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Research on Seepage Prevention and Reinforcement Techniques for Dams in Hydraulic Engineering Construction

Ruiming Song, Cheng Yin*, Ping Hu, Yong Yang, Yuling Hu, Fangling Li, Lei Lu, Guangbo Dong, Youhao Sun, Xunxun Chen

Anhui Water Conservancy and Hydropower Vocational and Technical College, Hefei, Anhui, 230000, China

*Corresponding author

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Abstract: In hydraulic engineering, the technology of dam seepage prevention and reinforcement plays a vital role. Under complex geological conditions, dams are often subject to various factors such as fluctuations in groundwater levels, increased soil permeability, flood flows along the embankment, direct erosion of water against the bank, and poor erosion resistance of the embankment foundation, all of which pose safety hazards including dam cracking and collapse. The reinforcement of seepage prevention is an indispensable component in dam construction for hydraulic engineering, crucial for enhancing the stability and impermeability of dams. Based on this premise, this paper first analyzes the difficulties encountered in project construction, and then delves into the techniques for dam seepage prevention and reinforcement in hydraulic engineering projects. It is hoped that this research will provide valuable insights and references for the construction and development of hydraulic engineering projects.

1. Introduction

Hydraulic engineering projects serve as crucial pillars for promoting sustainable socio-economic development. As an integral part of these projects, dams are vulnerable to geological factors that can trigger seepage issues, thereby compromising the overall stability of the hydraulic system[1]. Therefore, it is imperative to undertake scientific and rational seepage prevention and reinforcement construction for dams. Despite the remarkable advancements made in seepage prevention and reinforcement technologies, several challenges persist in the actual reinforcement process of dams. These include inadequate effectiveness of the reinforcement measures, susceptibility of the reinforcement structures to aging, damage, or failure after prolonged use, and the potential negative impacts of certain reinforcement methods on the surrounding ecological environment. Addressing these issues is paramount to ensure the long-term safety and functionality of hydraulic engineering projects.

1.1 Difficulties in Project Construction

(1) Large Voids and High Water Content:

The stratum structure is characterized by large voids and poor stability, rendering it highly susceptible to construction-induced deformations. Furthermore, the on-site soil layers are primarily composed of clay, fluid plastic silty fine sand, and weathered argillaceous siltstone[2]. When the stability of these layers is compromised during construction, their overall strength diminishes, potentially leading to dam foundation collapse and subsidence issues.

(2) Poor Permeability and Slow Consolidation:

The high water saturation level in the strata results in poor cohesion. Coupled with the dominance of cohesive soil, which exhibits low plasticity, the adoption of inappropriate construction methods can easily trigger settlement problems, thereby compromising both construction quality and safety.

(3) Low Strength and Bearing Capacity:

The special stratum structure, characterized by low density and large voids, is highly prone to deformation under external influences. This can give rise to cracks, settlements, and even collapse incidents, posing severe threats to the safety of people's lives and property.

2. Seepage Prevention and Reinforcement Techniques in Dam Construction

2.1 Pre-construction Preparation

Prior to commencing the seepage prevention and reinforcement work on dams, it is essential to formulate a technical scheme for seepage prevention construction in accordance with relevant technical specifications. This includes conducting pre-job technical briefings and training for construction technicians, inspecting and commissioning the mechanical equipment required for the construction process, and ensuring the availability of all necessary construction materials. Additionally, technicians must thoroughly survey the construction site to identify the critical areas requiring seepage blockage and reinforcement. They should compile statistics on skilled workers, raw materials, supporting machinery and equipment, and the quantity of work involved. Based on the on-site seepage conditions of earth dams, masonry dams, or concrete dams, the mix ratio of the components for the anti-seepage grout should be determined to ensure optimal reinforcement effectiveness [3-5]. Furthermore, focusing on the leakage points of the dam, it is crucial to seal off the leakage areas and their surroundings, thoroughly cleaning the leakage cracks, points, pipe holes, and the surfaces and vicinities of boreholes, removing debris, attachments, and loose or aged materials until the structural layer of the dam material is exposed. For concrete dams, the concrete structural layer must be visible after cleaning, while for earth dams, fresh soil should be exposed on the surface. The newly cleaned surfaces should be free from any debris, impurities, and standing water.

