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Safety evaluation of Matitan reservoir dam

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ABSTRACT

Safety evaluation of dams has importance in accessing their functioning. This essay carries out safety evaluation on the basis of Matitan Reservoir Project. Through analysis and recomputation, evaluation of project quality is A; operation management, B; safety of flood-prevention, C; safety of dam construction, A; vadose safety of the dam, B; metal structure, C. Analysis by synthesis, Matitan Reservoir Dam is graded as Band 3. At the end of the essay, the author offers some suggestion in reinforcement.

Key words: Safety evaluation of dam; flood control standard; structural safety; vadose safety; metal structure

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INTRODUCTION

There are over 87,000 reservoirs in China, among which most were built during the 50s to 70s in 20th century. Commonly found problems include low standards of flood control, poor project quality, improper management and maintenance, engineering aging – which result in great emergence of dangerously weak reservoirs. [1] At a rough estimate, there are over 30,000 dangerously weak dams in China. These reservoirs can't yield normal profit, and often become the weak part of the flood control system, threatening people's life and property security. In order to guarantee the dam's safe and stable operation, according to a decision released by the Ministry of Water Resources, it's required to evaluate the dams' safety regularly.[2] Assessment of dams' safety is the primary procedure of evaluating dam safety, which has a great significance in evaluating dams' safe operation.

This essay evaluates the dam's safety according to Guidelines of Dams' Security Assessment [3] , on the basis of Matitan Reservoir Project. This could be used as a reference for similar projects' security assessment.

BRIEF INTRODUCTION TO THE MATITAN RESERVOIR PROJECT

The Matitan Reservoir locates in the Matitan village, Bolingou Town, Guangyuan City, Sichuan Province. Its main function is to supply electricity, and it also takes responsibility in 13 ferries' service and water supply for the Two-river Hydropower Station downstream. The project is composed of the front river-blocking dam, the posterior power station, the headrace channel, the Two-river Hydropower Station downstream. The first hub building consists of, from the left to the right in turn, the left-bank non-overflow section, left-bank power intake and scouring sluice, over-flow dam and right-bank non-overflow section. The river-blocking dam is a gravity dam made up of laying stones with pulp, which has max height of 30 meters and the total length of 268 meters. The power intake and scouring sluice are embedded in the left-bank non-flow section; and the powerhouse is located at 46 meters from the left-bank non-flow section downstream, installed with three horizontal axial flow turbine generating units, which can offer a capacity of 560kw. The Two-river Hydropower Station is located at 10.6km from the dam downstream.

This project started in 1964, and first generated electricity in 1973, and fully completed in 1983.
During the past 40 years after the Matitan Reservoir was built, the flood terms have extended, which requires us to alter the data of design flood level and exceptional flood level in comparison to original designs on the basis of

recomputation according to current standards. In this period the "5.12" earthquake broke out and might pose great influence on the reservoir components. In order to ensure the safe and stable operation of the project, we need to evaluate the safety of the dam.

SAFETY EVALUATION OF THE DAM

The basic information and documents for evaluating the Matitan Reservoir Dam safety include the Matitan Reservoir design paper, the Two-river Hydropower Station design paper, the Matitan Power Station History, Cangxi County Annals of electricity, reservoir repair engineering data, reservoir site report, the reservoir's topographic map, dam site area topographic map, and geological survey report of the Matitan Reservoir Project. The evaluation content mainly include engineering quality evaluation, evaluation of dam operation and management, the flood control standard review, evaluation of dam structure safety, seepage safety evaluation, seismic safety review, evaluation of metal structure safety.

3.1 Engineering quality evaluation

3.1.1 Engineering geology and hydrogeology

The Matitan Project is located in the Yantze Paraplatform in the Third New Chinese Subsidence Zone, northeast part of the Central-Sichuan fold belt in Tai'ao, Sichuan, and the axis part of Cangxi Cycline. The geologic structure in this area is gently arcuate fold, without large faultage. The seismic basic intensity is □. The geological structure conditions are relatively simple, with a good regional stability. The reservoir's bank slopes have a good global stability without too much concern in slope instability and shore reengineering which may influence the reservoir's functioning. The massifs around the reservoir are wide and thick without the problem of water leakage to neighboring valleys. The reservoir area's groundwater discharge is in good condition, avoiding groundwater immersion. The reservoir sedimentation area mainly ranges at the far middle and tail parts from the dam, which has small effects on reservoir operation. There are no records of earthquakes caused by the reservoir.

