PRELIMINARY ANALYSIS OF UNDERWATER MAINTENANCE TECHNOLOGY TO THE WATER CUSHION POOL OF XILUODU HYDROPOWER STATION

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ABSTRACT

The Water Cushion Pool of Xiluodu Hydropower Station was maintained under water after the flood season of 2018. By summarizing the technology of inspection and repair underwater in this paper, the maintenance methods of hydraulic structures of Xiluodu Hydropower Station can be enriched. In addition, the research results can provide guidance and reference for related projects. The new requirements can also be put forward on concrete repair materials and construction technology, which can promote the development of maintenance technology of hydraulic structures.

1. INTRODUCTION

The Xiluodu Hydropower Station is located at the lower reaches of the Jinsha River, which is a giant water conservancy and hydropower hub focusing on power generation and taking into account sand blocking, flood control and improving downstream channel conditions. The hydropower station is equipped with two underground powerhouses on the left and right banks, each installed with 9 hydropower generating units with a single unit capacity of 770MW, and the total capacity of 13,860MW. The hydropower station uses a concrete double-curved arch dam with a maximum height of 285.50m. The flood discharge and energy dissipation facilities consist of 7 surface holes and 8 middle holes in the dam body, and a water cushion pool behind the dam, which makes the flood discharge with the characteristic of "layered outflow, air collision, and energy dissipation in water cushion pool". As an important part of the flood discharged and energy dissipation facilities, the water cushion pool can make a soft landing of the discharged high-speed water flow, and then pass through the "domestication" of the water body in the pool to smoothly enter the downstream channel to reduce the erosion of the riverbed.

The operation status of the water cushion pool is very important to the safety of the project. Studies have shown that: when the dam discharges flood, due to the large single-width flow and large angle between water flow and floor of water cushion pool, the water flow can form a large pulsating pressure on the floor. In addition, the discharged high-speed water flow with sand will also cause greater scour damage to the floor and slope of the water cushion pool. Therefore, it is necessary to carry out a comprehensive inspection and repair to the water cushion pool after the flood season each year. In the past, draining the water from the pool was used for the maintenance of water cushion pool after flood season, which was time-consuming and costly. More importantly, studies have shown that the most unfavorable condition of water cushion pool is emptying the water of the pool, which is a severe test to the anti-floating stability of water cushion pool. With the maturity of underwater maintenance technology, the water cushion pool of Xiluodu Hydropower Station adopted the underwater method for maintenance after the flood season in 2018.

2. UNDERWATER INSPECTION

The water cushion pool of Xiluodu Hydropower Station is a compound trapezoidal section, as shown in Figure 1.

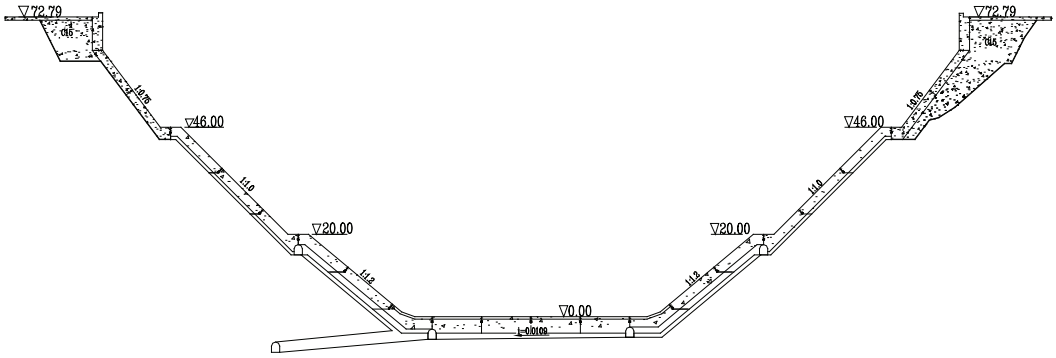


Figure 1 : Sectional view of the structure of water cushion pool

2.1 Inspection method

There is an advanced underwater maintenance robot in China Yangtze Power Co., Ltd., which is specially used for the underwater maintenance work of the high-water-head hydropower station. The cooperation of underwater robots and divers was used in the inspection to the floor and slopes of water cushion pool, with multiple technologies such as underwater photography, underwater exploration, single-beam sonar, multi-beam sonar, ultra-short baseline positioning etc., which has the characteristics of "full coverage, quasi positioning and high accuracy".

