Research on Cofferdam Construction Technology in Water Conservancy and Hydropower Engineering

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Abstract. With the continuous development and progress of society, the construction of water conservancy and hydropower engineering has become a cornerstone of national economic development. Therefore, it holds great significance to delve deeply into its applications and advancements in China. Among the various technologies involved, cofferdam technology plays a pivotal role in the construction of water conservancy and hydropower engineering. Its application has a substantial impact on the economic, social, and environmental benefits of such projects. Hence, it warrants thorough research and exploration. To illustrate this, this paper offers a concise analysis and discussion of cofferdam technology employed in the reconstruction of the Haimen Bay Bridge Lock in Shantou City, using it as a case study.

Keywords: water conservancy and hydropower engineering, cofferdam construction, Reconstruction of bridge gate

1. Overview

The application of cofferdam technology promises significant enhancements in the construction quality and standards of water conservancy and hydropower engineering projects. It also stands to benefit the design and development of related hydroelectric initiatives, ultimately contributing to the broader advancement of water conservancy and hydropower engineering as a whole. It is worth noting that the development of water conservancy and hydropower projects boasts a significant commitment to driving the country's economic growth. The incorporation of cofferdam technology into these projects will significantly amplify their overall benefits and positively impact the societal value of water conservancy and hydropower engineering. In recent years, there has been a notable expansion in both the scope and techniques associated with cofferdam construction. Through the implementation of a project, the construction technology of cofferdam is studied, this contributes significantly to the comprehensive adoption of this technology and holds substantial importance in enhancing its overall performance and safety.

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2. Project overview

2.1 Overview

The Shantou Haimen Bay Bridge Lock Expansion Project is located at the mouth of the Lianjiang River in Haimen Town, Shantou City. This strategic location places it approximately 2 kilometers to the south of the port city, 4 kilometers to the north of the urban center, and adjacent to the east of Baitu in Fengnan Township[1]. To the west, the project is positioned near Gucheng Village in Jingdu Town, and exercises control over an expansive drainage area spanning 1,354 square kilometers upstream. This vast area functions as a substantial reservoir with multifaceted purposes, encompassing flood control, prevention of saltwater intrusion, and the storage of fresh water. The project comprises several vital components, organized from left to right as follows: a breakwater connecting the left bank, empty container racks connecting the left bank, a connecting dam, drainage gates, a ship lock, a river closure dam, a wall connected to the container on the right bank, and a dike section connected to the right bank[2].. The project adopts a phased water diversion strategy, initially establishing a primary transverse section on the right bank. Subsequently, a primary longitudinal section is developed in conjunction with the primary transverse section, forming an integral primary longitudinal section. Permanent structures are then constructed within the excavation area during the first phase. Following this, longitudinal concrete dams are built during the second phase. The first-phase cofferdam is subsequently removed, and a second-phase horizontal earth and stone dam cofferdam is erected[3].. This cofferdam coordinates with the second-phase longitudinal concrete dam cofferdam, allowing for the excavation of the first phase on the right bank. Finally, the construction of permanent buildings is concluded during the second-phase project[4]..

2.2 Introduction to difficult points

The cofferdam project plays an important role in the reconstruction and expansion of the Haimenwan Bridge Gate in Shantou. The second type of large-scale water conservancy and hydropower projects should consider both reclamation of land from the sea and comprehensive utilization of water for production and domestic use. Although it is temporary, it can ensure the quality and safety of the hydraulic engineering construction and protect the construction workers and the safety of the project. In the construction process, the cofferdam project should be constructed according to the construction conditions, and scientific construction technology should be adopted. During the construction of the high cofferdam, how to control the site conditions and ensure the construction safety by relying on the technical conditions while protecting the main structure of the hydraulic engineering hydraulic engineering, it is also an important factor that affects the construction schedule and safety of Cofferdam. In the following sections, the construction solution of the cofferdam in the reconstruction and expansion project of the Haimenwan Bridge and sluice in Shantou is described.

