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Hydraulic Sliding Formwork Construction Technology for Main Pier Columns of Highway Bridges

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Abstract: Aiming at the problems of difficulty in balancing construction efficiency and quality, as well as the high safety risks of working at heights during the construction of main piers for highway bridges, this study takes a specific bridge project as an example to introduce the technology of hydraulically sliding formwork for the construction of main piers of highway bridges. An in-depth analysis of the project's construction process found that this technology can effectively improve construction efficiency, ensure the quality of concrete pouring, and significantly reduce the potential safety hazards of working at heights. It provides a reliable technical solution for constructing the main piers of highway bridges and has important reference significance for similar projects.

Keywords: Highway bridges; Main piers; Hydraulic pressure; Sliding; Formwork

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1. Introduction

As a key component of transportation infrastructure, highway bridges play a pivotal role in regional economic development and social exchanges, with their construction quality and efficiency being crucial. The main pier, as the core load-bearing structure of a highway bridge, has a direct impact on the performance, durability, and construction duration of the entire bridge project. In the field of modern bridge construction, as the scale of projects continues to expand and design requirements become increasingly demanding, traditional main pier construction techniques are gradually facing many challenges. Traditional construction methods, such as the full scaffolding method and the formwork turning method, often encounter issues such as cumbersome construction procedures, frequent formwork turnover, high risks of working at heights, and long construction durations when dealing with taller and larger main piers.

These problems not only increase construction costs but also potentially affect the quality and safety of the project. In this context, hydraulically sliding formwork construction technology for highway bridge main piers has emerged. This technology, with its unique advantages, has gradually been applied and promoted in many bridge projects. The hydraulically sliding formwork construction technology enables simultaneous concrete pouring and formwork lifting, reducing construction intervals and significantly improving efficiency. Through an automated hydraulic lifting system, the rising speed and position of the formwork can be precisely controlled, effectively ensuring the verticality and cross-sectional dimensional accuracy of the main pier, and improving the pouring quality and appearance of flatness of the concrete. Based on this, this article studies the technological process of hydraulically sliding formwork construction technology.

2. Project overview

A certain bridge serves as a key transportation node connecting the new urban area and the old city. The main bridge adopts a prestressed concrete continuous rigid frame bridge type, with a total length of 1,200 m and a main span of 200 m. There are 4 main pier columns, with designed heights ranging from 50 m to 80 m, and the tallest main pier column reaches 80 m. The main pier columns have rectangular cross-sections, with dimensions of 6 m in length and 4 m in width. The designed concrete strength grade is C50, and the concrete pouring volume for a single main pier column is approximately 1,200 m^3. The geological conditions of the project site are complex, with the upper stratum mainly consisting of silty clay and the lower stratum being sandstone. The groundwater level is located 10 m below the surface. The surrounding environment of the construction site is relatively special, with one side adjacent to an existing railway line and a narrow construction site, posing extremely high requirements for construction organization and safety protection [1].

3. Composition of the hydraulic sliding formwork system

3.1. Formwork system

The formwork system is crafted from high-quality Q235 steel, with a panel thickness set at 6 mm to ensure the strength and durability of the formwork. The height of the formwork is carefully designed to be 1.5 m, accommodating various needs during the construction process. To further enhance the overall stability and rigidity of the formwork, the back ridge section utilizes 10# channel steel, evenly arranged at intervals of 350 mm, effectively increasing the formwork's load-bearing capacity. Connections between the formwork panels are secured using M18 high-strength bolts, positioned at intervals of 200 mm along the edges of the formwork and 400 mm in the central part, ensuring tight connections. The width of the seams is strictly controlled within 1.5 mm to eliminate any gaps that could potentially affect the quality of the concrete [2]. Additionally, a layer of specialized release agent is uniformly applied to the inner side of the formwork, with a thickness of approximately 0.15 mm. This release agent not only effectively protects the surface of the formwork but also ensures that the concrete exhibits a smooth and clean surface after demolding.

