Real time monitoring of dams in dam daily management taking Xianlin Reservoir as an example

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Abstract. The safety monitoring is vital to the dam daily management. The real time monitoring of dams make it possible for the administrative to get first time data and make decisions when abnormal condition happens. Xianlin reservoir uses a modern remote monitoring system to collect real time data of the dam to manage the reservoir. Administrative can get warning if inappropriate situation happens through the system and the people on duty can also get the message. A smart analyzing system can also collect abnormal information such as damage of equipment like lightning strike. Besides, people can observe the real time situation of the dam in the control room though the screen. Simple analysis can be made in the system to help administrative to realize the whole situation of the reservoir. It helps ensure the safety of the dam and behave correctly in the daily management.

1. Introduction

Concrete faced rockfill dam is supported by rockfill and using concrete panels to avoid seepage. Concrete faced rockfill is of high safety and easy to construct. So it has become first choice for many constructions. There are a lot of concrete faced rockfill dams in china. It is vital to ensure that the dams can operate safely and effectively.

This passage, taking xianlin reservoir as an example, introduces the remote and smart monitoring equipment and system that produce reliable data for the engineers. Using the data, administrators are able to predict the displacements, seepage situation as well as internal forces trending. If there is anything abnormal happens, the remote monitoring system will show it on the monitoring system and inform administrators.

Xianlin Reservoir is the urban emergency water source of Hangzhou with a function of standby water supplement as well as improving water environment for the surroundings. The total storage is 19.84 million m$^3$ and the outlet tunnel has a max flow of 25m$^3$/s. The whole project mainly contains a concrete faced rockfill dam, two side dams, outlet tunnel and Dadaoshan pump station.

2. The monitoring sensors of Xianlin Reservoir

As illustrated in the figure 1, the Xianlin reservoir contains the dam displacement monitoring points, concrete panel strain and stress monitoring equipment and the dam seepage monitoring equipment.
2.1 The dam displacement monitoring points
The lateral displacement of the dam is measured using collimation line method. Two measuring lines are set in the two sides of the road on the top of the dam. There are 10 measuring points along with 4 lateral measuring base points which are corrected by 4 correcting base points.

The vertical displacement of the dam is measured using leveling method. Four measuring lines are set on the bank which contains 18 measuring points in total.

The displacement is measured routinely by the administrative and report to the manager in charge. If there is anything abnormal, actions will be taken toward it.

2.2 The concrete panel strain and stress monitoring equipment
Since the surface displacement is measured discontinuously, the measurement of internal strain and stress is vital to ensure the safety of the dam. So, sensors including 5 reinforcement meters, 2 sets of double-directed strain meter, a set of triple-directed strain meters and 3 sets of zero stress-strain meter are installed in the stake mark 0+134.00 to monitor the stress and stain inside the panel. All the sensors are connected to a microprogrammed control unit (known as MCU) and transmit the data to the control room. Administrative can get the real time data through the system.

2.3 The dam seepage monitoring equipment.
To examine the anti-seepage ability of the dam, osmometers are installed inside the dam. Osmometers are placed in the largest section of the dam. Eight osmometers are placed inside the dam to monitor the seepage situation inside the dam. Besides, a measuring weir is installed behind the dam to monitor the seepage amount though the dam body. All the data can be transmitted to the monitor system wirelessly for the administrative.
3. Remote monitor and management system
As talked above, the sensors are connected to MCU and MCU transmit signal to the control room wirelessly. The control system which is shown as fig. 2 have several components to help the administrative manage the dam.

Fig2. Linking and layout of the remote monitor and management system
As illustrated in the plot, five monitoring stations are established around the dam which are adit at right band DB1, adit at left band DB2, huijian auxiliary dam monitoring station, Shangtangnong monitoring station as well as a seepage weir monitoring station. 10 modules along with 73 sensors are linked though these stations to the control room by GPRS wirelessly. As the table one shows, sensors are linked to the stations and then send the data to the control room. People can get the data through computers as well as smartphones. Besides, a preliminary analysis will be made for the administrative to understand the condition of the dam.

