An Integrated Management System of Man-machine Communication for Tailings Pond Based on RSCIC

Guangming Yu\textsuperscript{1,2,*}, Yingnian Yu\textsuperscript{3}, Junwei Liu\textsuperscript{1,2}, Ju Qiu\textsuperscript{1,2}, Yanhua Zuo\textsuperscript{1,2}, Xiankun Zeng\textsuperscript{1,2}, Xin Dong\textsuperscript{4}, Weiquan Wang\textsuperscript{5}

1. School of Civil Engineering, Qingdao University of Technology, Qingdao 266033, China
2. Cooperative Innovation Center of Engineering Construction and Safety in Shandong Blue Economic Zone, Qingdao University of Technology, Qingdao 266033, China
3 Qingdao Company, Zhongqi Jiaojian Group Co., Ltd., Qingdao 266300, China
4 Shandong Zhaojin Company, Zhaoyuan 265400, China
5. Fuyunmengku Iron Ore Co. Ltd, Urumqi 830022, China

\textsuperscript{*}Corresponding author: yu-guangming@263.net

Abstract. Tailings pond plays a very important role in the construction of mine engineering. At the same time, tailings pond also produces huge pollution to the environment. If dam break occurs, it will cause loss of people and property. In this paper, a tailings pond management system based on RSCIC is studied, the monitoring content of the system is determined, the more innovative system and hardware are emphasized, the program flow chart of digital processing is put forward. Adopting scientific and effective means to manage the tailing dam automatically can not only strengthen the safety protection of the tailing dam, but also provide a certain theoretical basis for the construction of other digital tailings dam projects.

1. Introduction

Tailings pond is a place for storing mine residue or industrial waste residue, which is built by intercepting the terrain with poor terrain [1]. According to incomplete statistics, there are about 8,000 tailings dams of different sizes in China. However, it is inevitable that there will be over-exploitation and even non-compliance with the requirements of mining, leading to the tailings dam failure straight up. In recent years, dozens of large tailings dam accidents have occurred in our country, which bring great damage to the safety of people’s lives and property as well as the living environment. For example. In 2006, 17 people were dead and 5 injured in the dam break accident of a tailing pond in Shaanxi Province. In 2008, 128 people were dead and 35 injured in the dam break accident of a tailing pond of a mining company in Shanxi Province [2].

With the occurrence of several large tailings dam accidents, the government has increased its investment in the safety of tailings dam. With the deepening of the research theory and practical application of tailing dam safety in various scientific research institutions, people know more and more about tailings dam. It has been able to realize the real-time on-line monitoring of the tailings pond, and preliminary realization of the prototype of the digital tailings pond.

At present, our country has tailing ponds to realize the dam body stability and the safe production monitoring, although has separated from the artificial survey method, but will be affected by many
factors the disturbance and the restriction. For example, the workload of measurement is large, the accuracy of measurement is not accurate, the function is single, and so on. In this situation, it is necessary to explore a new tailings pond management system. Therefore, on the basis of the embryonic form of the digital tailings pond, this paper introduces the RSCIC system, through the characteristics of information, intelligence, real-time and network of the RSCIC system, carries on the comprehensive and effective control to the tailings pond. In the five letters of RSCIC, R stands for reconnaissance, S for surveillance, C stands for communication, I stands for intelligence, C stands for command.

2. Implementation and innovation of RSCIC system

At present, the monitoring system of tailings pond has been used in many practical projects. For example, the use of high-density resistivity method to monitor the infiltration line, the shortcomings of this monitoring mechanism is mostly manual monitoring, and a long period of work; using GNSS, GPS technology to monitor the deformation of the tailings dam. But for other parameters of the monitoring effect is not significant; the use of remote data transmission network based on RS-485 to monitor the seepage of the tailings pond, the function is relatively simple [3-5]. Therefore, the development of an automatic management system with higher efficiency and accuracy is a vital part of doing a good job in disaster monitoring of tailings ponds.

The purpose of RSCIC system is to reveal the particularity of tailings dam structure, the complexity of deformation and the danger of dam break, to study the instability mechanism of tailings dam, and to study and establish the theory and system of monitoring and early warning of tailings dam based on RSCIC. Submitting the risk early warning method of tailings dam based on RSCIC and compiling software provide some theoretical support for the safe operation of tailings dam, thus can promote its development through more scientific and innovative technical means.

