Comparative analysis of new technologies for dam Deformation monitoring

Xiaochen Xu[1,2]*, Xufeng Zhou[3], Dan Li[1,2], Chunhua Dai[1,2], Guochang Ge[1,2]

[1] Zhejiang Institute of Hydraulics & Estuary;
[2] Zhejiang Guangchuan Engineering Consulting Corporation, Hangzhou Zhejiang 310020;
[3] Shaoxing Shun'an Water Conservancy Project Management Co., Ltd, Shaoxing Zhejiang 312000

*Corresponding author's e-mail: 187369867@qq.com

Abstract. In order to analyze the applicability of new dam monitoring technology in dam deformation monitoring, a concrete face rockfill dam was selected, GNSS and machine vision monitoring system were arranged, and traditional monitoring methods were used for comparison. The results show that GNSS monitoring system is suitable for the displacement observation of open terrain, long-length dam or arch dam, and machine vision monitoring system is suitable for the linear dam with short dam length. It is necessary to select appropriate monitoring methods according to the specific conditions of the dam in order to meet the needs of dam deformation monitoring.

Keywords: Deformation monitoring; GNSS monitoring system; Machine vision monitoring system; Dam.

1 Introduction

At present, the surface deformation monitoring of large and medium-sized reservoir dam projects is still dominated by manual monitoring. Some reservoirs still have many shortcomings in manual monitoring methods, monitoring accuracy, reliability of monitoring instruments, analysis and processing of monitoring results, and especially manual monitoring cannot meet the requirements for intensive observation under special conditions (high water level in rainstorm, continuous monitoring before and after typhoon landing, and continuous monitoring at night), Therefore, it is necessary to achieve automated monitoring of surface deformation of reservoir dams [1] [2]. The existing automatic monitoring facilities include static dumpy level, tension line horizontal displacement meter, laser collimation system and measuring robot, etc. These monitoring facilities are not widely used due to the need for suitable topographic and geological conditions, high maintenance costs, high failure rate and high costs [3] [4].. With the development of GNSS and image recognition technology, GNSS and machine vision deformation monitoring system are gradually introduced into the field of dam monitoring, and their applicability in deformation monitoring of reservoir dam surface needs to be studied. Therefore, through the comparative analysis of the three monitoring methods

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of manual measurement, GNSS and machine vision monitoring, this paper carries out the applicability study of GNSS and machine vision in dam surface deformation monitoring, and grasps their respective application conditions.

2 Monitoring Principles

2.1 Artificial displacement monitoring

The horizontal displacement is observed using the collimation method, which measures the horizontal displacement of the displacement markers of the dam under external loads based on the connecting line of the working base points at both ends of the building. Suitable for straight dam types.

The vertical displacement is observed by the levelling method, and the displacement of the dam relative to the benchmark under the load is observed.

2.2 GNSS deformation monitoring

The principle of GNSS displacement monitoring is based on a satellite positioning system with known spatial location, using the basic principle of spatial resection to achieve absolute position of ground user terminal equipment [5] [6]. Through the data transmission system, address information is transmitted in real-time to provide displacement monitoring data for areas such as dams [7].

2.3 Machine vision displacement monitoring

The dam surface deformation monitoring system based on machine vision uses image recognition algorithm to convert video data into deformation data, realizing high-precision non-contact real-time measurement of the dam [8]. The principle is to lay the measurement target on the structure to be measured, and at the same time, install an industrial camera at the relatively stable position of the structure. The camera uses the "pinhole imaging" model to calibrate the image[9], realizing the conversion of the two-dimensional coordinates of the target displacement in the image to the three-dimensional coordinates in reality, so as to measure the vertical and horizontal two-way displacement of the measured object [10].

3 Monitoring arrangement

We select a medium-sized reservoir in Zhejiang Province as a pilot project, which is a reservoir mainly focused on flood control and irrigation, combined with comprehensive utilization of water supply, power generation, etc. The total storage capacity of the reservoir is 98.05 million m^3, and the installed capacity of the power station is 6800kW. It is a Class III project, at the same time it is a medium-sized reservoir. The dam type is a concrete face rockfill dam, with a maximum dam height of 66.5m, a dam crest length of 382m, a dam crest elevation of 148.5m, a dam crest width of 6m, and upstream and downstream dam slope of 1:1.3.

To compare the effects of GNSS and machine vision measurement, GNSS measurement points are installed at the elevation of 128.0m on the upstream and downstream slopes of the dam crest, machine vision measurement points are installed on the downstream retaining wall side of the dam crest, and manual measurement points are installed at each point for manual calibration as shown in the figure 1.