2.2 Drilling Operations

During drilling, the central line and verticality of the drill rod should be re-checked, and the levelness of the drilling machine body should be measured with a level ruler to minimize drilling deviations. Generally, the use of a grinding disk drill is required, with measurements taken every 5 meters of drilling depth. Any deviations detected should be immediately corrected[6]. To ensure smooth mud circulation and return, the diameter of the jetting pipe should be less than 30mm smaller than the borehole diameter. To effectively prevent borehole collapse, mud should be used to support the wall while drilling, and changes in the stratigraphic conditions should be closely observed throughout the process. Once the hole depth reaches the design standard, a hole deviation survey should be conducted, with the hole deviation rate required to be less than 1%. After hole completion, the rock core residue inside the hole should be replaced, and the grout within the hole should be refreshed.

2.3 Slurry Preparation

The process of slurry preparation is of paramount importance in the construction of seepage prevention and reinforcement measures for dams in hydraulic engineering. Firstly, during the preparatory stage, all containers must be thoroughly cleaned of stains, grease, organic matter, dust, and other impurities to ensure they are spotless and level[7]. The operating environment should also be kept dust-free and impurity-free to prevent contamination during the slurry preparation process. To ensure high slurry adhesion, bentonite raw materials with excellent water absorption and swelling properties are selected and added to a mud mixer. Clean water is then added at a water-to-soil ratio of 1:10, and the mixture is thoroughly agitated to ensure even distribution of moisture within the bentonite. Following this, a filter screen is used to remove larger particles and impurities. The resulting mixture is then channeled into a primary slurry tank, where heavier particles settle at the bottom. Subsequently, the slurry undergoes further purification in a secondary tank to guarantee its purity and stability.

In the secondary tank, adjustments are made in coordination with the mixing drum based on project requirements and material properties to enhance slurry performance. Specifically, acrylate emulsion is added as a binder, primarily to improve the adhesion and stability of the slurry, enabling better integration of slurry particles with the seepage prevention area. An acid-base buffer is incorporated to maintain the slurry's pH level within 6.5 to 10.0, as extremes in pH can compromise slurry performance and lead to grouting failures. Additionally, phosphate dispersant, a surfactant, is used to form an adsorption layer on particle surfaces, facilitating uniform dispersion of solid particles and enhancing slurry stability.

It is crucial to use the prepared grouting slurry within 4 hours of preparation, as prolonged exposure can lead to coagulation, rendering it unusable. Moreover, the slurry's temperature must be controlled between 5℃ and 34℃. Temperatures below 5℃ can cause slurry coagulation or crystallization, affecting its fluidity and uniformity, while temperatures above 34℃ can lead to denaturation or decomposition of slurry components, degrading its performance and quality.

2.4 Grouting Pressure and Final Grouting Criteria

Grouting operations typically commence with the first sequence of holes, whereby the optimal grouting pressure and construction methodology for the specific project are summarized and determined through actual construction practices. Generally, the pressure at the orifice pressure gauge is controlled within a range of 0.3 to 0.4 MPa. This pressure range ensures effective slurry penetration while preventing damage to the dam structure due to excessive pressure[8]. During construction, the grouting pressure is flexibly adjusted based on changes in the unit grout absorption rate. When the unit grout absorption rate is low, a single pressure increase or allowing natural pressure build up can be employed to ensure the slurry fully fills cracks in the dam. However, in cases where excessive pressure leads to grout leakage or a sudden increase in the unit grout absorption rate, the pressure should be appropriately reduced to prevent grout wastage and excessive damage to the dam.

The establishment of final grouting criteria is equally important. When the pressure reaches the design value, grouting can be terminated if the borehole ceases to absorb grout or the injection rate remains at or below 0.4 L/min for a continuous period of 30 minutes. Additionally, if the dam body ceases to absorb grout for three consecutive times, this also serves as a crucial criterion for terminating grouting. Adhering strictly to these final grouting standards ensures effective diffusion and filling of the slurry within the dam, thereby achieving the desired seepage prevention and reinforcement effects.