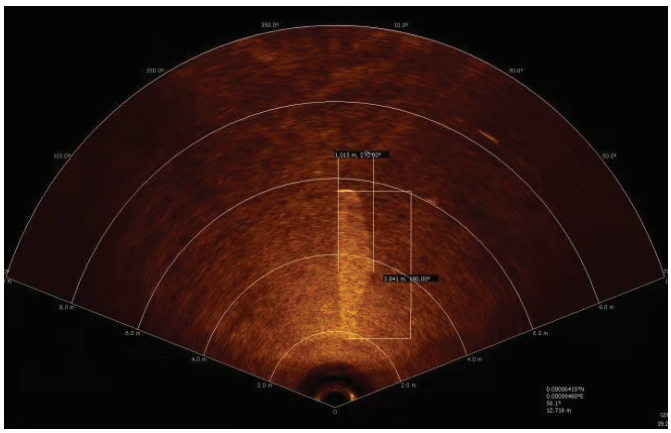
The specific inspection scheme was to arrange a survey line every 3m perpendicular to the direction of the channel, and the underwater robot equipped with single-beam sonar, multi-beam sonar and high-definition camera scans and photographs the underwater structure along the survey line to complete the visual presentation. At the same time, the underwater robot could determine the specific location of the defect using the depth gauge, gyroscope, ultra-short baseline equipped with it. For the suspected and undetectable areas detected by the underwater robot, the divers will conduct underwater exploration under the guidance of the guide ruler to accurately reflect the true state of the underwater buildings. The focus of this underwater inspection is the block seams, construction joints and concrete floor of the water tongue area.

2.2 Inspection results

Underwater inspection showed that the overall condition of the water cushion pool was good, and the types of defects existed mainly as follows:

1. The block seams on the slope surface are partially damaged, and there are some leakage channels;
2. The concrete of the floor and the slope is slightly damaged, where the damaged area mainly distributed near the water tongue area. Typical defects are shown in Figure 2;
3. The polyurea (previous repair material) on the structural seam surface of the EL.20m pavement is partially peeled off and damaged;
4. Partial damage at EL.3.0m horizontal construction joint;
5. Abandoned steel bars, debris, etc. are accumulated on the upstream side of the secondary dam.

(a) Underwater photography picture



(b) Sonar screenshot

Figure 2 : Comparison of two inspection pictures of typical concrete damage

The results showed that the Xiluodu Hydropower Station water cushion pool was generally good after the flood season in 2018, and no major defects were found. Concrete surface damage mainly occurred near the water tongue area; the construction joint was a relatively weak link, which was greatly affected by the pulsating pressure of flood discharge, and there was local damage; surface repair materials such as polyurea were easy to drop and peel under the pulsating pressure of water flow; The flood discharge of the dam body will carry debris such as steel bars, which accumulate in the water cushion pond will accelerate the concrete wear and tear, so it should be cleaned and salvaged regularly.

Through the cooperation of underwater robots and divers, the underwater structure of the water cushion pool can be clearly displayed, and it proves that the underwater inspection can accurately reflect the true state of the underwater structures. The inspection results are true and reliable, and can be used as a regular inspection method for hydraulic structures.

3. UNDERWATER REPAIR

This underwater repair takes into account experiments and explorations. Therefore, on the basis of collecting and comparing a variety of underwater maintenance materials, according to different types of defects, different repair materials and different construction techniques are used to strive to find the most effective maintenance solution.