3. Cofferdam design

The design of the second phase cofferdams of the lock renovation project for the Haimen Bay Bridge includes upper and lower sections of the downstream transverse cofferdams. The design elevation for the top of the upper section of the downstream transverse cofferdams is at ▽2.80

meters, while the lower section is at ▽2.70 meters. The top elevation of the longitudinal concrete cofferdams varies between 2.80 meters to 2.70 meters. Figure 1 depicts the design illustration.

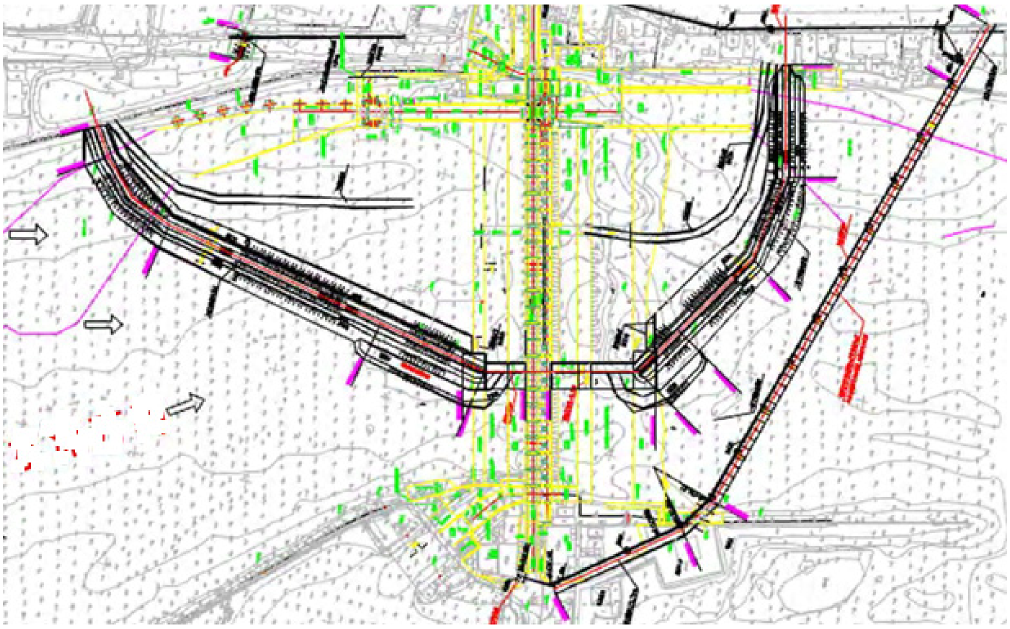

Figure 1 Layout Plan of the Second-phase Cofferdams (Water flow direction)

3.1 Construction diversion method

Second-phase Diversion (September 2019 - April 2020): In early October 2019, cofferdams were constructed on the left side of the river channel, creating an excavation pit on the left bank. The construction commenced on the left bank ship lock, a 1-span left bank drainage gate, a 14-span river barrier gate, and the left bank connecting the dam section. During the second-phase construction process, the already completed 7-span river barrier gate on the right bank was utilized for water discharge. The cofferdams of the second-phase project were demolished in early May 2020.

3.2 Design of cross-section cofferdam

3.2.1 Transverse cofferdam

In the second-phase project, the transverse cofferdam from the first phase was utilized, featuring a top height of 2.80 meters and a top width of 5 meters. Building upon the aforementioned analysis results, this paper introduces a novel design method for the dam base. Above the water surface, stone filling was employed to create a suspended dam with a water-facing ratio of 1:1.5 and a backwater ratio of 1:1.5. The slope's front side was safeguarded with large rocks measuring 500 millimeters in thickness, while the bottom received a cushion layer of 300 mm-thick gravel, and the backwater side was filled with a 400 millimeter-thick gravel layer. A load-bearing platform, 2 meters in height with a slope of 1:2.5, was constructed at a height of 0.5 meters inside the cofferdam. Below the 0.5-meter mark within the cofferdam, earth filling was employed, while above 0.5 meters, impermeable clay was utilized. To seal the cofferdam body and base, high-pressure walls were installed, featuring a 1.0-meter height at the top and 0.5 meters at the bottom, with a 1.5-meter spacing between the high-pressure walls. Steel-reinforced stone cages, 10 meters in width and 600 millimeters in height, were placed on both the upstream and downstream sides of the cofferdam, incorporating a 1400-millimeter stone filling at the bottom. The length of the upstream cross-section cofferdam in the second-phase project measured 411.46 meters, while in the second-phase project, its length was 314.10 meters.

