Safety state monitoring analysis of seepage from Daban Reservoir

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Abstract: To understand the seepage security state of Daban Reservoir dam, process line analysis, correlation analysis, infiltration slope drop analysis and permeability analysis were conducted on the seepage monitoring data, and single-factor and multivariate statistical models were established to demonstrate the influencing factors of the pipe water level. The results show that the dam is generally effective in preventing seepage, the change in seepage flow before and after the seepage wall is not significant, the measured infiltration line is higher than the design value, and the correlation between the pipe water level and the reservoir water level is significant. 2020 flood season seepage occurs on the downstream slope of the dam, the height is higher than the top elevation of the drainage body, the actual operation results verify the accuracy of the analysis of the monitoring data and there is a seepage flow safety hazard. It is recommended that measures be taken to eliminate potential seepage hazards and to strengthen safety monitoring and surveillance.

1. Introduction

Daban Reservoir is located in the upstream of Daban River in Longquan River Basin of Poyang Lake System, which is a medium-sized reservoir mainly for flood control and irrigation, combined with power generation, breeding and other comprehensive use, mainly composed of dam, spillway, water transmission tunnel, power station behind the dam, etc. The reservoir basin area is 45km², with a total capacity of 1727×10⁴m³, normal storage level of 64.80m, design flood level of 67.24m, and calibrated flood level of 68.11m. The top axis of the dam is 360m long, the top width is 7m, the maximum dam height is 28.70m, and the top elevation is 72.70m. The dam has been expanded several times, and the dam structure is complex, see Figure 1: Below 60.10m elevation is a homogeneous dam; from 60.10 to 66.05m elevation is a clay sloping wall dam; from 66.05 to 72.70m elevation is a clay core wall dam; from 2008 to 2011, the core wall and the dam base were reinforced with "concrete impermeable wall and dam base curtain grouting" anti-seepage reinforcement plan. The upstream slope of the dam is concrete hexagonal block slope protection, the downstream is turf slope protection, and the foot of the dam is equipped with slope counter-filter drainage, the top elevation of the drainage body is 54.00m, and the top elevation of the drainage ditch at the foot of the dam is 50.00m. The clay core wall, clay slope wall and homogeneous dam are mainly heavy powder loam, with low compactness, and the joint
surface of the dam is not treated when the dam is raised, so the overall seepage control effect is poor; the backwater slope of the dam is mainly gravel, with uneven filling and many voids; the dam body is not thoroughly cleared and is in contact with the lower strongly weathered bedrock, and there are gravel and other permeable interlayers, which is unfavorable to the seepage control of the dam[1].

This paper analyzes the seepage monitoring data of the pressure tube from 2012 to 2014 and three observations from 2019 to 2020 after the end of the de-risking and strengthening in 2011 to evaluate the seepage flow pattern of the dam.

2. Seepage monitoring facilities arrangement
In 2011, four monitoring sections were set up at 0+40, 0+125, 0+170 and 0+280, as shown in Figure 2. 19 pressure measurement tubes were placed in each section before and after the seepage control wall, at the 66m elevation of the downstream slope of the dam, at the 58m elevation of the dam and at the foot of the dam, with the bottom of the tubes drilled to the bedrock surface at an elevation of 45.20m, as shown in Figure 1.

3. Analysis of monitoring information
3.1 Seepage process line analysis
The trend of water level change of the pressure measuring tube in each section shown in Figure 3 is basically consistent with the reservoir water level, and the change of the tube water level is smaller than that of the reservoir water level with a lag. The water level of the tube gradually decreases from upstream to downstream, which is in line with the seepage law of earth and rock dams. The measurement points in front of the seepage control wall are affected by the change of water level, in which the value of No. 6 pressure measurement tube at section 0+125 and No. 11 pressure measurement tube at section 0+170
are almost the same as the reservoir water level, which indicates that the permeability of the dam is larger in front of the seepage control wall at the two sections.

Fig.3 Seepage pressure water level process line at each section

3.2 Correlation Analysis
From the correlation between the reservoir water level and the tube water level Table 2 shows that the correlation coefficients of all pressure measuring tube water level and the reservoir water level are greater than 0.6. The correlation coefficients of the measurement points before and after the impermeable wall of 0+040, 0+125, 0+170 and 0+280 and the reservoir water level are 0.823 and 0.684, 0.988 and 0.808, 0.986 and 0.959, 0.988 and 0.906, respectively, although The correlation of No.3, No.4 and No.5 pressure tubes in dam section 0+40 is larger than that of No.1 and No.1, except for the influence of rainfall factor, it may be the contact leakage between the seepage control system and the tooth wall connection part of the spillway retaining wall. There have possible bypass leakage.

