Study on the Disaster Mechanism Analysis and Enlightenment of Dam Failure

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Abstract. With the continuous advancement of infrastructure construction, dam, as an important water conservancy project, plays the role of water storage, flood regulation and power generation. However, due to the influence of extreme weather and other reasons, there may be the possibility of dam failure accidents when the dams are put into operation. The dam break accident may bring great losses to the downstream dam section. The theme of this paper is the disaster mechanism analysis and enlightenment of dam failure. By combining the statistics of dam break data with the analysis of potential causes, the disaster mechanism of dam break is obtained. According to the disaster mechanism, the corresponding treatment plan and future development trend are discussed, with the aim of monitoring the design, construction and operation stages of the dam. Suggestions for improvements include improving the dam's ability to withstand extreme weather, carrying out precise construction according to specific steps, and improving the professionalism of managers. These suggestions can reduce the probability of dam break accidents and reduce the casualties and economic losses caused by dam break accidents.

Keywords: Dam; dam failure; natural disaster.

1. Introduction

The dam has the functions of flood control, water storage and supply, water resource management and so on. In the world, the number is large, the variety is large, the distribution is wide, and the role is great. However, dam failure accidents often occur due to various internal and external reasons when DAMS are put into use. Since the founding of the People's Republic of China, more than 98,000 reservoirs have been built, with a total storage capacity of more than 900 billion m^3 [1]. According to statistics, from 1954 to 2021, a total of 3,558 dams broke in China, with an average annual average of 52.3 dam breaks. According to rough statistics, the main reasons for dam failure include flood overtopping dam failure caused by extreme climate, dam failure caused by engineering quality defects, and dam failure caused by improper management after operation. After the dam break accident, it will have a huge impact on the production and life of downstream residents, and greatly threaten the life and property safety of downstream people. In recent years, due to the concept of intelligent water conservancy has been proposed, the intelligent water conservancy construction industry will bring fresh blood to the industry, improve the efficiency of engineering construction and construction level. In this paper, the new system is combined with dam safety monitoring to find a better way to prevent dam failure disasters. During the construction period, the safety situation of the dam during construction is evaluated dynamically by installing monitoring instruments, data collection and integration analysis. In the initial storage period and operation period, the safety monitoring instrument is automatically collected and integrated, and professional software is used to realize real-time data collection, dynamic analysis, prediction and prediction, so as to form a complete dam safety monitoring system [2]. Due to the diversity of dam types, the capacity of flood control and flood storage is very different, and some dam failure accidents with distinct causes are selected for analysis. According to the cause of the accident, the mechanism of dam break is summarized, and the experience and enlightenment on risk prevention are obtained.

2. Analysis of Dam Failure Mechanism

2.1. Dam Failure Caused by Climatic

Due to the influence of extreme climate, the flood volume has increased dramatically, exceeding the flood storage capacity of the reservoir, and the proportion of dam break accidents is about 50% according to statistics. Therefore, climatic factors are the most important reasons for dam failure.

Earth-rock dam is one of the most common dam types in hydraulic engineering, and the dam height ranges from several meters to more than 300 meters. Earth-rock dam occupies the first place in all kinds of dam types because of its advantages such as wide adaptability, fast construction speed, good economic benefit, high seismic performance and local materials. Most of my land rock dams were built in the 1950s to 1970s, mainly small and medium-sized, restricted by various factors, earth and rock DAMS lack quality assurance, more hidden dangers, aging and disrepair of the reservoir and there are various diseases and potential risks [3]. Among dams with a dam height of more than 15m in China, the proportion of earth-rock dams can reach about 93% [4]. Among the failed dams, according to the classification of dam types, the failure ratio of earth-rock DAMS can reach 97.8% [5].

In August 1975, under the influence of Typhoon No. 7503, large-scale rainfall occurred in Henan Province. Under the action of heavy rain for several days, Banqiao Reservoir and Shimantan Reservoir finally broke the dam accident. According to incomplete statistics, the disaster affected 11 million people in 29 counties and cities, more than 1.1 million hm2 of cultivated land suffered serious floods, and more than 26,000 people were killed. The Beijing-Guangzhou Railway was washed 102km, interrupted traffic for 18 days, affected transportation for 48 days, and caused direct economic losses of 10 billion yuan. Banqiao Earth Dam is located in the upper reaches of Ruhe River in Biyang County, Henan Province. It is 24m high and 2020m long, of which the riverbed dam section is 400m long. The volume of the reservoir is 490 million m3. Earth dam is heavy silty clay thick core sand gravel dam shell, with upstream dam slope is 1:3 and 1:6, and downstream dam slope is 1:2.5 and 1:6. The Banqiao Reservoir project was completed in 1952. Shimantan earth dam, located in the upper reaches of Honghe River in Wuyang City, Henan Province, is a silty clay homogeneous dam. It was completed in 1952. The maximum dam height is 25m and the crest length is 500 m. The storage capacity is 92 million m^3 [6].