3.2.2 Longitude concrete cofferdam

A T-shaped reinforced concrete retaining wall was constructed upstream and downstream of Piers 15 and 16. This retaining wall had a bottom height of 0.5 meters and a spacing of 0.8 meters between high-pressure holes. The longitudinal length of the second-phase project, extending from Cofferdam 0+000.00 to Cofferdam 0+168.00 meters, measured 168.00 meters. Based on this, the upper section of concrete had a top height of 2.80 meters, while the lower section had a top height of 2.70 meters, with a top thickness of 0.8 meters and a top width of 10.6 meters. The cofferdam's bottom thickness was 1.2 meters, and the bottom width was 22.0 meters. When the bottom height of the cofferdam was below ▽-5.5 meters, Gabion stone cages were employed as the bearing structure, and they were evenly distributed on both sides of the protective wall. These stone cages could only be removed after the completion of the diversion. Detailed design profiles of the cofferdam for the second-phase project are provided in Figures 2 to 4.

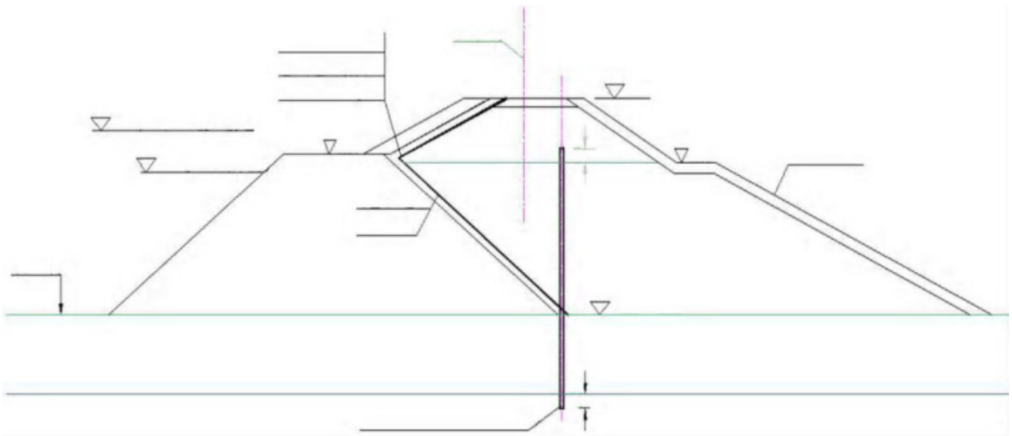

Figure 2 Cross-sectional profile of the upper transverse cofferdam in the second phase