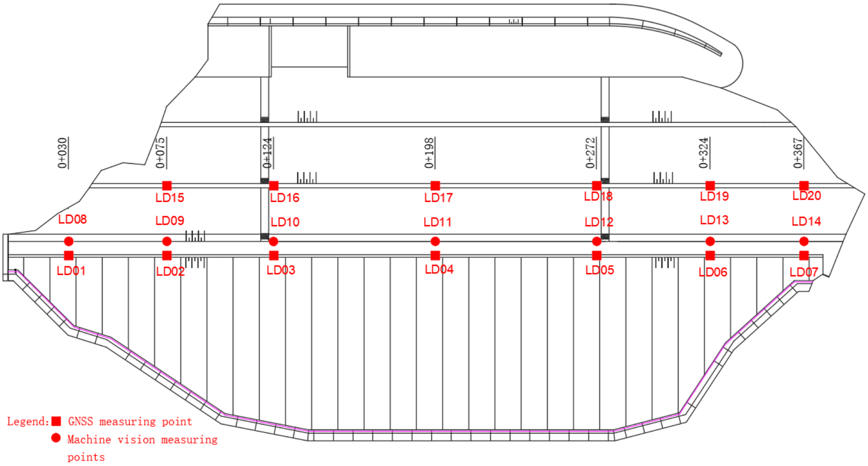

Fig. 1. Layout plan of Deformation monitoring

4 Analysis of monitoring results

4.1 Horizontal displacement

Figures 2 to 4 show the horizontal displacement hydrograph and manual comparison of GNSS measurement points on the dam crest, machine vision measurement points on the dam crest, and GNSS measurement points on the dam slope. From the figure, it can be seen that:

(1) The GNSS measurement point on the upstream side of the dam crest deforms upstream in the first half of the year, and there is a downward deformation trend in the second half of the year, mainly influenced by temperature. The upstream retaining wall has a vertical slope, while the downstream slope is a slope, as shown in Figure 5. The increase of temperature causes the downstream slope to elongate more than the upstream slope, causing the temperature increase to move towards the upstream side, and vice versa.

(2) The machine vision measurement points on the downstream side of the dam crest deform downstream in the first half of the year and upstream in the first half of the year, mainly influenced by temperature. The deformation principle is the same as that of the upstream retaining wall.

(3) The deformation trend of GNSS measurement points on the dam slope berm is not obvious, mainly due to the fact that the dam slope is filled with rockfill and is less affected by temperature and water level. After years of operation, it has basically stabilized.

(4) Both the GNSS measurement points on the dam crest and the machine vision measurement points can reflect the deformation law of the dam, and the changes in the measurement points are stable, which can meet the requirements of daily operation monitoring. Due to the steep upstream slope of 1:1.3, the GNSS measurement point on the dam slope obstructs the upstream receiving satellite signals, resulting in a significant deviation in the measurement results.

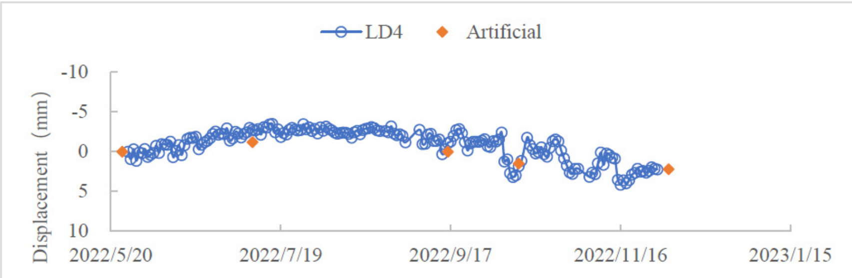

Fig. 2. Horizontal displacement hydrograph and manual comparison map of GNSS measurement point on dam crest

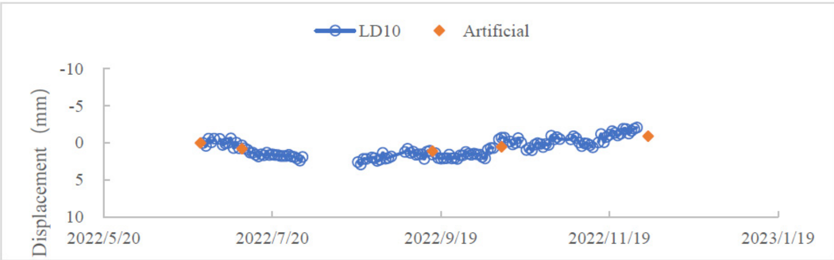

Fig. 3. Horizontal displacement hydrograph of dam crest machine vision measurement points and manual comparison map

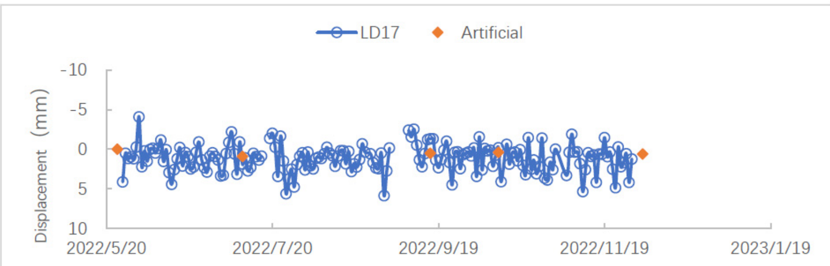

Fig. 4. Horizontal displacement hydrograph and manual comparison map of GNSS measurement point on dam slope

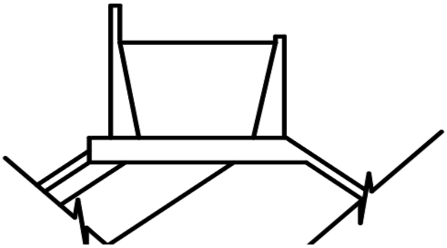

Fig. 5. Schematic diagram of dam crest structure

4.2 Settlement

Figures 6 to 8 show the settlement hydrograph and manual comparison of GNSS measurement points on the dam crest, machine vision measurement points on the dam crest, and GNSS measurement points on the dam slope. From the figure, it can be seen that:

(1) The settlement change of the GNSS measurement point on the upstream side of the dam crest is greater than the horizontal displacement change, and the manual comparison error is also large, reaching 3~4 mm.

