Process Analysis of Concrete Freeze-Thaw Damage Reinforcement Construction of Existing Diversion Canals at the Water Front Surface

Minjun Zeng[1,*], Zijun Ma[1], Xiaopeng Li[1], Zhaopeng Wu[1], Liang Ke[1], Zhaoqi Wang[1], Pei Yang[2]
[1]Lanzhou Railway Institute of Technology, Lanzhou, Gansu, China
[2]Gansu Power Investment Jiudianxia Hydropower Development Limited Liability Company, Dingxi, Gansu, China
**Corresponding Author.*

Abstract: Currently, the reinforcing construction process of freeze-thaw damage of concrete on the surface of existing diversion canals is one of the key problems to be solved in the reinforcing and repairing of existing diversion canals. Taking the reinforcement construction of freeze-thaw damage of concrete in the diversion channel of a power station in Jili as the background, a set of efficient and practical reinforcement construction process is proposed, aiming at restoring the strength and durability of freeze-thaw damage of concrete structure on the surface of the existing diversion channel, preventing and controlling the intensification of freeze-thaw damage of concrete on the surface of the existing diversion channel embankment, and ensuring the safe and stable operation of the diversion channel in the long term. The reinforcement construction process is simple and suitable for thin-layer repair, which shortens the original concrete surface chiseling time and improves the repair efficiency. This process was used to reinforce the freeze-thaw damage to the surface concrete of the diversion channel, 13 days ahead of schedule. This new reinforcement construction process can not only solve the diversion channel waterfront concrete freeze-thaw damage reinforcement construction, but also economic, but also for the maintenance of similar projects to provide reference.

Keywords: Existing Diversion Channel; Existing Concrete; Freeze-Thaw Damage; Construction Process

1. Introduction

Existing diversion channel waterfront concrete in the long-term use of the process, by the natural environment, especially the influence of cold climate, may suffer freeze-thaw cycle effect of damage. This damage not only affects the normal operation of the channel, but also may pose a threat to the overall safety of water conservancy projects.

At present, in the field of water conservancy engineering, scholars have conducted in-depth research on several key topics. For example, the quality defects of concrete in water conservancy projects [1] have been comprehensively analyzed from the causes to the treatment measures. The construction technology of concrete structures in water conservancy projects [2] has also been discussed in detail, covering all aspects from material selection to construction process. In the study of concrete impermeable channels, special attention was paid to the freezing and thawing problem in the winter water transmission operation, and the anti-freezing and thawing force was accurately calculated [3]. At the same time, the effect of freeze-thaw cycle on the frost expansion strain produced by bearing concrete [4] has also been widely concerned, and relevant research results have been published. In the construction of large reservoir projects, not only the key construction technologies have been studied in depth, but also the application and effect evaluation of these technologies have been emphasized [5]. And for the hydraulic buildings of field canal systems in irrigation areas [6], the experimental investigation of cyclic freezing and expansion mechanism has also been carried out, in order to reveal its intrinsic law and influencing factors. Meanwhile, systematic research has also been conducted on the technical points of control of aqueduct concrete in winter construction [7-11] to ensure that the

construction quality is not affected by the season. However, although the research in the field of water conservancy engineering has achieved a lot of results, the research on the construction process of reinforcing the freeze-thaw damage of concrete on the waterfront of existing diversion canals is still insufficient. Therefore, it is necessary to carry out a systematic research on the reinforcement construction process for the damage characteristics of concrete on the surface of existing diversion channels under the action of freezing and thawing, so as to provide scientific solutions for the actual project.

Jili a hydropower station diversion channel concrete freeze-thaw damage reinforcement construction as a specific background, for its special environmental conditions and engineering needs, the development of a set of innovative reinforcement construction technology. Prevention and control of existing diversion channel embankment near the surface of the concrete freeze-thaw damage aggravation, to ensure the long-term safe and stable operation of the diversion channel. This set of new reinforcement construction technology can not only solve the diversion canal surface concrete freeze-thaw damage reinforcement construction, but also economic, but also can provide reference for the maintenance of similar projects.