The RSCIC system (Fig. 1) consists of five modules that are both continuous and related to each other. For example, from the design, construction, completion and production of tailing dam, it is necessary to investigate the geographical and natural position, topographic and geological conditions, the shape of dam body, the arrangement of monitoring points on the dam body and the communication with the control and command center. All the data into the database, the need for intelligent analysis of data and among the rules of change and then put forward its evolution process early warning or production recommendations; all of the above modules are under the command of the command module.

The innovative and progressive nature of the RSCIC system is as follows.

![Fig. 1. Composition of RSCIC management system](image-url)
(1) Real-time monitoring: the real-time monitoring system of tailings pond can monitor the technical indexes such as rainfall, soakage line, water level, dry beach length, dam displacement, pore water pressure and so on.

(2) Video monitoring: scanning and recording the key parts of the dam body through the electronic monitoring system, forming a grid three-dimensional monitoring system at different angles and different spatial positions, so as to ensure the safe operation of the tailings dam.

Under the condition that the tailings dam has certain flood regulating capacity, the system can measure the indexes such as water level, rainfall, dam deformation, soakage line and so on. And these data are collected through the real-time online monitoring system [6]. In order to keep the tailing dam under a higher safety standard, the established system should cooperate with each other, realize the online monitoring and real-time analysis of the tailing dam, and reduce the hazard of the tailing dam to the minimum.

3. Working principle of RSCIC system

System mode of operation: Reconnaissance system should plan the layout of the monitoring system before collecting basic data. Information obtained by surveillance systems (such as tailings dam monitoring instrument, the water level warning, wireless transmission network, etc.). This information is transmitted to the main control platform through the communication system. The intelligent control platform provides the location of the tailings dam alarm to the manager through data analysis, the scene of mine tailing movement, velocity and seepage field in dam body. The manager further monitors the site through the control system and implements flood control measures according to the scene and tailings dam safety specifications. The specific working principle process is shown in Fig. 2.

Fig. 2. Working principle flowchart of Rscic system

3.1. Reconnaissance system

Investigation is the process from site selection, design to completion to on-line monitoring of tailings pond. The investigation of tailing pond is of great significance to the stability and safety of tailing pond. Whether the selected location of the tailings pond conforms to the safety regulations, the geological structure and lithologic characteristics of the selected location should be drilled and sampled. At the same time, the flood discharge capacity, water storage capacity and various factors which may cause danger to the downstream residents should be taken into account. In addition to the above aspects, we can also use professional equipment (Fig. 3) to survey and analyze the displacement, rainfall and flood level indicators, and collect data in real time. The real time analysis of the initial dam and the accumulative dam in the formation process of the tailings pond, etc [7].

The design and construction standards for tailings ponds should specify the safety parameters needed for operation, such as the total storage capacity, the final dam height and the final stacking height, etc.
3.2. Surveillance system

As shown in Fig. 4, the main observation and monitoring projects have saturation line position, dam body displacement, dry beach length, pond water level and rainfall, etc. After the collected data is transported to the central Management Center, the plan and profile of the monitoring point can be observed in the main control platform of the central Management Center, which can be alerted in real time when the data is over-timed.
3.3. Communication system
The purpose of communication is to collect and transmit the data observed by tailings pond to the management department. The communication system structure is shown in Fig. 5, which mainly includes 1 main line cable, several branch cables, data acquisition box and so on. The monitoring device transmits the received data to the automatic acquisition box through the sub-line, and then the GPRS transmission module and the INTERNET network are transmitted to the management center through the main line.

3.4. Intelligent system
The working process of the intelligent system is shown in Fig. 6. When all kinds of data collected are transported to the management center, the data report and calculation results obtained after analysis are classified and stored in the server. The controller gets the security information and technical data from the filtered data according to his own needs.
As the safety monitoring system of tailings pond is still unable to realize fully intelligent monitoring and inspection, it requires us to combine the manual inspection and compare and analyze the data obtained from the two to obtain more specific and scientific safety results [8].