3.1 Introduction of Repair Materials

The choice of repair materials is mainly considered from the mechanical properties of the material after curing and the convenience of construction. Corresponding repair materials are selected for different defect types, and their main properties are shown in Table 1.

Table 1 : Material properties and applicable types

Material name	Applicable defect types	Main feature
"Xiamen Brand" Underwater Sealant	Leakage parts such as structural surfaces and construction joints	Superior plasticity High viscosity in water, short curing time, good sealing High bonding strength, good compression resistance, good abrasion and corrosion resistance Easy to operate underwater
HK-UW-1 epoxy mortar (concrete)	Damage of concrete flow surface	Can be cured under water, high compressive and flexural strength after curing Good shrinkage and strong adhesion Does not disperse underwater, self-leveling, self-compacting Good impact and abrasion resistance Easy to operate underwater
HK-969 Joint Filling Material	Damage of structural joints and construction joints	Strong ability to adapt to deformation Good adhesion to concrete High tensile strength, not sucked out and washed away by water during flood Easy to operate underwater

3.2 Construction process

The detected defects will be repaired underwater by the diver. Since underwater operations are far more difficult than conventional construction, the construction process is required to be as simple as possible. For the repair of different types of defects, the construction process is listed as follows:

(1) Damage of concrete surface

Repair principle: Damages less than 1cm in depth will not be repaired; Damages with a depth of 1cm to 3cm are repaired with epoxy mortar; Damages greater than 3cm in depth are repaired with epoxy concrete.

Construction process: Clean up the sediment and debris in the damaged area →Treating the base surface with a wire brush →Transport the mixed material to the area to be repaired →Fill material and scrape with spatula →Stable after about 30 minutes.

(2) Defects of block seams and structural seams

Repair principle: Seepage cracks are repaired with underwater sealant, which has both the function of plugging and seepage prevention and structural reinforcement; Defects of impervious cracks are repaired with HK-969 Joint Filling Material; Defects of polyurea falling off and being broken need to be trimmed first.

Construction process: Clear loose debris in damaged areas →Use a high-pressure water gun to remove dust from structural seams →Transport the mixed material to the area to be repaired →Fill the repair material into the seam →Compact the material and smooth it with a spatula to ensure a smooth surface →Stable after about 30 minutes.

3.3 Repair results

After the repair, the concrete condition of the water cushion pool structure is effectively improved, the seepage volume of the drainage gallery at the bottom of water cushion pool is greatly reduced, and the structural safety of the water cushion pool is further ensured. The comparison of the concrete condition of the water cushion pool before and after repair is shown in Figure 3.

(a) Before repair

(b) After repair

Figure 3 : Comparison before and after repair

4. CONCLUSION

Using the underwater method to repair the water cushion pool of Xiluodu Hydropower Station not only saves construction time and costs, but also benefits the structural stability of the water cushion pool. The inspection results proved the reliability of the underwater inspection and revealed the damage type and distribution law of the water cushion pond during flood discharge. It should be taken as the focus of attention in the future and can also provide reference significance for related projects. With the promotion of underwater maintenance technology, higher requirements will be imposed on concrete underwater repair materials and processes, which can promote the development of maintenance technology for hydraulic structures.

REFERENCES

Xu W L, Liao H S, Yang Y Q, Wu C G. 1988. Numerical Calculation of Flow Field in Plunge Pool of Xiluodu Project. Journal of Sichuan Union University (Engineering Science Edition), 09:34-38.

Wang Y W. 2013. Analysis on the operation risk of water cushion at Xiluodu hydropower station. [J] Dam and Safety, 02:12-14.

Su J W, Wang P C. 2017. Preliminary analysis of diving and underwater technology. [J] Henan Water Resources & South-to-North Water Diversion, 06:21-22.

Zeng H. 2011. Underwater maintenance technology of Gezhouba hydraulic structure. [C] China Water Resources Technology Information Center <2011 National Conference on Application of Safety and Disease Disposal Technology for Hydraulic Spilled Buildings>:101-103.