According to The Geological Survey Report of Matitan Reservoir Project [4], the dam base is mainly composed of weathered sandstone; the two banks mainly consist of strong-weathered sandy mudstone. This project has good geological conditions with good stability and little possibility of dam base's bathydermal gliding. The shoulders of the two banks are embedded in middle-weathered and fresh pedestal rock and maintain good stability. The dam has been functioning for several years with good stability even though it suffered through the "5.12" earthquake and no obvious breaks or distortion have ever been found.

3.1.2 Construction quality review

(1) Through drilling check, pressurized-water testing, the dam's actual measurement and the appearance quality inspection, analyzed in comparison with operation records, the following sections meet required quality specifications: the dam foundation, bank slope excavation, anti-seepage treatment of foundation grouting, concrete and reinforced concrete engineering, engineering construction of laying stones with plasma;

(2) No documented data of reservoir's metal structure installation and debugging are available for review; The gate and hoist have not been maintained and replaced since they were put into use; Through field survey we find that the trash rack bars have corroded seriously, the service gates in the blasting holes also corrode seriously, parts of the rubber water bars are broken, the bolts are corroded, the rubber water bars in the left side of the bulkhead gate are missing;

(3) The surface of the overflow dam's weir crest was net-suspended with concrete in April 2010 according to C20, which is in good condition of water passing with nice smooth and flatness;

(4) The dam body and mortar are aging, the above level of water-varying regions upstream and the surface of dam slope stones downstream have different levels of weathering, part of the mortar is washed off by water, there are some small cracks of different length in the overflow dam crest's concrete, which has been partly eroded by water.

According to Guidelines of Dams' Security Assessment [3], the Matitan Reservoir Project quality is evaluated qualified.

3.2 Evaluation of operation and management

The Matitan Reservoir has established corresponding management policies which can be reasonably adopted according to authorized dispatching rules; it also writes down chronicles of operating events and sets up contingency plans, but the hydrological telemetry system is not perfect. Detailed records and evaluations of the dam's previous repairs and reinforcements together with their effects could be found, but the maintenance system is not carried out fully. The reservoir dam has only been equipped with water level monitoring facilities and newly-setup displacement

monitoring facilities, the monitoring facilities are not complete, and there is no corresponding monitoring data. According to Guidelines of Dams' Security Assessment [3], the evaluation of operation and management is graded poor.

3.3 The flood control standard review

3.3.1 The dam's flood control standard and design flood

Through review, the design flood return period of water retaining and drainage buildings is 50 years; the return period of check flood is 500 years; The flood return period of powerhouse is 50 years, its return period of check flood is 100 years. This meets the "Flood Control Standard" (GB50201-94) and "Hydropower Junction Projects' Grading and Design Safety Standards" (DL5180-2003).It is the same as the original design standard.

The Matitan Reservoir has no measured flood data, so when we calculate the statistics of storms according to the "Manual of middle and small watershed storm flood computation in Sichuan Province", we ascertain the dam's design flood and check the results' reasonability with rational formula. The ascertained plan flood process line is shown in figure 1, figure 2.