3.5. Command system

The dynamic data collected by the instrument can be alerted to the danger after computer processing, which can be controlled from the source. If the infiltration line is too high, the mining can be suspended. If the length of dry beach is insufficient, it can change the position of the drainage pipeline or build a dam. The workflow of the command system is shown in Fig. 7 to ensure that the received data is real-time dynamic data, and automated security analysis is carried out to ensure the smooth operation of the warning system.

According to the analysis and judgment data, the displacement of the tailings dam is judged qualitatively, so as to be able to grasp the force of the tailings dam, evacuate the dangerous people on the basis of the early warning information, and take effective reinforcement measures to prevent the occurrence of greater damage.

![Fig. 6. Intelligent system work flow chart](image)

![Fig. 7. Flowchart of the command system](image)
3.6. Overall optimization of RSCIC system
The monitoring system of tailings pond based on RSCIC integrates multiple work on the basis of communication technology. The dynamic monitoring system of RSCIC automation can not only improve the working ability of managers, but also show the advantages of the age of big data in the rapid automation.

4. Implementation steps of RSCIC system

4.1 In-site investigation stage
The work flow chart of RSCIC in the exploration phase as shown in Fig. 8, must first master the tailings dam site, from the natural conditions, geographical environment, historical extreme weather conditions investigation as follows.

(1) Firstly, we should understand the engineering geological conditions of the tailing pond, such as rock hardness and mechanical properties, seismic grade and so on, and make qualitative and quantitative evaluation of some necessary investigation factors, so as to make preparations in advance.

(2) To investigate the hydrogeological conditions of the site, such as the depth of groundwater and the possible seepage flow, so as to make a comprehensive evaluation of the dam body.

(3) After ascertaining the possible adverse effects of bad geological conditions, we should take different protective measures according to different phenomena, determine the required indexes and data, and correctly classify the grade of rock and soil.

(4) According to the characteristics of different soils, stability analysis is carried out according to different standards.

(5) To provide effective and scientific safety measures. In the later design, the information of the location of the monitoring instruments should be taken into account in the design of the tailings dam, especially the monitoring pipeline channels should be left when the overflow wells and overflow culverts are poured.

4.2 Selection of monitoring indexes for surveillance system
(1) The water level of the tailings dam is relatively stable because of the waste residue accumulated in the tailings dam for a long time. The waste residue removed from the tailings dam will inevitably percolate in the course of flowing. At the same time, it is also possible that the pond water level will rise rapidly due to heavy rainfall during the flood season. In this life cycle, the tailings performance may be changed due to some reasons other than human activities. All of these are the reasons that lead to the abnormal seepage of tailings dam. Therefore, the reasonable control of the location of the soakage line is the most important task in the monitoring task.

(2) The monitoring of pond water level is used to check whether the flood control capacity of tailings pond can meet the safety requirements. Specifically, a complete design document will give the
specified design flood level, the highest flood level and the regulation of flood depth, these indicators must meet the design requirements. Therefore, accurate control of the height of the pond water level can effectively avoid the occurrence of accidents, but also conducive to the safety inspection of the relevant departments.

(3) Once the tailing dam breaks, it will be disastrous and irreparable. Therefore, it is necessary to establish a disaster evolution process, which can intuitively respond to indicators, can take appropriate measures in time to prevent dam deformation and other disasters, so as to avoid or reduce the occurrence of disasters.

(4) In the quantitative evaluation of the flood control capacity of the tailings pond, it is necessary to determine the beach top elevation and the allowable dry beach elevation under the designed maximum flood level. Because of the limitation of technical means, the calculated results of total dry beach length and flood regulation dry beach length are not convincing enough. Therefore, in the automatic monitoring process, it is necessary to be equipped with an accurate and rapid determination method.

4.3 Security management of communication system
The communication system of RSCIC consists of several branch cables that collect information through data sensors and then connect the cables to the automatic collection box. For the sake of safety, all the cables are covered with PPR pipes and buried in the ground to ensure the safety in use. In addition from the point of view of economy and stability the data collected from the different profiles of the field are processed and sent to the computer room of the monitoring center for automatic preservation. All authorized users can monitor or analyze the data through the Internet or remote login surveillance system.