The monitoring station in the main dam are powered by 220V electricity. The Huijian auxiliary dam and the Shangtangnong monitoring station are powered by solar energy panel and accumulator as back energy source.

Table 1. Linking instruments of adit at left bank

| No | Number of Module | Model of Module | Number of Tunnel | Instrument Design number | Type of instruments       |
|----|------------------|-----------------|------------------|--------------------------|--------------------------|
| 1  | 1                | vibrating wire  | 0101             | P2                       | Osmometer                |
| 2  |                  |                 | 0102             | UP1                      | Piezometer tube          |
| 3  |                  |                 | 0103             | UP2                      | Piezometer tube          |
| 4  |                  |                 | 0104             | UP3                      | Piezometer tube          |
| 5  |                  |                 | 0105             | UP7                      | Piezometer tube          |
| 6  | 2                | potentiometer   | 0201             | J3F1-1                   | Three-direction jointmeter |
| 7  |                  |                 | 0202             | J3F1-2                   | Three-direction jointmeter |
| 8  |                  |                 | 0203             | J3F1-3                   | Three-direction jointmeter |
| 9  |                  |                 | 0204             | J3F2-1                   | Three-direction jointmeter |
| 10 |                  |                 | 0205             | J3F2-2                   | Three-direction jointmeter |
| 11 |                  |                 | 0206             | J3F2-3                   | Three-direction jointmeter |
| 12 |                  |                 | 0207             | J1                       | Singe-direction jointmeter |
| 13 |                  |                 | 0208             | J2                       | Singe-direction jointmeter |
4. Analysis of the monitoring data though operation period

The Xianlin reservoir tried operating in June 2015 and started to operate in April 2016. The dam has been operated safely over three years. As there are so many sensors in the dam, we only choose some typical sections to do the analysis.

4.1 Typical displacement analysis

As for the displacement, we choose the height of 70.4m to analyze. As the data show, the points in different location coordinate with each other. After the construction period, the displacement rate is fairly low. The lateral displacement of the dam is little and coordinate as well. After the construction period, the dam does not move too much. The largest displacement happens at the 0+080 place which is as large as 43.2mm from construction period. The displacement occurs recently is fairly small.

4.2 Typical dam stress and strain analysis

In the concrete panel stress analysis, we choose the 13rd panel to analyze since there were cracks found in this panel. The effective total strain corresponds to the temperature which indicate that the change of the strain in the panel is driven by the concrete hydration heat as well as the surrounding temperature change. It performs as compressing stress when the temperature rise. On the contrary, the panel behave pulling stress when the temperature decrease. In total, the sensors work correctly. The crack has been repaired and additional sensors are placed around the crack. The data are normal now.

4.3 Dam seepage analysis

4.3.1 Dam body seepage analysis

Dam have osmometers to monitor the internal seepage condition. Water pressure stays low while the water table has changed. This indicate that the change in the water table has little influence on the osmometer and then prove that the purdah has good function.
4.3.2 Dam seepage amount analysis
The dam uses a seepage weir to calculate the amount of water that seepage though the dam body. The amount changes due to a water table change as well as rainfall. Before the water was stored, the seepage is about 0.22 L/S. Along with the rise of water table, the seepage amount has increased to about 1.37 L/S which does not increase much. The seepage condition of the dam is relatively good according to the monitoring history.

5. Conclusion
The Xianlin reservoir has been operated about four years. The remote monitoring system helps the administrative to operate the reservoir safely. The smart analysis system gives the administrative first-time data and preliminary analysis.

In general, the Xianlin concrete faced rockfill dam is operating safely. The displacement is relatively small, and the internal stress stays at a low level. The seepage through the dam body is small which indicate the purdah has a good effect. The amount that water seepage through the dam body does not increase much with the rise of water table.

The remote monitoring and smart analyzing system is very meaningful for the daily management of the dam. Administrative can get the information at first time which lower the risk and save the valuable time if something abnormal happens.

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