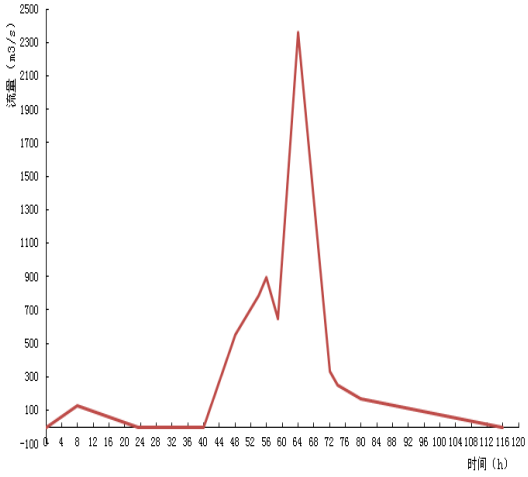

Fig.1:Flood process line(P=2%)

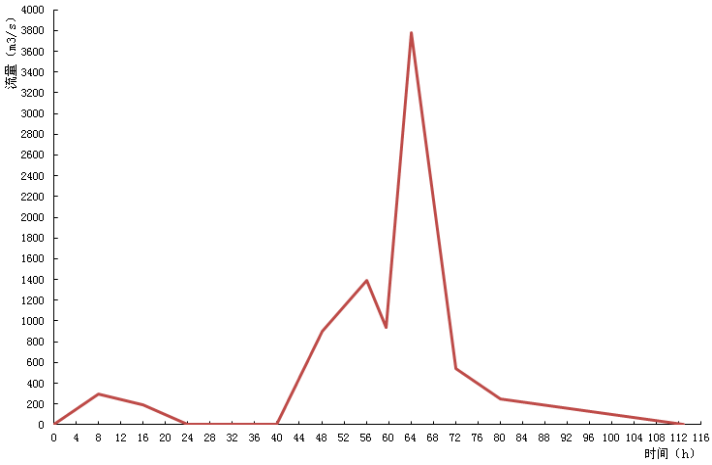

Fig. 2: Flood process line(P=0.2%)

The reservoir's normal pool level is 549.85 m, the original design flood level is 552.55 m, the original check flood level is 553.55 m. According to the current standard review, we get the reservoir's calculated design flood level of 553.45 m, and check flood level of 554.66 m, respectively 0.9 m and 1.11 m higher than original corresponding water levels. Under the same design standards condition, review results are more reliable compared to the original design results.

3.3.2 The dam flood control ability

According to the "Specifications for Stone Masonry Dam" [5], the crest elevation of non-overflow dams should be set in accordance with normal pool level and check flood level together with their corresponding run-up waves, wind-rising waves and security height. Among these, the wave height and the height between the wave center line and static water level should be calculated according to the Guanting Reservoir Formula. The crest elevation check results of non-overflow dams are shown in table 1.

Table 1 The crest elevation check results of non-overflow dams (unit:m)

Working condition of calculation	Wave height	Wind-rising height	Security height	Crest level of wave wall
Normal pool level	0.63	0.17	0.40	551.05
Check flood level	0.38	0.09	0.30	555.43

Table 1 shows that the calculation of the crest level of wave wall is 555.43 m, flushed with the wall's actual elevation, thus the crest level of wave wall meets required specifications. The vertex height of the non-overflow dam's basic section triangle is 553.60 m, higher than the normal pool level of 549.85 m, meeting the required specification.

3.3.3 Discharge capacity review

The over-flow dam is a kind of open practical weir without brake, with the weir crest elevation of 549.85 m, and weir crest width of 130 m, and the energy dissipation method is flip trajectory bucket. Through recomputation, the

discharge capacity at design flood level is 1980m3/s, and 3150m3/s at check flood level. The over-flow dam can discharge design floods and check floods safely.

When the dam discharges check flood, the air face of the dam has a height of 540.85 m, the guide wall's actual height is lower than its calculated value 2.37m, which does not meet the required specifications. When this works, the air face of the dam is 1.61m higher than flip bucket, which results in ineffective deflecting flows.
According to the Guidelines of Dams' Security Assessment [3], the dam's flood control is graded C.

3.4 The structural safety evaluation
3.4.1 The dam strength check
According to the "Specifications for Stone Masonry Dam" [5], it is calculated by the method of material mechanics, the main calculation contains stress at the dam foundation surface, the upstream and downstream sections of the folding slope. The calculated results are shown in table 2.

