a long period of operation. Based on this, the design and construction work of highway bridge engineering is very important. The cause of highway bridges continues to develop, and the types of structures are gradually enriched, such as Suspension bridge, steel framed bridge, etc. In some scenic areas, wooden bridges are often chosen to meet people's aesthetic requirements. Nowadays, in the construction of highway bridges, the most important and widely used materials are concrete and steel bars, and there are certain differences in the demand for materials among different bridge types.

According to the materials used in the main load-bearing structures [2], there are wooden bridges, steel bridges, masonry bridges (including brick, stone, and concrete bridges), reinforced concrete bridges, and prestressed reinforced concrete bridges.

1) Wooden bridge: A bridge built from wood. The advantage of wooden bridges is that they can be made from local materials, with simple structure and convenient manufacturing. Small spans are often made into beam bridges, while large spans can be made into pedestrian or arch bridges. Its disadvantages include easy decay, high maintenance costs, consumption of wood, and susceptibility to fire. Mainly used for temporary bridges or forest area bridges.

2) Steel bridge: A bridge constructed from steel for its span structure. Steel has high strength, superior performance, and a small ratio of apparent density to allowable stress, resulting in a larger crossing capacity of steel bridges. The manufacturing of steel bridge components is most suitable for industrialization, with convenient transportation and installation. The erection period is short, and it is easy to repair and replace after damage. However, the steel is prone to corrosion and maintenance is difficult.

3) Masonry bridge: A bridge constructed of bricks, stones, or plain concrete. This type of bridge is often constructed as an arch structure mainly for compression resistance, including brick arch bridges, stone arch bridges, and plain concrete arch bridges. Due to the high compressive strength of stone materials and the availability of local materials, stone arch bridges are more commonly used in highway and railway bridges

4) Reinforced concrete bridge: also known as ordinary reinforced concrete bridge. The bridge span structure is constructed of reinforced concrete. This type of bridge, with sand and gravel aggregates that can be locally sourced, is easy to maintain, has low driving noise, long service life, and can be constructed through industrialization and mechanization. Compared with steel bridges, the amount of steel used and maintenance costs are relatively low, but it has a significant weight. For bridges with extra large spans, it is often inferior to steel bridges in terms of crossing capacity, construction difficulty, and speed. The prestressed reinforced concrete bridge span structure is constructed with prestressed concrete. This type of bridge utilizes the reaction force of pre tension of steel bars or steel wires (cables) to make the concrete pre compressed before being loaded, without tensile stress during the operation stage (called fully prestressed concrete), or with tensile stress without cracks or control cracks within the allowable width (called partially prestressed concrete).

Its advantages are: it can make reasonable use of high-strength concrete and high-strength steel, thereby saving steel, reducing the self weight of the structure, and increasing the crossing capacity of the bridge; Improved the working state of the tensile zone of the structure, improved the crack resistance of the structure, and thus increased the stiffness and durability of the structure; During the loading stage, it has high bearing capacity and fatigue strength; Cantilever pouring method or cantilever assembly method can be used for construction, without affecting navigation or traffic under the bridge; Facilitate the promotion of prefabricated concrete structures.

With the development of bridge seismic engineering [3] and the summary of earthquake damage experience, the seismic vulnerability assessment methods for highway bridges have been revised several times. The main purpose of this work is to identify the seismic weak points of these highway bridges on site without undergoing complex calculations.

Through statistical analysis, the factors that affect the seismic vulnerability of highway bridges are divided into two categories for measurement and research. Classify the degree of damage into high vulnerability (Level A), medium vulnerability (Level B), and low vulnerability (Level C) (as shown in Table 1). Analysis of previous earthquake damage has identified 15 items that affect the seismic vulnerability of bridges. These 15 items are mainly composed of four factors, namely: ground motion intensity; The structural characteristics of the upper structure and foundation; Anti collapse facilities for the upper structure; Site components. Each item is further divided into several levels.

3. PROBLEMS IN THE DESIGN AND CONSTRUCTION OF HIGHWAY BRIDGE FOUNDATION

3.1 Insufficient preliminary survey and unreasonable design scheme

The construction of highway bridges is mainly carried out based on the feasibility report of the project and the construction drawing design after the preliminary design plan review. Scientific and reasonable design ensures the smooth progress of subsequent production processes and the compliance of finished product effects with design requirements. However, it is impossible to study the specific planning and feasibility of all individual units of the project when planning and formulating design plans. When the design and construction departments do not fully understand the safety awareness of specific structures, only focus on overall economic benefits, lack systematic and accurate research, and even at the cost of shortening project completion time. Due to the lack of rationality and safety, the construction of these highway bridges ultimately cannot meet the needs of market economy development and people's livelihood development.