| Point No. | Correlation coefficient $R$ | Point No. | Correlation coefficient $R$ | Point No. | Correlation coefficient $R$ | Point No. | Correlation coefficient $R$ |
|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|
| 1#        | 0.764                      | 6#        | 0.988                      | 11#       | 0.986                      | 16#       | 0.988                      |
| 2#        | 0.684                      | 7#        | 0.808                      | 12#       | 0.959                      | 17#       | 0.906                      |
| 3#        | 0.847                      | 8#        | 0.878                      | 13#       | 0.886                      | 18#       | 0.849                      |
| 4#        | 0.774                      | 9#        | 0.724                      | 14#       | 0.793                      | 19#       | 0.912                      |
| 5#        | 0.799                      | 10#       | 0.646                      | 15#       | 0.616                      |           |                            |

3.3 Infiltration slope drop analysis
The infiltration slope drop of each pressure measurement tube, as projected from the safety monitoring data of the pressure tube from 2012 to 2014, is shown in Table 2, which is smaller than the allowable infiltration slope drop, and the infiltration slope drop of the downstream slope of each section is small and does not change much under high and low water levels, indicating that the dam is mainly protected by the seepage control system composed of seepage control walls. 0+125 section and 0+170 section have a larger infiltration slope drop before and after the impermeable wall under high water level, which indicates that the impermeable wall of this dam section has a better impermeable effect: 0+280 dam
section has the smallest infiltration slope drop before and after the impermeable wall, which indicates that the impermeable wall at this dam end has a poor impermeable effect.

### Tab.2 Dam infiltration slope drop

| Cross-section | High water level infiltration slope drop | Low water level infiltration slope drop |
|---------------|----------------------------------------|---------------------------------------|
|               | Before and after impermeable wall | Downstream slope | Before and after impermeable wall | Downstream slope |
| 0+40          | 0.80 | 0.08 | 0.73 | 0.08 |
| 0+125         | 1.47 | 0.09 | 1.03 | 0.08 |
| 0+170         | 0.96 | 0.11 | 0.52 | 0.09 |
| 0+280         | 0.39 | 0.09 | 0.15 | 0.06 |

### 3.4 Statistical model analysis

#### 3.4.1 Model expressions

According to the analysis of the process line between the pressure measurement tube and the reservoir water level, the pressure measurement tube is affected by the reservoir water level is relatively significant, while rainfall also has a certain impact on the pressure measurement tube water level, the amount of rainfall, a long period of time, the reservoir water level rises, the pressure measurement tube water level rises, the pressure measurement tube water level is also affected by temperature and timing factors. In this analysis, the expressions of the statistical model of Daban Reservoir established by several influencing factors such as reservoir water level change factor ($H_i$), late back factor of water level at measurement points ($H_{i-1}$), and time-effective factor ($t$) are

$$h = C_0 + C_1 H + C_2 H^2 + C_3 H^3 + C_4 H_{i-1} + C_5 H_{10} + C_6 H_{15} + C_7 H_{20} + C_8 H_{25} + C_9 H_{30} + C_{10} H_{35} + C_{11} H_{40} + C_{12} H_{45} + C_{13} H_{50} + C_{14} H_{55} + C_{15} H_{60} + C_{16} P + C_{17} P_i + C_{18} P_5 + C_{19} P_{10} + C_{20} \ln(t + 1) + C_{21} \sin\left(\frac{2\pi t}{365}\right) + C_{22} \cos\left(\frac{2\pi t}{365}\right)$$

In the formula: Constant term $C_0$, Regression coefficient $C_i$($i=1~22$); Reservoir level on that day $H$, Average of reservoir level before day $i$ $H_{i-1}$; Rainfall of the day $P$, Average of previous $i$-day rainfall $P_i$; Timing factor $t$ (The number of days from the beginning of water storage or the starting measurement date is multiplied by 0.01).

The statistical model was calculated for the period from March 31, 2012 to November 1, 2014, with a total of 1577 groups of sample points. In this paper, five pressure measuring tubes of section 0+40 are used as an example for calculation, and the regression coefficients of the statistical model are shown in Table 3. from the table, it can be obtained that the constant terms of the statistical model of five pressure measuring tubes of section 0+40 are positive, the water level of tube 2 is negatively correlated with the primary side of the reservoir water level, and tubes 1, 3, 4 and 5 are positively correlated with the primary side of the reservoir water level; the water level of tube is not correlated with the secondary side of the reservoir water level, and tube 1 is negatively correlated with the tertiary side of the reservoir water level. The higher the secondary side of the reservoir water level, the smaller the coefficient of the significance level influence factor, indicating that the pressure measuring tube water level and the primary side of the reservoir water level are closely related, while the coefficient of the daily average reservoir water level factor from 5 to 60 days before the previous reservoir water level has positive and negative, indicating that the previous reservoir water level has a late influence on the pressure measuring tube water level; the coefficients of the rainfall factor are all positive, which is consistent with the influence of the rainfall factor on the pressure measuring tube water level, and the time-effective component is negative, indicating that the efficiency of the dam is gradually Siltation, impermeable conditions gradually improve; temperature factor is positively correlated, consistent with the law of seepage movement.
### Tab.3 Table of regression coefficients for the statistical model for section 0+40