Table 2 Stress calculation of the dam body(unit:kPa)

Working condition of calculation	Non-overflow dam				Over-flow dam			
	Dam foundation surface		folding slope (height545.55m)		Dam foundation surface		folding slope (height 538.28m)	
	Up-stream	Down-stream	upstream	Down-stream	Up-stream	Down-stream	upstream	Down-stream
Normal pool level	301.82	252.16	211.45	41.14	135.84	317.73	129.97	112.74
Design flood level	177.54	347.45	147.15	69.44	98.34	343.97	35.60	195.80
Check flood level	165.96	349.28	118.93	85.57	10.98	362.54	13.17	231.86

We can see from table 2, the maximum pressure of the non-overflow dam is 349.28kPa, the maximum pressure of over-flow dam is 362.54kPa. According to The Geological Survey Report of Matitan Reservoir Project [4], the allowable compressive stress of the stone-laying body is 800kpa, that of the masonry stones in the body is 2000kpa, that of the mudstone foundation in the non-overflow section is 350kpa, that of the sandstone foundation in the non-overflow section is 3800kpa, that of the sandstone foundation in the overflow section is 3800kpa. Thus the vertical normal stress on the dam foundation surface is less than the allowable compressive stress of the stone-laying body, the masonry stones in the body and the foundation, and the minimum vertical normal stress on the dam foundation surface is compressive resistance, which meets the required specifications.
3.4.2 The dam's anti-sliding and stability review
According to the "Specifications for Stone Masonry Dam" [5], three cases should be taken into consideration in dam's anti-sliding and stability review: sliding analysis along the cushion concrete and bedrock contact surface, sliding analysis along stone-laying body and the cushion concrete contact surface, and sliding analysis between the stone-laying bodies. According to the Shear Formula, the calculated results of anti-sliding and stability of the non-overflow and overflow dams are shown in Table 3 and Table 4.

Table 3 calculated results of anti-sliding and stability of the non-overflow dam

Working condition of calculation	Specification. e	Calculated value			
		along the cushion concrete and bedrock contact surface	along stone-laying body and the cushion concrete contact surface	between the stone-laying bodies	
				between the stone-laying bodies of the dam foundation	between the stone-laying bodies of folding slope(545.55m)
Normal pool level	3.00	3.67	5.59	3.89	38.70
Design flood level	3.00	3.04	4.21	3.17	11.73
Check flood level	2.50	2.52	3.85	2.69	8.78
Parameter choice		f '=0.6 c'=200kPa	f '=0.75 c'=350kPa	f '=0.5 c'=250kPa	f '=0.5 c'=250kPa

Table 4 Calculated results of anti-sliding and stability of the overflow dam

Working condition of calculation	Specification. e	Calculated value			
		along the cushion concrete and bedrock contact surface	along tone-laying body and the cushion concrete contact surface	between the stone-laying bodies	
				between the stone-laying bodies of the dam foundation	between the stone-laying bodies of folding slope(545.55m)
Normal pool level	3.00	4.11	5.23	3.65	6.69
Design flood level	3.00	3.49	4.23	3.11	4.00
Check flood level	2.50	3.21	4.13	2.89	3.51
Parameter choice		f '=0.7 c'=250kPa	f '=0.75 c'=350kPa	f '=0.5 c'=250kPa	f '=0.5 c'=250kPa

We can see from table 3: when it is at the normal water level, the safety coefficient values of non-overflow dam's anti-sliding and stability are 3.67, 5.59, and 3.89 under above three cases, which are above the Specification. E. We can see from table 4: when it is at the normal water level, the safety coefficient values of overflow dam's anti-sliding and stability are 4.11, 5.23, and 3.65, also above the Specification. E. In addition, no matter it is at design flood level or check flood level, the computed values of the non-overflow and overflow dams both meet the required specifications.

According to The Geological Survey Report of Matitan Reservoir Project [4], there are no found disadvantageous weak structural surface and slope structural planes in the dam's foundation body. So we don't need to do deep layer sliding review in the gravity dam.

According to the Guidelines of Dams' Security Assessment [3], the dam's structural safety is graded A.