3.2 The durability of the bridge does not meet the requirements

In the process of planning and designing bridges, designers must ensure the requirements of engineering quality and service life, and consider the aesthetics and integrity of the bridge. With the increasing traffic flow, the requirements for the bearing capacity of bridges are also increasing. How to improve quality and extend lifespan

while maintaining overall aesthetic appeal is an important issue for any designer. During the use of bridges, it is inevitable to encounter problems such as weathering and corrosion, which can affect the service life of the bridge and cause stability issues. In addition, the degree of weathering and erosion varies greatly due to regional differences in climate conditions. If these comprehensive issues are not considered in the design process, it will inevitably affect the durability of the bridge. In order to prevent this situation from happening, all participants must prioritize the safety of bridge strength during both design and construction processes.

3.3 The construction technology is single and the relevant technical personnel are not proficient in it

Although China's highway and bridge construction has achieved certain results in recent years, especially in plateau mountainous areas, the construction technology is relatively single, the construction technicians lack experience, the use efficiency of construction technology is low, project quality is poor, and delays often occur. During the construction process, due to the lack of application of seismic and settlement prevention technologies, the quality of the bridge experienced abnormal conditions after operation.

3.4 Affected by overload conditions

When designing a bridge, its designed bearing capacity will be greater than the design requirements, and normal circumstances will not affect the reliability of the bridge. However, in actual operation, overloading is not uncommon. The main reasons for the overload problem are: firstly, many bridges' designed traffic capacity during the original engineering construction did not meet the current requirements, and the number of vehicles increased far exceeded expectations. Bridges are still in use, and some drivers are also overloaded with transportation, which is a problem.

3.5 Due to issues with the design of the surface waterproof layer

Due to the fact that waterproof coatings in bridge structures are important materials for anti-corrosion technology, the waterproof requirements for concrete are relatively high. In the process of engineering construction, if the quality of concrete is C30, it is important to calculate the steel mesh of the concrete protective layer to avoid concrete cracking and ensure uniform coating. When designing waterproof covers, attention should be paid to installation issues and consideration should be given to the negative bending moment of the bridge. In addition to careful calculation of the load on the bridge itself by designers, it is also necessary to fully consider the drainage problem of the bridge. Only by doing a good job in the drainage design of the bridge can it truly be waterproof.

4. CONSTRUCTION TECHNOLOGY OF BRIDGE PILE FOUNDATION

4.1 Construction setting out

Before construction begins, the site should be leveled and compacted with a roller so that machinery and materials can enter the site without obstacles. After everything is ready, the surveying personnel will measure and set out according to the design plan, and report to the supervising engineer for review and approval. After on-site layout and approval by the supervising engineer, Eight single pile protection piles were pulled horizontally through the center of the pile, and after construction, the measurement personnel regularly observed and recorded the protection piles.

4.2 Embedding of casing

After the measurement is completed, immediately carry out the installation of the casing. When selecting the casing, the diameter of the casing should be slightly larger than the pile diameter, and the casing must be filled with waterproof material to prevent it from hanging. After the installation of the box, it should be measured and inspected again to ensure that the center of the box is aligned with the center of the support legs. If it does not meet the requirements, it must be corrected in a timely manner. Install fences and clear Warning sign around before drilling.

4.3 Drilling and mud preparation

After the drilling rig and casing are installed in place, carefully inspect various equipment, recheck the plane position of the casing burial, and check the mud preparation and quality. From the beginning of drilling operations

to the completion of drilling, it is necessary to ensure that the current operation is not interrupted, and a dedicated person should record the drilling project. After the drilling is completed, specific records and relevant data should be reported in a timely manner. Mud drilling is often tested and evaluated. According to different geological conditions, the viscosity of the mud is controlled between 16 and 28Pa • s. If it does not meet the requirements, it should be adjusted in a timely manner. The mud head should always be maintained at around 2 meters, so that the ground pressure in the well exceeds the underground pressure to prevent the collapse of the hollow wall.

4.4 Hole cleaning

After the drilling reaches the design elevation, check the indicators such as aperture, depth, position, and angle to ensure compliance with the requirements. The hole must be cleaned immediately. The hole cleaning must comply with the following standards: the soil inside the pit must be free of 2-3mm particles, the soil sand content must not exceed 2%, and the soil viscosity must be 17-20 passes. It is strictly prohibited to increase the drilling depth instead of cleaning the hole.