After the dam break events of Banqiao Reservoir and Shimantan Reservoir occurred, the causes of dam break were investigated. According to the official investigation report, during the design and survey phase before the construction of the two reservoirs, the upstream hydrological data was missing, and the values calculated by the 1,000-year flood standard were not accurate enough. At the same time, under the influence of the typhoon in August 1975, the flood peak discharge far exceeded the design standard, which was the direct cause of the final dam break of the reservoir. In the end, dam break accidents occurred in Banqiao Reservoir and Shimantan Reservoir, resulting in huge casualties and economic losses [7].

According to the analysis of the accident report, there are two important reasons leading to the dam break accident. First, the precipitation caused by the extreme weather caused by the typhoon landing suddenly changes dramatically. Under the action of continuous heavy rain, the flood peak discharge in flood season far exceeds the design data. The storage capacity of the reservoir cannot bear the flood volume, and exceeds the design flood level and check flood level after the flood control high water level, and climbs over the wave wall, the flood overflows and causes the dam break. Fig.1 (a) shows the dam failure caused by flood water overtopping. Second, in the data collection stage before the construction of the reservoir, the upstream hydrological data is missing, and the existing data cannot meet the requirements of the construction of the reservoir. The designers did not carry out the necessary hydrological survey due to the lack of data, and the design data was limited. According to the investigation, the flood of Banqiao Reservoir and Shimantan Reservoir when the dam broke was once in 650 years, and did not reach the flood flow of once in 1,000 years taken in the normal design, so the lack of rigor in the design and investigation stage also left hidden dangers

for the occurrence of dam break accidents. Due to the extreme climate impact, the flood volume increases sharply, exceeding the flood storage capacity of the reservoir and resulting in the proportion of dam break accidents according to statistics about 50%, which is the most important cause of dam failure [8]. Fig. 1(b) shows the dam break caused by dam failure.



(a) Dam break caused by flood water overtopping



(b) Dam break caused by dam failure

Fig 1. The dam broke as a result of flooding.

2.2. Reason of Engineering Quality

There are many quality reasons leading to dam failure, including dam body leakage, dam body landslide, dam foundation leakage, spillway leakage, spillway quality, water tunnel leakage, water tunnel quality and so on. Compared with the overflow dam break caused by the increase of rainfall caused by extreme climate and the flood peak flow exceeding the design flow, the dam break caused by the work quality can be more attributed to the engineering construction does not meet the engineering design requirements.

In order to meet the needs of production and life, the amount of mineral mining is increasing, and dam breaking accidents occur frequently because of the engineering quality of tailings after mining. After the tailings dam break occurs, the residual metal elements in the tailings will leak in large quantities, seriously affecting the safety of downstream residents and polluting downstream land. According to the survey, among the 69 tailings pond dam break accidents from 1960 to 2015, 35 cases of piping damage accounted for 50.72%. 24 cases of flood overtopping accounted for 34.78%; the unstable dam body accounted for 8.70% in 6 cases. Geological disasters accounted for 5.80% of the total. Pipe failure and flood overtopping are the two main causes of dam break of tailings pond, the sum of which accounts for 85.51% [9]. The main reason of piping failure is seepage failure. Most of the conditions of infiltration failure come from engineering quality reasons.

No reference was made to local hydrogeological data in the design stage of tailings pond. In the investigation stage, the geological conditions around the tailings dam are not investigated in detail. In the construction stage, the construction is not carried out in strict accordance with the design requirements, and the quality of the dam body has problems. These reasons will have a great impact on the quality of the project. When the tailings dam with engineering quality problems is put into use, the probability of dam failure is greatly increased. Fig.2 shows the leakage of the dam body.



Fig 2. Leakage of the dam body.

2.3. Reason of Improper Project Management

In the course of operation of water conservancy project, there are not few cases of dam break accidents due to improper management. Excessive water storage, negligent management and non-maintenance as required will lead to increased probability of dam failure.

