Reservoir Storage Safety Identification and Evaluation

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Abstract. Impoundment safety appraisal is the necessary basis for impoundment acceptance of water conservancy and hydropower projects. The reservoirs without safety appraisal or unqualified appraisal will not be impoundment acceptance. Based on the aquifer safety appraisal of Jiaozishan Reservoir, this paper describes the aquifer safety appraisal procedure and appraisal system through the evaluation of project flood control capacity, dam stability and seepage, and provides reference for the subsequent aquifer safety appraisal of water conservancy projects.

Keywords: water storage; review; safety appraisal; reservoir

1 Introduction

According to the "Interim Measures for the Safety Appraisal of Reservoir Impoundment of Water Conservancy and Hydropower Construction Projects" and relevant professional technical regulations and standards, in order to improve the quality of project acceptance and ensure the timely delivery of the project, a safety appraisal of reservoir impoundment should be conducted before the reservoir is filled with water [1]. This paper mainly evaluates the project's flood control capacity, dam stability and seepage by rechecking them, and puts forward the opinion on the safety appraisal of reservoir impoundment as an important basis for the safety acceptance of reservoir impoundment [2].

2 Project Overview

Jiaozishan Reservoir is a comprehensive utilization reservoir project to solve the water supply of market towns, farmland irrigation and industrial water supply. The project scale is medium-sized. The Jiaozishan reservoir project consists of two major parts: the dam area hub project and the canal system project. The main buildings of the dam area hub project are composed of dam, spillway, diversion tunnel and water conveyance

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tunnel. The dam is a weathered material dam with asphalt concrete core wall; Spillway, diversion tunnel and water diversion tunnel are arranged on the right bank. The safety appraisal of water storage under the sluice mainly involves the dam area hub project, that is, the dam, the spillway, the diversion tunnel and the water delivery tunnel project.

3 Project Flood Control Capacity Review

3.1 Review of Flood Discharge Capacity Of Buildings

Jiaozishan reservoir is designed to discharge floodwater by spillway and spillway tunnel. The maximum discharge in the initial main flood season is 564.8m^3/s, and the maximum discharge in the late flood season is 379.7m^3/s.

Spillway Discharge Capacity. Hump weir for spillway design of reservoir, weir crest elevation 2196.50m (normal water level 2201.50m), weir width 8.0m, controlled by a set of 8.0m×5.5m arc gate, calculated by the program flood control, after the reservoir flood control capacity adjustment, the highest flood level once in 1000 years 2202.50m, (m0 = 0.41, H0 = 6.09m), the maximum discharge of 218.4m^3/s. Energy dissipation by bottom flow is adopted.

The spillway discharge capacity is reviewed using the calculation formula of Spillway Design Code (SL252-2000) :

$$Q = m_0 B\sqrt{2g}\ H_0^{3/2}$$

The hydraulic model test shows that the comprehensive discharge coefficient of the spillway in the discharge process is 0.35 ~ 0.42, and the design of 0.41 is basically reasonable. The spillway of the reservoir can meet the discharge requirements of the flood in the main flood season and the flood in the later flood season.

Discharge Capacity of the Water Delivery Discharge Tunnel. Diversion spillway tunnel building form is pressure in the front section, no pressure in the back section, the design adopts a diameter of 5.2m reinforced concrete round hole, controlled by the arc gate, initial analysis: by the program flood control calculation, after the adjustment of flood storage capacity, a flood in 1000 years in the check flood level, the maximum discharge of the spillway hole 346.4m^3/s.

The review of the flood discharge capacity of the spillway tunnel is calculated according to the hydraulic formula:

$$Q=\mu Be\sqrt{2g(H-\varepsilon e)}$$

Through hydraulic model test of the spillway tunnel of this project, the comprehensive discharge coefficient of the spillway process is 0.60 ~ 0.80, the design adopts 0.59 ~ 0.68, the value is reasonable, and the discharge capacity of the spillway tunnel meets the design requirements[3].

Flood Discharge Capacity of Reservoir Flood Discharge Facilities. The flood level of the design reservoir is 2202.59m once every 1000 years after flood adjustment, the maximum discharge of the spillway is 218.4m^3/s, and the maximum discharge of the spillway tunnel is 346.4m^3/s, with a total discharge of 564.8m^3/s, which meets the flood control requirements of the main flood season of the reservoir. The initial analysis of post-flood flood shows that the flood level in 1000 years is 2202.07m, and the maximum discharge water is 379.7m^3/s, of which 190.8m^3/s is discharged from the spillway and 188.9m^3/s is discharged from the spillway.

The flood discharge facilities designed for Jiaozishan reservoir can meet the requirements of flood discharge once every 1000 years.

3.2 Project Flood Control Safety Review

Jiaozishan Reservoir check flood level 2202.59m, crest height 2204.00m, wave wall height 1.0m, wave wall top height 2205.00m.

According to the "Code for Design of rolled earth-rock dam" (SL272-2001), the calculated elevation of the dam top of the project is controlled by the normal storage water level and seismic conditions. The characteristic water level of the reservoir, the overheight of the dam crest and the result of the review of the calculated crest elevation are shown in Table 1[4].

Table 1. Results of dam crest elevation calculation of Jiaozishan reservoir

Reservoir Water level (m)	Dam crest elevation	Calculate crest elevation (m)
Normal water level 2201.50	2.650	2204.150
Design flood level 2202.07	2.650	2204.720
Check flood level 2202.59	1.545	2204.135
Normal water level plus earthquake	1.545 + 1.9	2204.945

Review at this stage:

(1) the height of the design dam top of the reservoir is 1.41m higher than the checked flood level.