3.5 Seepage safety evaluation

At the normal water level, we have not found phenomenon of mass leakage in the dam body. Through field survey and supplementary investigation, the dam foundation and the left dam's shoulder have low seepage, and non-overflow dam surface has larger permeability coefficient, with leakage around the dam in the right dam shoulder. There are partial point seepages in both overflow dam and non-overflow dam. The environmental water here has low erosive effects on the concrete.

According to the Guidelines of Dams' Security Assessment [3], the dam's seepage safety is graded B.

3.6 Seismic safety review

According to the "Chinese seismic zoning map", the basic earthquake intensity in the Matitan Reservoir Project Zone is Ⅵ degree. This project is of level 3 engineering, and the main buildings also level 3 engineering. According to the "Code for Seismic Design of Hydraulic Structures" (DL5073-2000), this project may not need to carry out seismic review.

3.7 Metal structure security assessment

According to the "Water Conservancy and Hydropower Engineering Specifications for Design of Steel Gates" [6], we have recomputed the metal structure designs. The service gates' intensity and rigidity of scouring sluice both meet the required specifications, but the calculated panel thickness (8.4mm) is close to the original panel design thickness (10mm). The converted stress values of the service gates' panel are 210.2MPa and 224.4MPa respectively under design conditions and check conditions, which are close to their admissible values. The calculated width values of the panel under the two conditions are 14.3mm and 14.8mm, both above its original designed width 12mm. This indicates that applying the gate's original designed width cannot meet the stability required for the panel at review design flood level and review check flood level. No matter it is under design conditions or check conditions, the values of bending stress, shearing strength and deflection of the girder are all smaller than admissible values and meet the required specifications. But under the two conditions, the values of bending stress of secondary beam are 17.3% and 25.4% larger than admissible values, which cannot meet the required specifications. After design review, the trash rack bars' values of bending stress, shearing strength, the holistic buckling safety factors of cantilevers and midspan all meet required specifications.

According to the Guidelines of Dams' Security Assessment [3], the dam's metal structure safety is graded C.

COMPREHENSIVE ASSESSMENT OF THE DAM'S SAFETY

According to the Guidelines of Dams' Security Assessment [3], with overall analysis of the Matitan Reservoir Dam's construction quality, operations management, flood control, seepage safety and metal structure safety, the Matitan Reservoir Dam is evaluated as Band 3.

RECOMMENDATION FOR THE RESERVOIR'S REINFORCEMENT

To ensure the safety of the dam, and make full use of the reservoir's benefits, I strongly recommended reinforcement as soon as possible:

(1)Repair the masonry cracks on the outside of the dam body; if the inside of the dam body is not solid, we can carry out grouting treatment;

(2)Further check the reasons of the seepage around the dam's right shoulder; when necessary, we should treat it with grouting;

(3) Establish water regimen automatic measuring and reporting system, and fully carry out the dam's maintenance system;

(4) Add 0.40m to the height 540.85m of the guide wall downstream the overflow dam; when under check flood, we should strengthen status inspections to the flood discharge of overflow dam and deal with emergencies in time;

(5) Replace the intake service gate and reinstall the blasting hole bulkhead gate to seal up water.

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REFERENCES

[1] ZHANG Shichen, YANG Zhenghua, GUO Cunjie. *Water Resources and Hydropower Engineering*, v.41, n.4, pp.82-86, **2009**.
[2] Water Construction and Management [**2003**] NO. 271, Reservoir Dam Safety Evaluation Methods[S]
[3] SL258-2000, Guidelines for Reservoir Dam Safety Evaluation [S].
[4] Sichuan Construction Survey and Design Institute. Report of Matitan Power Plant Engineering Geological Investigation [R].**2012**,5.
[5] SL25-**2006**, Code for Masonry Dam Designs [S].
[6] SL74-95, Water Conservancy and Hydropower Engineering Specification for Steel Gate Design [S].
Paskaleva K. *International Journal of Innovation and Regional Development*, v.1, n.4, pp.405-422, 25 January, **2009**.