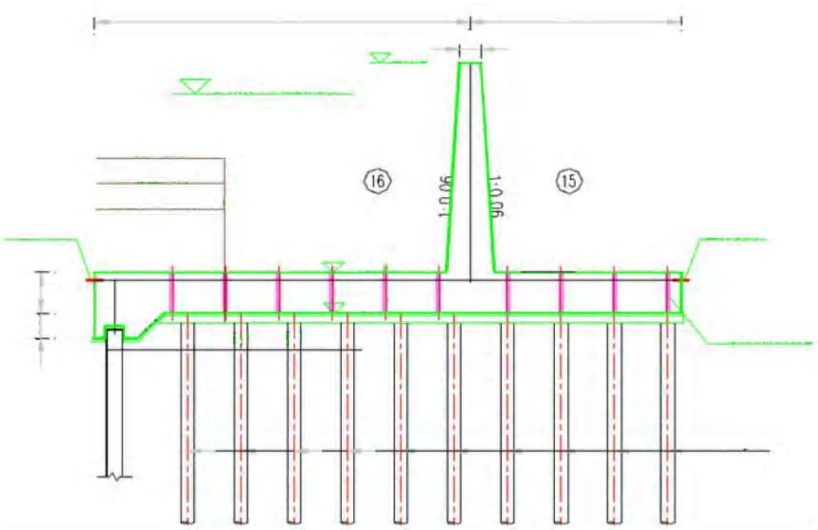

Figure 3 Cross-sectional profile of the longitude concrete cofferdam in the second phase

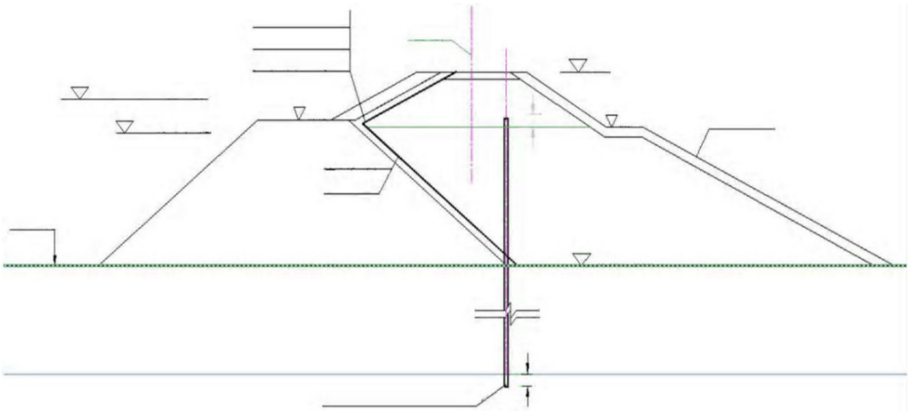

Figure 4 Cross-sectional profile of the lower transverse cofferdam in the second phase

4. Cofferdam construction

4.1 Cofferdam filling

The cofferdam filling was carried out in sections, with the upper and lower sections of the dam head divided into four segments along the longitudinal direction of the cofferdam to expedite the dam construction process[5]. This was an enlarged dam that served the purpose of land reclamation from the sea. In the second-phase cofferdam construction, a soil and stone mixture was utilized. In areas where the height of the first-phase cofferdam exceeded 0.5 meters, available stones were transported directly to the second-phase cofferdam using 15-ton dump trucks. Subsequently, bulldozers leveled the stones, and 10-ton vibratory rollers compacted them to achieve a compaction density of no less than 91%. The filling of the soil-stone mixture should be within a 3-meter range from the axis of the impermeable wall and must be filled with gravel or a soil-stone mixture with a particle size not exceeding 10 cm. Dam slope repairs were carried out following design specifications, and soil compaction was performed during the filling process[6].

4.2 Cofferdam heightening construction

Upon draining the excavation pit, the upper 0.50 meters of the soil layer on the cofferdam shell was heightened and thickened until reaching the design top surface height. After the pit was excavated, it was positioned according to the coordinates of the pit axis, and any floating debris on the top was promptly cleared. The mud deposition inside the cofferdam could only commence after removing the floating debris. Simultaneously, reinforcement work was carried out on the clay cofferdam body, and cofferdam and slope protection measures were implemented. In this regard, the clay cofferdam body was transported to the filling site by a 2-ton excavator from the No. 1 soil material yard, utilizing 15-ton dump trucks for unloading and backfilling[7]. On this basis, a new dam-filling method was proposed based on these procedures. The construction involved four separate inspection processes, during which the clay cofferdam body was transported to the filling site using dump trucks. It was then unloaded at the filling site, following the cofferdam axis. Stationary unloading was employed in this process. The cofferdam body was evenly distributed, and the soil was spread to a depth of 60-80 centimeters during compaction. Stacking during compaction should occur in both upward and downward directions within a range of more than 20 centimeters. A frog-type pile driver was used for the area adjacent to the dam within a 1.5 to 2-meter range. After compacting the soil materials, their density was checked according to the design requirements. Only when it met the specifications could the next phase of work proceed.