4.5 Production and installation of steel reinforcement framework

Qualified steel bar raw materials shall enter the site and be placed in a centralized production site. Cushion blocks shall be added at the bottom and covered at the top to prevent the steel bars from getting damp and rusting. According to the design drawings, adjust the material of each reinforcement cage to minimize the number of main reinforcement connections as much as possible, in order to save materials and reduce waste. The manufacturing and installation of steel bars must strictly comply with national and current industry standards. After the production of the steel reinforcement cage is completed and approved by the supervising engineer, it can be lifted into the hole. During the lifting process, the position should be measured and corrected at a fixed point, and real-time adjustments should be made to ensure that steel reinforcement cage does not sink or float when pouring concrete.

4.6 Pouring underwater concrete

Underwater concrete pouring generally adopts the conduit method, and water supply uses steel pipes with a diameter of 25-30 centimeters. Before pouring underwater concrete, a sufficient number of pipes must be prepared along the pile foundation. The mixing ratio of underwater concrete must be determined through standard tests before construction. Due to the influence of dirt on the strength of underwater concrete, the concrete grade is usually determined by experiments rather than design. Due to the continuous pouring of underwater concrete, all relevant materials must be prepared before pouring. When pouring concrete for the first time, the square volume of the trench needs to be calculated before pouring, so that the drilling depth of the trench is at least 1m. The drilling depth for the next excavation is estimated to be 2-6m, and the concrete strength exceeds 80%. Concrete testing When the pile foundation concrete reaches the design strength, generally at least 28 days before the next construction, the Pile foundation shall be tested by ultrasonic flaw detection method to ensure that there is no pile break, interlayer, shrinkage and other phenomena [3].

5. EFFECTIVE MEASURES TO SOLVE THE DESIGN AND CONSTRUCTION PROBLEMS OF HIGHWAY BRIDGES

5.1 Carry out bridge design work well

When designing and constructing highway bridges, personnel from all parties should pay attention to the structure adopted by the bridge. If using highway bridges, it is important to ensure that their stability meets the requirements of the design or construction process, as piles carry most of the load. Firstly, relevant personnel can improve stability through efficient maintenance, and after the main construction is completed, appropriate maintenance can be carried out on the finished product. For example, if gunny bags are used for curing or asphalt lotion is sprayed, these two methods are relatively common processing methods at present. During the maintenance period, it is not possible to completely avoid vehicle traffic, and it is necessary to limit the weight of incoming and outgoing vehicles, as well as control the driving speed of vehicles.

5.2 Application of waterproof design for highway bridges

If the waterproof design is insufficient, water will seep from the road surface into the interior of the bridge during

the rainy season, directly affecting the quality or service life of the bridge. Therefore, attention should be paid to waterproof design. In the selection of materials in design, during the initial design stage of highway bridges, it is necessary to consider selecting materials with good quality and spatial characteristics to avoid the consequences of poor design. Generally speaking, the waterproof layer must comply with the specifications and regulations, and must start from four aspects: (1) the road surface of the bridge should have necessary adhesion to avoid peeling; (2) Concrete laying should be consistent with road laying; (3) To prevent bridges from being corroded by rainwater, it is necessary to strengthen the laying of drainage pipes; (4) When installing drainage pipes, pay attention to preventing rainwater from damaging the concrete structure.

5.3 Ensure smooth construction of steel reinforcement engineering

In the construction process of highway bridges, the production of steel reinforcement cages is difficult, and operators must use large machinery for lifting. The professional requirements for mechanical operators are high, and relevant units need to be cautious when selecting personnel. During the welding process, operators must be careful to avoid damage issues. When welding, the operator can choose to use multiple devices for welding together or choose one device for welding separately. No matter which method is used, Operators must pay attention to the alignment of the holes, otherwise it will affect subsequent operations [4].

5.4 Carry out the construction work of cofferdam foundation pit excavation

During the excavation process of the cofferdam foundation pit, the first thing to do is to carry out precipitation treatment. By injecting water into the foundation pit to stop water, the thickness of the injection is determined. If there are problems such as water and mud seepage near the foundation pit, a relatively remote location should be selected for the injection water stop. At the same time, the construction of the retaining pile will be carried out. If it encounters a relatively hard object, it will lead to leakage and other problems, The stability of the bridge structure foundation is reduced. Therefore, in the face of this situation, corresponding reinforcement measures can be taken for the soil. For foundation pits, it is necessary to ensure a uniform safety distance between the edge of the pit and the slope, which cannot be less than 0.5m. This is a static requirement, but for dynamic requirements, it must exceed 1m.