4.4 Early warning control of intelligent system
The intelligent system of RSCIC automatically analyzes the information it collects and alerts it when it exceeds the preset value. Therefore, the establishment of a sound early warning model and the preparation of scientific prediction software, can better predict the stability of the tailings dam, the development of safe and reliable control measures [9]. The main functions include real-time data display and query, remote data access, automatic flood routing, different levels of automatic early warning, video recording and real-time monitoring, as well as the daily safety monitoring of tailings pond informatization.

![Intelligent early warning system based on RSCIC](image)

Fig. 9. Organization chart of intelligent system

The organization chart of the intelligent system is shown in Fig. 9, and the main components are as follows.

(1) Timely alarm: The system will automatically identify the hazard information and make the corresponding judgment. The information can be sent to the controller at the first time through GPRS, WIFI, SMS and many other ways.

(2) Data analysis and prediction: Through comprehensive analysis and comparison of the relevant data, such as water level of dam pond, soakage line, large displacement of dam body, rainfall and seepage flow of dam body, the correlation among various data is calculated, and the health condition of dam body is comprehensively judged.
(3) Statistical reports: Classification and presentation of various data to facilitate extraction of useful data. Support the export and print.

4.5 Integration of the command system
The command system of RSCIC integrates the above four stages, this system can consult the data of water level, rainfall, depth of infiltration line, deformation of dam and so on needed by tailings management in real time. On the basis of theoretical analysis and data comparison, work measures are optimized.

5. Conclusions
This paper mainly studies the application of RSCIC system in the digital management of tailings ponds, giving a brief account of the present situation of the research on the monitoring technology of tailings in our country. Secondly, the equipment and working principle of RSCIC system are introduced, and the running system and working flow of RSCIC system are described in detail. The automatic safety monitoring of tailings pond is a part of digital mine construction, it is also the need of modern management of enterprises.

The establishment of RSCIC system can not only protect the lives and property of the downstream people, but also reduce the environmental pollution caused by dam break. Therefore, it not only promotes the long-term stability of society, but also accumulates valuable experience for the research and development of automatic safety monitoring and early warning system of tailings pond.

Acknowledgments
The research was jointly supported by the National Natural Science Foundation of China (51674150) and the Construction Science and Technology Projects of Urumqi (2016002).

References
[1]. Zhang Z.Q., Hu J., 2010. Automatic monitoring system for safety of tailings dam. Mining Engineering, vol. 8, no. 02, pp. 53-55.
[2]. Wang C., Wang Y.H., Li Q.M., Zhou Z., Shi Z.D., Meng X.S., 2008. Research on an online mine tailings dam optical fiber surveillance technology. Shandong Science, vol. 21, no. 06, pp. 4-8.
[3]. Zhang L., Li Y.Q., Sun H., 2011. Applications of online deformation survey monitoring system in tailing pond of metal mine. Computer Engineering & Software, vol. 32, no. 01, pp. 61-63.
[4]. Zhan J.J., Xiao T.Y., 2013. Research and application of monitoring system for tailings dam based on GPS data. Journal of Safety Science and Technology, vol. 9, no. 04, pp. 5-10.
[5]. Li Z.K., Zhang Y.P., 2008. Research and design of tailing dam seepage monitoring system based on RS-485. Mining and Metallurgy, vol. 36, no. 03, pp. 77-80.
[6]. Zeng Q.W., Xie D.R., Su J.D., Yuan M., 2010. Risk analysis of dam failing of the tailings reservoir. Industrial Safety and Environmental Protection, vol. 36, no. 01, pp. 44-46.
[7]. Li Q.M., Liao G.L., Wang Y.H., Wang Q., 2007. Study on assessment methods for safety in controlling flood and possibility of cracks of tailing dams. Journal of Safety Science and Technology, no. 05, pp. 24-29.
[8]. Wu Q., Chen Q., 2008. An analysis of environmental effects induced by environmental problems in mines. Hydrogeology & Engineering Geology, no. 05, pp. 81-85.
[9]. Yu G.M., Song C.W., Pan Y.Z., Li L., Li R., Lu S.B., 2014. Review of new progress in tailing dam safety in foreign research and current state with development trend in China. Chinese Journal of Rock Mechanics and Engineering, vol. 33, no. S1, pp. 3238-3248.