Research on Data Analysis of a Long Slope Wireless Monitoring

Xin Yang1*, Shihao Jiang1
1 Nari Group Corporation/State Grid Electric Power Research Institute, Nanjing, Jiangsu, 211106, China
*Corresponding author’s e-mail: yangxin@sgepri.sgcc.com.cn

Abstract. Slope collapse is one of the most important hazards faced by most water conservancy projects. Due to the long transmission distance and unstable data transmission of existing monitoring methods, the slope safety analysis and evaluation have a great impact. Based on slope design and safety monitoring, this paper proposes to use wireless acquisition and transmission technology to carry out safety monitoring on long slopes, to further improve the accuracy of data, expand the application scope of slope monitoring. And it has been successfully applied in slope monitoring of a water conservancy project.

1. Introduction
Slope collapse is one of the most important hazards faced by most water conservancy projects. It has more occurrence frequency, wider distribution range, and serious consequences [1]. In France, the left abutment of the Malpasset double-curved arch dam collapsed, killing more than 500 soldiers [2]. And a large landslide on the left bank of the Vajont arch dam in Italy killed 1925 people downstream [3]. A huge landslide occurred on the slope of the Manwan Hydropower Station in Yunnan, China, which caused the construction period to be delayed for more than a year and the processing funds exceeded 100 million CHY. Therefore, the monitoring of slopes has become increasingly important, especially in the operation period and construction period.

At present, most of the monitoring methods for slopes use monitoring instruments [4]. During the construction period, due to site conditions, it is often necessary to manually perform data measurement on the monitoring instruments at each monitoring point. During the operation period, all monitoring instrument cables are collected together, and then automatic data collection is performed. This not only consumes a lot of manpower and capital, but also often results in unstable data transmission due to the long slope distance and excessive cable loss, which has a great impact on the safety analysis and evaluation of the slope.

Based on slope design and safety monitoring, this paper proposes to use wireless acquisition and transmission technology to carry out safety monitoring on long slopes. And the monitoring of the slope of a ship lock further improves the accuracy of the data, expands the application range of slope monitoring, and better realizes the safety monitoring of the slope.

2. Design principles of slope safety monitoring
(1) The slope safety monitoring work is controlled by many factors. How to correctly select economical and effective monitoring methods and optimize the monitoring design in order to achieve an accurate evaluation of the slope stability is the most important issue in slope safety monitoring design [5].
(2) The main focus is on monitoring the safety of buildings. The setting of monitoring items and the arrangement of measuring points should not only meet the needs of the safe operation of monitoring projects, but also take into account the verification design;

(3) The arrangement of the permanent monitoring equipment should be combined with the monitoring arrangement during the construction period as much as possible, so that a project can have multiple uses and can reflect different priorities in different periods [6];

(4) Various monitoring items should be checked and confirmed by each other;

(5) The equipment selection should highlight long-term stability, reliability, and as few types as possible to facilitate management, construction, and automation [7];

(6) While conducting instrument monitoring, attention should be paid to manual inspections to complement each other, and all monitoring data should be sorted and analyzed in time to discover unsafe factors in time and take effective engineering treatment measures [8].

3. Project Overview
A water conservancy project is a large-scale reservoir. The project category is Grade II. The normal water storage level is 67 m and the total storage capacity is 710 million m³. It is a comprehensive water conservancy project focusing on improving the urban environment, water landscape and shipping, and taking into account other. Among them, the upstream slope of the ship lock is about 1200 m, and the downstream slope is about 600 m. A total of 15 sets of inclinometers are arranged on the slope. 15 seepage pressure gauges monitor the displacement of the slope in the free direction and the groundwater level. A total of 15 wireless collection devices are arranged. Data collection and transmission are carried out on the four monitoring sections of the entire slope, and two wireless gateways are arranged in the central control room to receive and summarize the collected data.

4. Wireless monitoring data analysis
4.1. Slope inclinometer monitoring
The slope deformation is monitored by 15 sets of inclinometers to monitor the horizontal displacement of the slope body in the free direction. It can be seen from the monitoring data and the process line that the horizontal displacement of the slope mainly occurred in June 2017, and began to stabilize in July 2017. In August 2017, the right-hand section of the upstream approach channel 0-305, elevation above
74 m. The horizontal displacement has increased significantly. After the impoundment was opened to navigation in November 2017, the change was basically about 10 mm. At present, the maximum cumulative horizontal displacement of the slope in the direction toward the sky is located on the right section of the downstream approach channel ship 0 + 860. The maximum displacement value is 35.59 mm, and the displacement values of other parts are within 20 mm.

![Figure 3. Process line of upstream inclinometer](image)

![Figure 4. Process line of downstream inclinometer](image)

4.2. **Slope groundwater level monitoring**
A total of 15 sets of pressure measuring pipes were installed on the slope. The value of the pressure gauge in each position of the pressure measuring pipe was mainly affected by the groundwater of the slope. During the rainfall, the slope water level increased and the measured value increased. From the monitoring data, the water level of the slope section on the right side of the downstream approach channel 0 + 860 is greatly affected by rainfall, which is 2.49 m, and the other parts are smaller, which is basically about 1 m.
5. Conclusion
The slope in the case study is steep, and its safety and stability directly affect the project safety of the waterway, so real-time analysis and feedback of the monitoring data is particularly important. Through wireless data collection and transmission, monitoring data analysis and safety forecast, it can better feedback the construction support effect and provide data support for the reservoir safety during the operation period, so that the management staff can evaluate its stability in following operation period. Overall, the current wireless collection equipment is running well and can provide timely and effective feedback data to provide a guarantee for the safe operation of the project.

Acknowledgments
This work was supported by Open Foundation of Changjiang survey, planning, design and Research Co., Ltd(CX2019K01), Fundamental Research Funds for the Central Public Welfare Research Institute (No. Y119002).

References
[1] Zhou C. (2013) A review of research on full life cycle safety control of high and steep slopes in hydropower projects. Journal of Rock Mechanics and Engineering. 32 (06): 1081-1093.
[2] Zhang G. (1998) Enlightenment from the accident of Malpasse Arch Dam in France. Journal of Hydroelectric Power. (04): 97-99.

[3] Zhong L. (1994) Enlightenment from the landslide event of the Vaiang Reservoir in Italy. Chinese Journal of Geological Hazards and Prevention, 1994 (02): 77-84.

[4] Yang L. (2019) Application of deformation monitoring technology in bridge monitoring. Science and Technology Innovation. (35): 126-127.

[5] Zhong S, Cao R. (1993) Safety monitoring design of the high slope of Geheyan Water Control Project. Journal of the Yangtze River Academy of Sciences. 10 (3): 73-79.

[6] Zhang J. (2007) Analysis and Evaluation of Xiaolangdi Dam Safety Monitoring System. Hohai University.

[7] Shi P, Li Y, He F, et al. (2016) Safety monitoring design of the Guoduo Hydropower Project [J]. Hongshuihe. 35 (3): 22-25.

[8] Zhang H. (2018) Monitoring design and analysis of the high bank slope on the left bank of the Guji Water Control Project. Engineering Technology Research. 27 (11): 154-155.