3.2. Hydraulic lifting system

The hydraulic lifting system consists of three core components: hydraulic jacks, a hydraulic control console, and oil lines. For this project, YKT-50 hydraulic jacks with a rated lifting capacity of up to 5 tons were chosen, adequate for various challenges during construction. A total of 24 jacks are evenly distributed around the main pier column, with a horizontal spacing of approximately 1.8 m between adjacent jacks, ensuring stable and uniform lifting. The ZKT-60 hydraulic control console, featuring precise pressure control and travel display with a pressure control accuracy of 0.4 MPa, provides intuitive and accurate operational guidance for construction workers. The oil lines are connected using high-pressure seamless steel pipes with an inner diameter of 12 mm and a total length of approximately 400 m. Through reasonable oil line arrangement and precise oil supply control, each jack receives a uniform and stable pressure during the lifting process, achieving the goal of synchronous lifting [3].

3.3. Operating platform design

The operating platform is an essential auxiliary facility during construction, consisting of a main operating platform, an upper auxiliary platform, and inner and outer hanging scaffolds. The main operating platform adopts a sturdy truss structure welded with 12# angle steel, covering an area of approximately 80 m^2 and designed with a carrying capacity of up to 3 kN/m^2, adequate for construction workers, equipment, and some materials. The upper auxiliary platform, located 2 m above the main operating platform and covering an area of approximately 40 m^2, is primarily used for reinforcing bar extension and initial binding, providing a more spacious and convenient operating space for construction workers [4]. The inner and outer hanging scaffolds, made of 48 mm diameter steel pipes with a width of 0.8 m, are suspended below the main operating platform and adjusted using manual hoists. These scaffolds not only facilitate formwork cleaning and maintenance but also aid in the finishing and curing of the concrete surface, ensuring improved construction quality and efficiency.

4. Technological process of hydraulic sliding formwork construction technology for main pier columns of highway bridges

4.1. Preliminary preparation

Before construction, conduct a detailed survey of the construction site, build access roads, and widen and level the site to ensure smooth passage for construction vehicles and machinery. Purchase raw materials such as steel bars, cement, and sand that meet quality standards according to engineering design requirements, and conduct strict inspections. Among them, the yield strength, tensile strength, and other indicators of steel bars must comply with relevant steel standards, and the stability, strength, and other indicators of cement must meet the cement standard values. Comprehensively inspect, debug, and pre-assemble various components of the hydraulic sliding formwork system. Conduct a simulated sliding test at the assembly site to ensure stable and reliable system operation. Organize construction workers to conduct technical clarification and safety training to familiarize them with construction techniques, operating procedures, and safety precautions. Workers can only start working after passing the assessment. After completing the foundation construction of the main pier column and achieving the designed strength, use a total station instrument for precise surveying and setting out to determine the center position and outline of the main pier column. Set stable control points on the top surface of the foundation for measurement, monitoring, and correction during the construction process [5].

4.2. Steel bar binding

The processing and fabrication of steel bars are centralized in a dedicated processing field. According to the detailed requirements of the design drawings, the steel bars are precisely processed into various specifications of semi-finished products. In the construction of the main pier column, HRB400 grade threaded steel with a diameter of 32 mm is selected for the vertical steel bars, and the arrangement spacing is set to 250 mm to ensure the strength and stability of the structure [6]. HRB335 grade steel bars with a diameter of 14 mm are selected for the horizontal hoops, and the arrangement spacing is 200 mm, which further strengthens the integrity and shear resistance of the structure. The connection method of steel bars adopts advanced straight thread sleeve connection technology, which is not only high in strength but also convenient for construction. To ensure the safety and reliability of the structure, the number of steel bar joints in the same section is strictly controlled within 50% of the total number of steel bars, effectively avoiding potential hazards that may arise from too many joints. During the steel bar binding process, operators use the operating platform, positioning bars, and binding wires to accurately fix the position of the steel bars, ensuring that the spacing and protective layer thickness of the steel bars strictly comply with the design requirements. To precisely control the thickness of the protective layer, special 55 mm thick concrete spacers are used. These spacers are arranged in a quincunx pattern with a spacing of 1.2 m, effectively preventing the steel bars from directly contacting the formwork and ensuring the accuracy of the steel bar position and the construction quality of the concrete.