2. Project Overview and Disease Causes Analysis

2.1 Project Overview

Jili a hydropower station diversion channel length of 1673 m, cross-section is trapezoidal shape, the design of longitudinal slope of 1/2500, the bottom width of 5.0 m, the height of the embankment up to 8.4 m, both sides of the embankment slope of 1:1.5. channel using the middle of the φ6 reinforcing steel mesh sandwiched between the C15 concrete, the thickness of 20 ~ 30 cm, the concrete below the geotechnical membrane used for seepage control. The diversion flow rate is 270 m3/s, the water depth is 6.12m, and the flow rate is 3.11 m/s. The water flow rate is 270 m3/s, the water depth is 6.12m, and the flow rate is 3.11 m/s.

2.2 Analysis of Disease Causes

At present, obvious concrete surface freezing and thawing spalling damage has been found in the area of water level change of the canal embankment. This damage has resulted in concrete surface spalling to a depth of about 15 cm and an affected area of about 340 square meters. Statistical research and analysis found that this kind of freeze-thaw spalling damage shows a trend of increasing year by year, if not take effective measures in time, it will constitute a serious threat to the safe operation of the whole diversion canal.

According to the current degree and area of the freeze-thaw denudation damage, it will take at least about 20 days to complete the repair work if conventional repair methods are adopted. However, during the repair period, the aqueduct will have to stop operation or lower the water level, which will directly lead to a loss of up to 9.6 million kwh of power in the power station, which will have a significant impact on the economic benefits of the power station. At the same time, lowering the water level of the power canal to operate will also increase the wear and tear of the unit and add additional maintenance costs.

In addition, there is a certain construction safety risk in the maintenance process, and corresponding safety measures need to be taken to protect the safety of construction personnel. Therefore, in view of this serious freeze-thaw stripping damage problem, there is an urgent need to study and adopt a more efficient and safe reinforcement construction process, in order to shorten the maintenance cycle, reduce the power loss and unit wear, and ensure the safety of the construction process. This will be an important task and challenge at present.

3. Key Technical Measures of the Process

This study proposes a set of efficient and practical reinforcement construction techniques for the reinforcement of freeze-thaw damaged concrete on the waterfront of a diversion channel in Jili. At the same time, the selected repair materials have excellent characteristics such as impact resistance, abrasion resistance and early strength, forming a good synergy with the existing power canal waterfront concrete. The aim is to restore its structural strength and durability, prevent and control the aggravation of freeze-thaw damage to the concrete on the surface of the embankment of the existing diversion channel, and ensure the long-term safe and stable operation of the diversion channel. In order to meet the above requirements, the following practical and effective measures have

been taken:

(1) Technical measures

In the construction method, due to the slope ratio of the power channel is 1:1.5, and the silt attached to the embankment below the water surface, it is impossible to construct directly.

For the maintenance of the channel up to 850 meters long, the use of segmental erection of floor-standing steel pipe scaffolding method, every 10 meters a section, a total of 85 sections need to be erected, each section of the erection time is controlled within 3 hours, significantly reducing the erection time, improve the overall construction efficiency.

In terms of construction materials, maintenance materials that meet the requirements of impact resistance, abrasion resistance and early strength were strictly screened. After in-depth comparison and research, special quick-setting concrete for hydraulic buildings was selected, which is relatively less difficult to construct and has stable performance.

(2) Organizational measures

On the time of construction team entering the site, ensure that the construction team has entered the site 5 days before the drainage of the channel, complete the preparation of construction materials as well as on-site concrete mixing and transportation equipment in place, laying a solid foundation for the smooth start of the construction.

In terms of schedule, the construction team made full use of the 8-day period for overhauling and testing of a power station unit in Jili to carry out detailed scheduling and division of the construction section. By reasonably arranging the construction personnel, it ensures that the work of each construction section can be carried out in an efficient and orderly manner.