Russia's Sayanshushensk Hydropower Station has a total installed capacity of 6.4 million kW and a corresponding storage capacity of 31.3 billion m3 when the normal storage level of the reservoir is 540 m, making it the largest hydropower station in Russia. The dam is a concrete gravity arch dam. The maximum height of the dam is 245.5 m, the crest arc length is 1066.1 m, the crest elevation is 547 m, the crest width is 25 m, and the foundation width is 105.7 m. The concrete volume of the dam body is 8.5 million m^3. The water thrust of the dam is close to 30 million t, of which 60% is borne by the dam body's own weight, and the remaining 40% is borne by the mountains on both sides. The construction of the power station began in 1960, the dam concrete was poured in October 1972, and it was opened in 1978. On August 17, 2009, a dam break occurred at the Sanyashushensk Hydropower Station in Russia, resulting in 74 deaths, one missing and economic losses of 1.65 billion rubles. During the investigation of the accident, it was found that the dam body was not damaged, and the reason of reservoir water gushing came from the damage of Unit 2 of hydropower station. The investigation into the cause of the damage of the hydropower station unit found that the staff began to take emergency measures to deal with the water gusher accident about an hour after the unit occurred, which eventually led to the accident.

It is obvious that after the water gushing accident occurred in the turbine unit, the hydropower station management staff did not carry out emergency treatment in the first time, and the intermittent time was even more than an hour [10]. It is a very typical dam break accident due to improper management.

3. Enlightenments from Dam Failure

In view of the dam failure problem, through the analysis of the dam failure mechanism, the following Revelations can be obtained:

(1) In the design stage of hydraulic engineering, it is necessary to investigate the engineering geology and hydrogeology conditions of the engineering site. Therefore, the data required for design is collected, the data of upstream and downstream hydrographic stations of the hub is studied, and the data that does not meet the design requirements is discarded.

(2) In the construction phase of the water conservancy project, the construction should be carried out in strict accordance with the design requirements, and cannot cut corners and save construction steps. Construction materials should also meet the design requirements to prevent engineering quality problems caused by construction materials that do not meet the requirements.

(3) After the completion of the project, it is necessary to conduct management in accordance with the norms, clarify the responsibilities of each management department, and improve the quality of management personnel and the ability to deal with emergencies. In addition, it is necessary to check and maintain the equipment regularly according to the regulations, and seriously deal with the phenomenon of excessive storage.

(4) Due to the rise of intelligent water conservancy, an efficient and accurate hub monitoring system is formed by combining artificial intelligence with the monitoring system of water conservancy construction projects. The Internet + water conservancy project will revolutionize and update engineering technology, improve the vitality of the industry, and promote the improvement of project management level. Fig.3 shows a water lock equipped with sensors. The weather forecast will be linked with the upstream and downstream hydrological stations of the dam, and an information interworking network will be built to assist the upstream and downstream hydrological stations to calculate the peak flood flow data under extreme weather conditions, and make flood prevention preparation plans in advance to minimize losses [11].



Fig 3. A water lock equipped with sensors.

4. Conclusion

This paper mainly studies the disaster mechanism of dam failure, analyzes the causes of dam failure accidents, and draws the following conclusions.

(1) Through the research of the dam failure accident, the paper discusses the three stages of dam design, construction and operation. In the design stage of the dam, there may be a lack of engineering geological and hydrogeological data required for the design of the hydrological station. In view of this situation, it is necessary to obtain data from the local water resources bureau or conduct experiments in strict accordance with the requirements to measure the data required for design. In the construction phase of the dam, the construction technicians need to operate in strict accordance with the design requirements, and the construction materials need to meet the strengthening requirements of the design to improve the quality of the project. During the operation phase of the dam, regular inspections are carried out according to the regulations and safety maintenance is carried out on the dam body. Managers should have good ability to respond to emergencies.

(2) In view of the dam failure mechanism, the future prospect can be made. With the development of new technologies, try to find some new technologies to help the water conservancy project to optimize. At present, Internet + is the general trend of social development, and Internet + water conservancy projects can become the development direction of today and in the future. Smart water conservancy will greatly improve work efficiency, by uploading the data of the hub project and the upstream and downstream hydrographic stations to the Internet, forming a data sharing space, and improving the efficiency of dam flood control and storage. The use of satellite remote sensing technology to monitor and maintain the dam, safe and efficient to ensure the normal operation of the dam. With using Unmanned Aerial Vehicle and ultrasonic detection technology to conduct dam maintenance, directly and accurately monitor the condition of the dam. In the environment of rapid development, combined with the application of cutting-edge technology, bring fresh vitality to the industry.

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