4.3. Formwork installation and debugging

The pre-assembled formwork is safely and precisely lifted to the top surface of the main pier column foundation and installed based on the accurately measured setting-out position. During installation, technicians use theodolites and level gauges to monitor the verticality and levelness of the formwork in real-time, ensuring that the verticality deviation is controlled within 1/1000 and the levelness deviation does not exceed 6 mm to meet the construction accuracy requirements. After the formwork installation is completed, the debugging work of the hydraulic lifting system begins immediately. During debugging, professionals carefully check the connections between the jacks, hydraulic control console, and oil pipes for tightness and leak-free conditions, ensuring the system's safety and reliability. Subsequently, a no-load test run is conducted to observe the stability and synchronicity of the jack's lifting and lowering, as well as the accuracy of the pressure display and stroke control on the hydraulic control console. Any issues identified during the debugging process are immediately rectified to ensure that the hydraulic sliding formwork system operates normally and stably, providing solid and reliable support for subsequent concrete pouring and sliding operations [7].

4.4. Concrete pouring

In the concrete pouring process, an HZS120 concrete mixing plant is used for centralized mixing to ensure precise concrete proportions and stable quality. The concrete ingredients strictly follow the designed ratio of cement, sand, stones, water, and additives, which is 1:2.5:3.8:0.48:0.03. This ratio is carefully calculated to meet the project's various performance indicators. The slump of the concrete is strictly controlled within the range of 150–180 mm to ensure good workability and pouring quality. Concrete transportation relies on 10 m^3 capacity mixing trucks, which maintain continuous rotation of the tank during transportation to effectively prevent concrete segregation and ensure the quality and performance of the concrete during pouring. The pouring operation adopts a layered pouring method, with each layer's thickness precisely controlled at around 350 mm to ensure uniform distribution and compactness of the concrete. During pouring, the concrete is evenly distributed from the center of the main pier column to the surrounding area, ensuring uniform concrete distribution across the entire pouring area without obvious voids or bubbles. To further improve the compactness and strength of the concrete, a 50-type insertion-type vibrating rod is used for vibration. The vibrating rod is inserted into the lower layer of concrete with a depth of not less than 60 mm, and the vibration time is controlled between 20–30 seconds until the concrete surface no longer sinks, no bubbles emerge, and the surface is covered with a layer of cement paste, indicating that the desired vibration effect has been achieved [8]. Additionally, throughout the entire concrete pouring process, dedicated personnel are responsible for monitoring the working status of the formwork, steel bars, and the hydraulic sliding formwork system. If any abnormalities are detected, such as formwork deformation, steel bar displacement, or failures in the hydraulic sliding formwork system, the pouring operation is immediately stopped. The cause is investigated, and appropriate measures are taken to address the issue, ensuring the safety and quality of the construction.

4.5. Hydraulic climbing

The initial climbing operation can be started when the concrete is poured to about 70% of the formwork height and the concrete strength reaches 0.3–0.5 MPa. The height of the initial climb is strictly controlled to around 60 mm, with the main purpose of observing the strength of the concrete exiting the mold and the working status of the climbing system. During the initial climbing process, close attention is paid to the slump of the concrete and the ease of climbing. Once abnormalities such as concrete slump or difficulty in climbing are found, the mix proportion of the concrete or climbing parameters is immediately adjusted to ensure smooth climbing [9]. After the initial climb is normal, it can be transferred to the normal climbing stage. The speed of normal climbing is comprehensively determined based on factors such as the setting time of the concrete, temperature conditions, and construction process requirements, and is generally controlled between 250–350 mm/h. During the climbing process, the hydraulic control panel is used to synchronously control the jacks, ensuring that the travel difference between each jack does not exceed 15 mm, to ensure stable and uniform climbing. To ensure the accuracy of the verticality, cross-sectional dimensions, and axis position of the main pier, a total station is used to perform a measurement check every 1.5 m of climbing. If deviations exceed the allowable range, measures are immediately taken to correct them, such as adjusting the climbing height of the jacks or setting wedges between the formwork and the concrete, to ensure that the accuracy and quality of the main pier meet the design requirements.