In summary, by adopting these technical and organizational measures, a set of efficient and practical solutions was successfully provided for the freeze-thaw damage reinforcement of concrete on the surface of the diversion channel of a power station in Jili. It effectively reduces the loss of power generation of the power station and ensures the construction safety.

4. Process Implementation Process

4.1 Key Measures for Construction Organization

As the maintenance work area covers an area of about 340 square meters and is 850 meters long, the urgency of the maintenance cycle, the complexity of the construction difficulty, and the unpredictable factors such as the weather are fully taken into account. For this reason, the whole construction area was divided into five clear working surfaces along the channel direction, and each working surface was equipped with corresponding construction resources and equipment. At the same time, the construction personnel were carefully divided into five maintenance teams and one specialized concrete mixing and transportation team. Each maintenance team was responsible for the construction of one working face, while the concrete mixing and transportation team was responsible for providing a continuous supply of concrete to all working faces. After precise calculation and arrangement, each team was set to complete 24 square meters of maintenance work per day, thus ensuring that the overall maintenance schedule could be completed within the estimated 7 days.

During the actual construction process, it was found that the repair volume could reach 4.5 square meters per hour when five maintenance teams worked simultaneously. To ensure construction efficiency, each maintenance team was arranged to work 10 hours a day and was equipped with three diesel generators, two for normal operation and one for backup, to ensure a stable and reliable power supply during the construction process.

In addition, the strategy of transporting concrete mixing materials to the working surface in batches was adopted, and the work mode of mixing and repairing as they were carried out was realized on site. This not only reduces the transportation and storage time of concrete, but also ensures the freshness and construction quality of concrete.

4.2 Selection of New Materials

After in-depth consideration of the repair cases of freeze-thaw damage of concrete in recent years and their effects in terraced power stations, high-quality materials that meet the needs of quick-setting, impact resistance and wear resistance have been carefully selected. These materials include polymer mortar (using SK hand-scraped polyurea for surface sealing), modified epoxy mortar repair mortar, and quick-setting concrete specially designed for hydraulic buildings.

Polymer mortar combines the excellent adhesion of polymer materials with the durability of inorganic materials, demonstrating high compressive strength, fast curing, and superior benefits.

Modified epoxy resin repair mortar is particularly suitable for repairing various damages to concrete structures. It has excellent adhesion, impermeability, spalling and freeze-thaw resistance, and can effectively meet the challenges of repair in harsh environments.

As a repair material that can be applied directly to diseased areas, quick-setting concrete for hydraulic buildings stands out for its strong compressive and adhesive strength. It is not only suitable for thin-layer repair, but also has the comprehensive ability of waterproofing, corrosion resistance, freeze-thaw salt corrosion resistance and UV resistance, which is very suitable for the repair of freeze-thaw damage on the water surface of the embankment of a diversion canal in Jili.

After careful analysis and comparison of the performance indexes of these materials, it was finally decided to use special quick-setting concrete for hydraulic buildings to carry out the repair of freeze-thaw damage on the surface of the embankment of a diversion channel in Jili. This choice aims to ensure the efficiency and quality of the repair work, while minimizing the loss of power generation of the power station and guaranteeing the safety during the construction period.

4.3 Production of Special Working Platform for Construction

Considering the special slope ratio of 1:1.5 of the embankment of the diversion channel of a power station in Jili, and the actual situation that the repair part is mainly concentrated in the two-thirds area of the embankment, the challenge of the embankment below the water surface being covered with silt and algae, slippery surface and lack of suitable working platform is faced, as shown in Figure 1. In order to solve this challenge, a special working platform for slope-adhering construction was adopted, which was machined from Φ20 rebar, as shown in Figure 2. The design of the platform fully considered the need for slope movement, so it was equipped with universal wheels with a diameter of 75mm at the four corners, as shown in Figure 3. When the platform needs to be moved to the designated working surface, the staff can easily install the universal wheels on the four corners of the special scaffolding by means of sleeves and pull the platform to move by using the safety rope. Once the platform reaches the working position, the universal wheels will be removed and the platform will be securely suspended from the embankment top ground anchor using the safety rope to ensure stability and safety during construction.