4.3 Cofferdam protection

The process of implementing rock protection for the cofferdam involves several essential steps to ensure its effectiveness. Initially, upon entering the construction area, meticulous attention was given to anchoring the stern and aligning it parallel to the vessel's axis. Precise positioning of the stone placement followed, facilitated by two GPS mobile stations that enhance the accuracy of locating both the bow and stern, with corrections made to minimize errors. When laying the foundation stones for the protective bottom layer, a trial placement method was employed to determine their exact positions. Subsequently, a reinforcing cage was used for filling the foundation, and steel frames were transported from the factory and strategically placed in the construction area for rock loading. During the construction process, stones were filled manually or with the use of a backhoe loader. Providing comprehensive technical and safety training to construction personnel was essential, ensuring they were well-prepared for the task. The construction process for rock slope protection was meticulously followed, as depicted in Figure 5. Slag was the chosen material for slope protection, and its application requires prior slope excavation and foundation inspection. Only after confirming there are no issues should slag be used for backfilling, ensuring that a thickness of 40 centimeters for filling meets the design requirements. Once the backfill was complete, compacting the slag material and fine leveling of the slope took place. Finally, retaining walls were installed on the slope per design guidelines, effectively preventing slope collapse and ensuring the cofferdam's long-term stability.

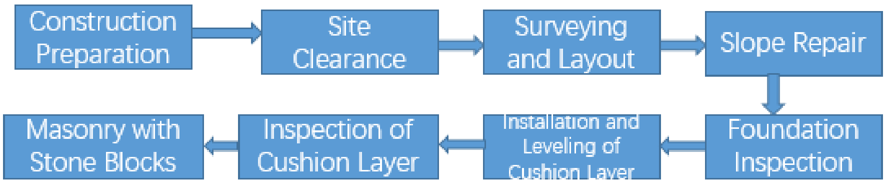

Figure 5 Construction flowchart of slope protection by stone block (Construction Preparation→Site Clearance→Surveying and Layout→Slope Repair→Foundation Inspection→Installation and Leveling of Cushion Layer→Inspection of Cushion Layer→Masonry with Stone Blocks)

4.4 Cofferdam dismantling

The dismantling of the second-phase cofferdam involved the excavation and removal of concrete structures. Initially, in the backwater area of the cofferdam, a temporary work platform was constructed using excavated materials. Subsequently, the cemented soil of the cofferdam was crushed using a crusher attached to an excavator. Following the design specifications, controlled blasting was carried out on the cofferdam, with the assistance of mechanical equipment such as excavators and dump trucks for the blasting process. Two designated work areas were established at the ends of the upper and lower beams for the withdrawal and unloading activities. Underwater excavation of the cofferdam was performed using hydraulic machinery. For the secondary cofferdam construction, a direct transport method was employed.

5. Conclusion

In a word, in water conservancy and hydropower projects, cofferdam is very significant, it plays a decisive role in ensuring the completion of the whole project, will result in bad results. Therefore, the stability of cofferdam and quality supervision is particularly important, the use of new technology is essential, but also to continue the effective support of the project. Taking the construction of cofferdam in the reconstruction and expansion project of Haimenwan Bridge and sluice in Shantou as an example, the process from design to construction is described in detail in this study, the construction risk factors that can not be directly investigated on the spot can be digitized, visualized and visualized, and the comparison of data and images can guide the operators to formulate effective measures in time, it is very important for the stability and quality supervision of cofferdam, and it can be used for reference for the construction of follow-up cofferdam project.

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