4.6. Formwork cleaning and maintenance

After each hydraulic climb, the surface of the formwork is promptly cleaned. A scraper and steel wire brush is used to remove concrete, mortar, and debris adhered to the surface of the formwork, which is then rinsed clean with a high-pressure water gun. At the same time, the connecting bolts, welds, and back ribs of the formwork are inspected. If there is any loosening, deformation, or damage, they are promptly tightened, repaired, or replaced. The hydraulic lifting system, including jacks, oil pipes, and the hydraulic control panel, is inspected and maintained. The sealing performance of the jacks, the connection of the oil pipes, and the operating parameters of the hydraulic control panel are checked to ensure that the hydraulic lifting system performs well and operates reliably. Regular inspections are conducted on the operating platform, internal and external hanging brackets, etc., to check the stability of the platform structure, the flexibility of the hanging brackets, and the integrity of safety protection facilities. Any potential safety hazards are promptly eliminated to ensure the safety of construction workers [10].

5. Conclusion

The application of hydraulic climbing formwork technology for highway bridge main piers in the "Guangming Bridge" project has achieved good results. Through this technology, the construction efficiency of the main piers has been significantly improved, and the construction period has been reduced by about 35% compared to traditional construction methods. At the same time, it has effectively ensured the construction quality of the main piers, with a one-time qualification rate of concrete strength of over 99%. The appearance quality of the main piers is smooth and flat, with no obvious defects. In terms of construction safety, the risk of working at heights has been reduced by reasonably setting up operating platforms and safety protection facilities, resulting in a significant reduction in the incidence of safety accidents. However, in the actual construction process, attention still needs to be paid to issues such as oil temperature control in the hydraulic system and wear monitoring of the formwork. With the continuous development of technology and the accumulation of construction experience, the hydraulic climbing formwork technology for highway bridge main piers will continue to improve, providing stronger technical support for the construction of highway bridges.

Disclosure statement

The author declares no conflict of interest.

References

[1] Cheng Z, 2023, Application Analysis of Hydraulic Sliding Formwork Construction Technology in Bridge Construction. Transport Manager's World, 2023(36): 89–91.

[2] Hao J, 2023, Application of Hydraulic Sliding Formwork Construction Technology for Thin-walled Hollow Piers in Highway Bridge Engineering. Transportation World, 2023(09): 175–177.

[3] Niu Y, 2020, Application of Sliding Formwork Technology in Bridge Construction in Alpine Regions. Green Environmental Protection Building Materials, 2020(12): 104–105.

[4] Yu B, Zhang L, 2017, Application of Sliding Formwork Construction Technology in the Construction of High Piers of Highway Bridges. Transportation World, 2017(28): 82–83.

[5] Geng M, 2018, Application of Hydraulic Sliding Formwork Technology in Pier Construction During Bridge Construction. Architectural Technology Development, 45(22): 90–91.

[6] Le X, Chen Z, 2021, Application of Hydraulic Sliding Formwork Construction Technology in Bridge Construction. Heilongjiang Transportation Technology, 44(10): 248 + 250.

[7] Rao X, 2018, On the Application of Hydraulic Sliding Formwork Construction Technology in Highway Bridge Construction. Sichuan Cement, 2018(08): 67.

[8] Li T, 2019, On the Application of Hydraulic Sliding Formwork Construction Technology in Highway Bridge Construction. Low Carbon World, 9(06): 208–209.

[9] Fan Z, 2019, Application of Hydraulic Sliding Formwork Construction Technology in Highway Bridge Construction. Transportation World, 2019(24): 88–89.

[10] Hu J, 2019, Hydraulic Sliding Formwork Construction Technology in Highway Bridge Projects. Transportation World, 2019(22): 86–87.