(2) The settlement deformation of the machine vision measurement points on the downstream side of the dam crest is relatively small, and the manual measurement error is also small, with an error range of 1-2 mm. It can reflect the normal deformation of the dam and meet the needs of dam settlement deformation observation.

(3) The deviation of settlement change of GNSS measuring points on dam slope is large, and the stability of measured values is insufficient, which cannot meet the needs of deformation monitoring of dam settlement.

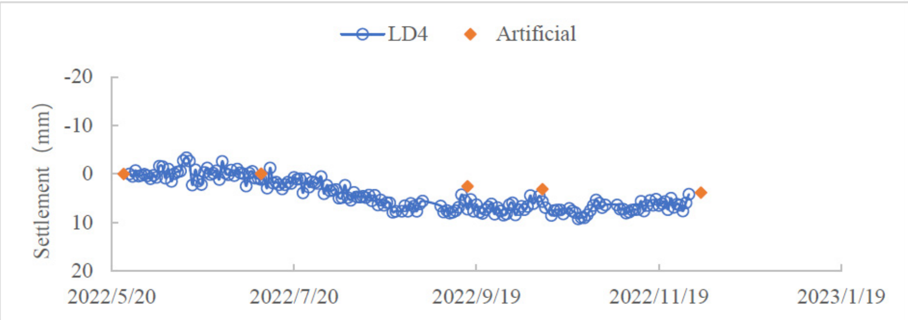

Fig. 6. Settlement hydrograph and manual comparison map of GNSS measurement points on the dam crest

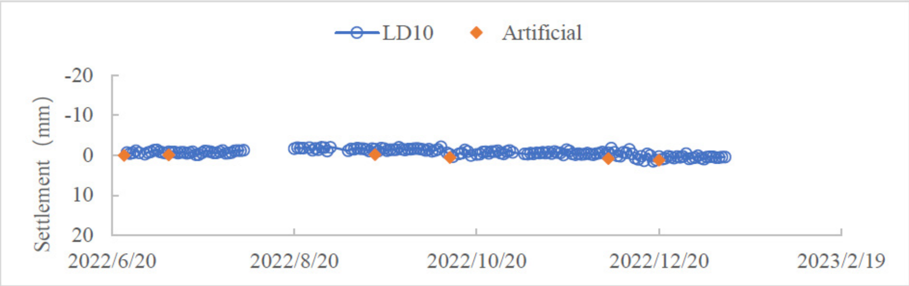

Fig. 7. Machine vision settlement hydrograph and manual comparison map at dam crest measurement points

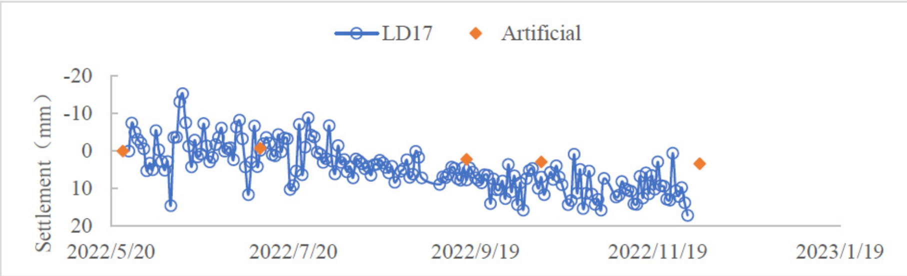

Fig. 8. Settlement hydrograph and manual comparison map of GNSS measurement point on dam slope

5 Conclusion

(1) The horizontal displacement monitoring accuracy of GNSS deformation monitoring system is higher than that of settlement monitoring. Under appropriate topographic and geological conditions, its horizontal displacement can reflect the deformation law of the dam and meet the needs of dam deformation monitoring. And it can measure three-dimensional coordinates and reflect changes in spatial position.

(2) The machine vision measurement system has high horizontal displacement and settlement accuracy, which can reflect the deformation law of the dam. However, as the monitoring distance increases, the monitoring accuracy will decrease, and can only measure displacement in two directions. It is not suitable for situations such as arch dams that require observation of displacement in three directions.

In summary, GNSS measurement points are suitable for displacement observation of open terrain, long-length dams, or arch dams. The machine vision monitoring system is suitable for linear dams with shorter dam lengths. It is necessary to select appropriate monitoring methods according to the specific conditions of the dam in order to meet the needs of dam deformation monitoring.

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