5.5 Reasonable application of computer technology

The application of computer technology is more common today, and production can be optimized through interaction and practical functions. During the design and construction process of highway bridges, technicians perform various tasks, including data collection, graphic design, and drawing. For example, in addition to collecting geographic information, relevant personnel can also use GIS technology, which is very useful. In addition to collecting information, GIS technology allows designers to manage and analyze data information by comparing 3D models, and display data information on three dimensions. This method is suitable for areas with complex terrain and can conduct detailed exploration and analysis of the surrounding geographical environment. Similarly, modeling techniques contribute to the design and construction of bridges. In the application process, various factors such as economy, feasibility, and construction time can be comprehensively considered to develop a bridge foundation model. By comparing the design model with actual construction, various possible crises can be addressed.

5.6 Avoid corrosion of steel bars

Reinforced concrete is the most commonly used material in highway bridge construction, and the load-bearing capacity of steel bars directly affects the stability of the bridge. To ensure load-bearing capacity, steel corrosion issues should be avoided as much as possible. In daily use, the outer protective layer of steel bars can ensure that they are not affected by corrosion. Once the outer protective layer is damaged, long-term exposure of steel bars to air, water, and other substances can lead to corrosion and affect the stability of the bridge. Therefore, daily protection is important. Firstly, staff must carefully select steel bars, choose the highest quality steel, and avoid drainage areas as much as possible during storage, and regularly clean rainwater. Attention must also be paid to ensuring that materials such as cement have the correct labeling and do not generate excessive heat when in contact with water. Before the official start of construction, relevant personnel must inspect the steel and take effective remedial measures if serious corrosion problems are found. In addition, to avoid similar problems in the future, it is necessary to conduct in-depth research on the causes of corrosion and effectively prevent them [5], in order to effectively prevent the occurrence of such problems.

5.7 Reasonable selection of infrastructure form

In the construction of highway bridge engineering, the form of bridge foundation structure depends on the geological conditions of the construction site. Currently, commonly used bridge foundation structures. Mainly including direct foundation, caisson foundation, and pile foundation structure. Among them, direct foundation refers to directly setting the foundation plate of highway bridge engineering on the bearing foundation to ensure the load transfer of the upper structure. When the construction site of highway bridge engineering is in a geological environment of bedrock erosion or when the bedrock is buried deeply, it is necessary to lay a deep foundation to achieve the transmission of load on the upper structure. In the construction of direct foundations, open excavation construction technology is usually used, and the bottom sealing construction of the open caisson is carried out to ensure the stability of the foundation structure. When the shallow soil of the road bridge construction site foundation is poor and the bearing layer is buried deep, it is necessary to improve the stability and strength of the foundation structure. Generally, the Pile foundation structure should be used as the bridge foundation.

5.8 Carry out the construction of piers, abutments, and columns

One is to do a good job in template construction. In highway bridge engineering, the size of the template determines the number of columns, platforms, and column shape during construction. Therefore, in structural design, it is necessary to strictly control the length and shape of the template, accurately measure the template, and ensure its quality requirements; The second is concrete structure. During the concrete pouring process, it is necessary to carefully control the height of concrete falling and vibration to reduce pollution on the construction site; Thirdly, it is necessary to correctly check the verticality of the concrete structure. When building highway bridges, the height of columns and columns is relatively high, and it is necessary to ensure that the formwork is firmly supported. In addition, the concrete pouring strength of the foundation pile should be at least C25, the thickness of the protective layer should be at least 7 centimeters, and the overlapping length of the upper and lower protective walls should be at least 20 centimeters; It is important to avoid the rainy season as much as possible during the construction process.

6. CONCLUSION

In the construction process of highway bridges, design is a very important content, and the rationality of design work directly affects the safety of the entire highway bridge. Therefore, highway bridge designers must improve their requirements for stability during the construction process, ensure safety during the construction process, and continuously improve the overall design level of the bridge. In addition, deepening the construction process and regular follow-up visits should be part of the design, and timely handling of discovered problems can not only ensure the quality of highway and bridge engineering from design to construction, but both are indispensable, laying a solid foundation for the sustainable development of the highway transportation industry.

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