After the actual test on site, the mobile platform not only meets the needs of 2-3 people working at the same time, but also shows the significant advantages of easy movement, flexible operation and fewer operating personnel. This innovative solution not only greatly improves the construction efficiency, but also provides a safe and stable working environment for maintenance personnel.

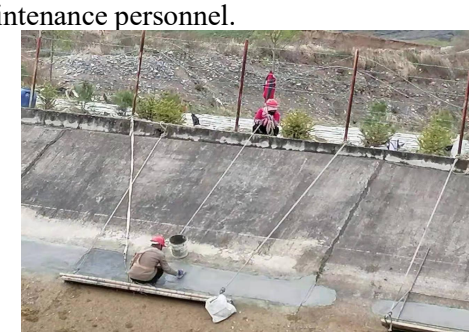

Figure 1. Construction-Specific Work Platform

Figure 2. Ground Anchor Tensioner

Figure 3. 75mm Specialized Universal Wheel

5. Characterization of the Process and

Evaluation of Its Effectiveness

5.1 Evaluation of the Characteristics of the Process

The main features of this new reinforcement construction process are significant and offer multiple advantages. Firstly, it utilizes new materials for the repairs, which are simple and suitable for thin-layer repairs. This feature reduces the chiseling time of the original concrete surface, which significantly improves the progress of the repair. Compared with the traditional method, the application of new materials not only simplifies the operation process, but also improves the repair efficiency, making the whole repair process more efficient and quicker. Secondly, a special platform was innovatively made for slope-posted construction. The design of this platform takes full account of the actual needs of the construction, not only reduces the number of operators, but also realizes the rapid and flexible movement of the platform. Compared with the original on-site steel pipe platform, the production time of the slope-mounted mobile platform is shorter, and the manpower required for moving is greatly reduced. Specifically, it takes 3-5 hours to set up the original steel pipe platform, 4 people need to operate it at the same time when moving, and it takes 1 hour to move between working surfaces. In contrast, it takes only 3 hours to build a slope-mounted mobile platform, requires only 2 people to move it, and it can be quickly moved to the next working face within 10 minutes. This improvement not only saved about 50 minutes per working face, but also reduced the number of operators by 2, for a total time saving of 70 hours. The application of this new reinforcement construction process not only improved maintenance efficiency, but also reduced labor costs. By choosing new materials and making a special working platform, the optimization and upgrading of the repair work was successfully realized, providing a strong guarantee for the safe operation of water conservancy projects.

5.2 Evaluation of the Effectiveness of the Process

This new reinforcement construction process shows significant economic advantages in terms of material selection. The special quick-setting concrete for hydraulic buildings is adopted as the main repair material, and its comprehensive unit price is the lowest compared with other alternative materials. According to the price comparison of concrete freeze-thaw damage repair materials in recent years, the comprehensive unit price of epoxy resin repair mortar is about 1150 yuan/m² (including demolition repair, thickness of about 15cm), polymer mortar (SK hand-scraping polyurea sealing) is 950 yuan/m² (the same demolition repair, thickness of about 15cm), while the comprehensive unit price of special quick-setting concrete for hydraulic buildings is only 715 yuan/m² (the same conditions). The comprehensive unit price of quick-setting concrete for hydraulic buildings is only 715 RMB/m² (the same condition). Through careful costing, it was found that at least 79, 900 RMB could be saved by using quick-setting concrete as the main material for this construction (based on a repair area of 340m²).

Significant savings were realized in the cost of construction safety measures. In the common construction process, the erection of floor-standing steel pipe scaffolding needs to cover 20 working surfaces, and the height difference from the bottom of the canal to the maintenance surface reaches 6m, totaling 2, 160m² of scaffolding. According to the cost calculation of 20 yuan/m² per square meter of steel pipe scaffolding, this part of the cost is as high as 4.32 million yuan. However, by improving the scaffolding design, 5 pairs of special working platforms with slope ratio (1:1.5) Φ20 rebar construction were made, and the total cost was only 0.4 million RMB. This improvement not only improved the construction efficiency, but also saved 39, 200 RMB in the cost of construction measures.