2.5 Reinforcement and Maintenance

Reinforcement and maintenance play a pivotal role in addressing post-construction seepage issues arising from dam seepage prevention and reinforcement projects. Prior to commencement, a detailed maintenance plan and work scheme should be formulated, outlining specific schedules, frequencies, and content of inspections, as well as the methods and measures for upkeep and repairs [9]. The specific measures for dam seepage prevention reinforcement and maintenance are as follows:

(1)Regular Inspections: The water conservancy project management unit should regularly dispatch dedicated personnel to inspect the dam's seepage prevention and reinforcement structures. Utilizing professional detection equipment and testing tools, comprehensive checks should be conducted to assess the integrity and stability of the reinforced seepage prevention areas. Particularly after extreme weather events such as heavy rainfall or floods, the frequency of inspections should be increased.

(2)Environmental Cleanup: Regularly, dam maintenance personnel should clear weeds, trash, and other debris surrounding the dam to maintain a clean environment that prevents damage and corrosion to the seepage prevention materials. Additionally, they should ensure the drainage system remains unobstructed and promptly drain any accumulated water to prevent adverse effects on the reinforced seepage prevention areas due to water pressure.

Enhanced Perimeter Safety Management: Install visible warning signs, guardrails, and other facilities to safeguard the dam's seepage prevention and reinforcement areas from damage caused by personnel and vehicles.

(3)Record-keeping and Archiving: The water conservancy project management unit must establish comprehensive records and archives for seepage prevention reinforcement maintenance, including inspection reports, repair logs, and personnel information, facilitating future traceability and management. Notably, repair records should detail the maintenance measures, problem-solving processes, and effectiveness evaluations.

(4)Scheduled Maintenance: Based on the service life and performance requirements of the seepage prevention reinforcement materials, dam engineers should conduct regular maintenance activities such as leak sealing and replacing aged materials to ensure the reinforced structures maintain optimal working conditions.

In conclusion, systematically planning and managing dam seepage prevention reinforcement and maintenance efforts provide a solid foundation for the reliable operation of hydraulic engineering projects.

3. Conclusion

In summary, to effectively enhance the stability and safety of hydraulic dam engineering structures, it is imperative to fully leverage the advantages of seepage prevention and reinforcement technologies during construction. This necessitates a thorough investigation of the site's geological and hydrological conditions, followed by a rational selection of construction techniques. From site preparation to construction operations, rigorous quality control measures should be implemented to ensure the safety and quality of the engineering structures. It is hoped that this study can provide technical insights and references for relevant construction entities.

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References

[1] Wang Guangchang. Discussion on the Seepage Prevention and Reinforcement Technology for Dams in Hydraulic Engineering Construction [J]. Value Engineering, 2020, 39(12): 117-118.
[2] Wang Xiaoru, Zhang Shi'an. Analysis of Seepage Prevention and Reinforcement Technology for Dams in Hydraulic Engineering Construction [J]. Northeast Water Resources & Hydropower, 2023, 41(11): 14-16, 49.
[3] Zhu Shizhan. Application of SMW Wall in Deep Foundation Pit Support of Hydraulic Pumping Station Engineering [J]. Groundwater, 2023, 45(02): 294-295.
[4] Aziz A, Soroush A, Fattahi M S, et al. Prevention of Water Seepage Impact on the Soluble Rocks Using Colloidal Silica[J].Water,2024,16(9)
[5] Dayu L, Changhong L, Yongyue H, et al. Investigation on the Prevention and Treatment Measures of Seepage Failure of the Fine-Grained Tailings Dam: A Case of Iron Tailings Reservoir in China[J].Mining, Metallurgy & Exploration,2024,41(2):875-887.
[6] Huiqin Y, Dongmei L, Chaofu P .Application and Analysis of Curtain Grouting in Seepage Prevention and Reinforcement of Masonry Dam[J].E3S Web of Conferences,2021,23303013.
[7] A. D K. Effectiveness Assessment of a Technique for Dam Reinforcement [J].Power Technology and Engineering, 2023, 56(1): 25-30.
[8] Oleg G, B H, Fakhriddin B, et al. Strengthening technology and modeling of dams from reinforced soil[J].IOP Conference Series: Materials Science and Engineering,2021,1030(1):012155.
[9] Qiang X, Tianran Z, Jianyun C, et al. The influence of reinforcement strengthening on seismic response and index correlation for high arch dams by endurance time analysis method [J]. Structures, 2021, 355-379.