(2) the normal storage water level plus earthquake condition is 2204.945m, which is 0.055m lower than the crest height of the wave wall.

(3) The height of the dam top and the crest of the wave wall designed by the reservoir meet the standard requirements, and the reservoir dam is safe in flood control.

4 Dam Stability and Seepage Review

4.1 Review of Dam Seepage

Jiaozishan Reservoir is classified as earth-rock dam according to the material, and the seepage situation of the dam body determines the water storage capacity of the dam

body and whether the dam will break and other safety problems. According to the "design Code of rolling type earth-rock dam", the seepage calculation of the dam should be carried out working condition analysis. According to the design situation of Jiaozishan reservoir, four working conditions required by the code are selected for review.

Calculation of Working Conditions.

Working condition 1: dead water level
Working condition 2: normal storage water level + downstream water level
Working condition 3: Design flood level + downstream water level
Working condition 4: Check flood water level + downstream water level

Calculation Result. A typical cross section of 0+140.0m across the dam is used for calculation and analysis, and the results of seepage calculation in the cross section are shown in Table 2.

Table 2. Seepage calculation results of 0+140.0m cross section of dam

Condition of operation	Downstream surface escape point elevation /m	Single width leakage /(m^3/s)
Working condition 1	2125.44	8.12 x 10
Condition 2	2125.44	1.58 x 10
Condition 3	2125.44	1.59 x 10
Condition 4	2125.44	1.60 x 10

The seepage calculation results show that under various calculation conditions, the escape point is located at the corresponding water level in the downstream, the average single wide seepage flow is about 0.146L/s during the full storage period, and the total seepage of the dam body is about 46.8L/s.

4.2 Calculation of Dam Slope Stability

Calculation Method. The Swedish method, simplified Bishop method and Morgenstern - Price method are used to calculate and analyze the slope stability of a typical section 0+120.0m across the dam[5].

Calculating Working Conditions. According to the Design Code for roller compacted earth-rock dam, the following four working conditions should be used for calculation of dam slope stability analysis. The analysis of these four working conditions reflects the stability and safety factor of the dam slope under different water levels. If the stability and safety factor is greater than the allowable value of the code, the dam body is stable and safe in daily operation.

Working condition 1: Stable percolation period of dead water level (normal operation conditions)

Working condition 2: stable seepage period of normal water level (normal operation condition)

Working condition 3: Design flood level stable seepage period (normal operation conditions)

Working condition 4: Check flood level stable seepage period (extraordinary operation condition I)

Calculation Results. The calculation results of dam stability are shown in Table 3.

Table 3. Safety coefficient of dam slope stability in 0+120.0m cross section of dam

Working Conditions	Calculation of safety factor						Permits Safety factor
	Upstream dam slope			Downstream dam slope			
	Swedish law	Bishop method	Morgenston-price method	Swedish method	Bishop method	Morgenston-price method	
Working condition 1	1.696	1.910	1.898	1.591	1.633	1.633	1.30
Working condition 2	2.183	2.355	2.335	1.588	1.632	1.632	1.30
Working condition 3	2.195	2.361	2.342	1.588	1.632	1.632	1.30
Working condition 4	2.206	2.367	2.349	1.588	1.632	1.632	1.20

It can be seen from the dam stability calculation results that the three slope stability analysis and calculation methods of Swedish strip method, Bishop method and Morgenstern - Price method all show that the dam slope safety coefficient of the upper and lower reaches of the dam is greater than the allowable value of the code, indicating that the dam body is stable and safe.

4.3 Settlement Calculation

Lianhe Dam of Jiaozishan Reservoir is a weathered material dam of asphalt concrete core wall, which belongs to the category of earth-rock dam. It will produce settlement after filling. If the settlement exceeds the standard requirements, it will cause harm to the stability of the dam, so it is necessary to check the settlement amount.

The formula for calculating the settlement amount is:

$$s_{\infty} = \sum_{i=1}^{n} \frac{p_i}{E_i} h_i$$

After review: the final settlement of the maximum section of the dam body at 3m downstream of the dam axis is 0.68m, which is less than 1% of the dam height (0.99m), and the settlement of the dam body meets the requirements of the code. Considering the settlement amount of the dam top reserved after the settlement during the construction period, the project is considered as 70% of the settlement during the construction period, and the dam needs to reserve the final settlement amount of 47.6cm. For safety consideration, the maximum settlement amount reserved after the completion of the dam construction is 0.5m, and the reserved settlement of the dam top meets the ultra-high requirements of the code.

5 Conclusions

Reservoir water storage safety appraisal is a systematic work, related to the safety of water storage projects and the safety of people's lives and property, and has great responsibility. It is the necessary basis for water storage acceptance of water conservancy and hydropower projects. Any reservoir without safety appraisal or unqualified appraisal will not undergo water storage acceptance. The evaluation of project flood control capacity, dam stability and seepage flow is an important part of water storage safety evaluation, and an important index to judge whether the reservoir operation is safe. In this paper, combined with the appraisal work of Jiaozishan reservoir, the evaluation method of project flood control capacity and dam stability and seepage flow in the appraisal of water storage safety can provide reference for reservoir storage safety appraisal and reservoir management.

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