The expected downtime for maintenance was originally 8 days, but with the implementation of this new reinforcement construction process, combined with careful organization and application of technology, the repair of freeze-thaw damage to the concrete embankment of the diversion channel of a power station in Jili was efficiently completed in only 7 days, which was successfully completed 13 days earlier than the original plan. The repaired power channel of a Jili hydropower station performed well in the subsequent fall and winter safety inspection in November without any scouring damage.

Analysis of the study found that this new construction process saved at least $119, 100 in costs. It fully demonstrates the advantages of

the new reinforcement construction process in terms of economic benefits, and also reflects the advantages in project management and technological innovation.

6. Conclusion

Taking the reinforcement construction of concrete freeze-thaw damage of a power station diversion channel in Jili as the background, a set of efficient and practical reinforcement construction technology is proposed. First of all, the reinforcement construction process, for the existing diversion channel on the surface of the concrete freeze-thaw damage to the mechanism and characteristics of the concrete, through the optimization of the choice of materials, reinforcement methods and construction processes, to achieve a rapid and effective repair of the damaged concrete. In addition, by simplifying the construction process, optimizing the configuration of construction equipment and improving the skill level of construction personnel, the construction period is shortened, the construction cost is reduced and the reliability of the reinforcement effect is ensured. Through the implementation of this process, the strength and durability of the freeze-thaw damaged concrete structure of the existing diversion channel is restored, and the intensification of freeze-thaw damage of the concrete adjacent to the water surface of the embankment of the existing diversion channel is prevented and controlled. Successfully solved the problem of reinforcing the freeze-thaw damaged concrete of the existing diversion channel, and improved the operational efficiency and service life of the channel.

References

[1] Gou Wentao. Causes of concrete quality defects and treatment measures in water conservancy projects. Building materials development guide, 2023, 21 (24): 51-53.

[2] Zhang Lu. Analysis of concrete structure construction technology of water conservancy project. Science and Technology Information, 2023, 21 (21): 153-156.

[3] Song Ling, Ouyang Hui, Yu Shuchao. Calculation of freezing and anti-freezing expansion force in winter water transfer operation of concrete impermeable channel. Journal of Agricultural Engineering, 2015, 31 (18): 114-120.

[4] Dong Zhenping, Huang Xinkai, Lei Yongjie, et al. Study on freezing strain of bearing concrete under freeze-thaw cycle. Journal of Xi'an University of Architecture and Technology (Natural Science Edition), 2023, 55 (04): 515-519+545+633

[5] Lin Siqing, Li Yongjiang, Cao Xiansheng, et al. Research and application of key technologies for large reservoir engineering construction. China Water Conservancy and Hydropower Press: 201711.635.

[6] Chen Jinbo, He Xiuliang. Experimental investigation of cyclic freezing and expansion mechanism of field canal system hydraulic buildings in irrigation area. Heilongjiang Water Conservancy Science and Technology, 2024, 52 (03): 1-5.

[7] Lu Peng. Experimental study on permeability coefficient of cracked fiber concrete lining of water transmission channel. Northeast Water Conservancy and Hydropower, 2021, 39 (03): 53-55.

[8] Ren Hengyi. Experimental study on concrete mechanics of lining materials for water conveyance canal. Water Resources Technical Supervision, 2021, (03): 138-143.

[9] Qin Jie, Lu Shenglin. Damage treatment of underwater concrete in Yantan extension diversion channel. Hydropower and pumped storage, 2018, 4 (02): 112-116+120.

[10] Wang Y. Experimental study on the durability of concrete in the diversion canal head project of Junzhuzhike village in Yumin county. Shaanxi Water Conservancy, 2019, (06): 16-18+21.

[11] Wang Shengnan, Zhou Jinlock. Technical points of winter construction control of Yunfeng hydropower station tailwater canal concrete. Heilongjiang Water Conservancy Science and Technology, 2021, 49 (06): 165-166+189.