| Regression coefficient | 1<sup>st</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> | 4<sup>th</sup> | 5<sup>th</sup> |
|------------------------|--------------|--------------|--------------|--------------|--------------|
|                        | V            | R            | V            | R            | V            |
| C0                     | 39.90        | 53.40        | 43.17        | 44.54        | 0.00         |
| C1                     | 1.58         | 0.76         | 0.26         | 0.69         | 0.23         |
| C2                     | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C3                     | -0.15        | 0.00         | 0.05         | 0.68         | 0.00         |
| C4                     | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C5                     | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C6                     | 0.00         | 0.00         | -0.27        | 0.70         | -0.15        |
| C7                     | 0.00         | 0.00         | 0.48         | 0.72         | 0.15         |
| C8                     | 0.00         | 0.00         | -0.26        | 0.68         | 0.00         |
| C9                     | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C10                    | 0.00        | 0.47         | 0.59         | 0.32         | 0.64         |
| C11                    | 0.00         | 0.39         | 0.53         | 0.00         | 0.00         |
| C12                    | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C13                    | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C14                    | -0.50        | -0.21        | 0.00         | 0.00         | 0.00         |
| C15                    | 0.43         | 0.22         | 0.05         | 0.35         | 0.00         |
| C16                    | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C17                    | 0.00         | 0.00         | 0.06         | 0.00         | 0.00         |
| C18                    | 0.00         | 0.00         | 0.01         | 0.21         | 0.00         |
| C19                    | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C20                    | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |
| C21                    | 0.00         | 0.00         | 0.64         | 0.85         | 0.13         |
| C22                    | 0.00         | 0.00         | 0.00         | 0.00         | 0.00         |

#### 3.4.2 Statistical model fitting effect

Figure 4 shows the statistical model fitting diagram of the five pressure tube pipe water level at section 0+40, combined with Table 3, it can be seen that: among the factors excluding the temperature factor, the highest primary correlation coefficient of the reservoir water level; in the late time, the simple correlation coefficient of the daily average reservoir water level factor from the first 5 to 60 days can be seen that only two simple correlation coefficients exist for the first pressure tube, followed by the second and third pressure tube 5 to 60 days average reservoir water level. The number of simple correlation coefficients for the second and third pressure measurement tubes is higher, including 6 for the second one and 5 for the third one, indicating that the lagging factor of the pressure measurement tubes behind the dam has obvious influence and is the main source of error in the model fitting values. In addition, other factors such as rainfall of rainfall will have some influence on the fourth and fifth gauging tube water level, and there are also factors such as temperature and time lag will also cause errors on the gauging tube water level, but in general, these factors will not play a big role.
4. Analysis of the effect of impermeable system

Three on-site measurements of the pressure tube level were carried out from 2019 to 2020, and the measurement results and the potential of the measurement points of each section are shown in Table 4. The pressure measuring tube potential on both sides before and after the seepage control wall decreased less, and the pressure measuring tube potential after the seepage control wall was higher than the design value in general, and the seepage control effect did not reach the design expectation.

In July 2020, when the highest reservoir water level reached 66.42m, the dam foot drainage ditch turned sand and water, the left and right sides of the dam in the prismatic drainage above the escape, consistent with the conclusions obtained from the analysis of monitoring data. Using the flood monitoring data of the 0+40 section and the flood escape elevation of the 0+24.8 section (56.10m), the infiltration line of the 0+24.8 section in the flood reservoir water level of 66.42m is projected in Figure...
5(a); using the flood monitoring data of the 0+170 section and the 0+280 section and the seepage elevation behind the 0+234 section (55~57m), the infiltration line of the 0+234 section in the flood reservoir water level of 66.42m is projected. The infiltration line at 66.42m is shown in Figure 5(b). The infiltration line of the dam body at section 0+24.8 and section 0+234 and the elevation of the downstream slope escape point are significantly higher than the design value, which is consistent with the actual operation. Under high water level, the infiltration line of 0+24.8 section and 0+234 section is higher than the slope drainage, and the infiltration stability does not meet the specification requirements.

5. Conclusion
The analysis of the seepage monitoring data of the reservoir from 2012 to 2014 and the field measurement data from 2019 to 2020 shows that the pressure tube water level is mainly affected by the upstream water level, and the influence of rainfall, temperature and timing is small, dam containment system is not effective in preventing seepage, there may be contact leakage on the right side of the dam at the connection with the spillway retaining wall, there may be seepage around the dam on the left side of the dam, and there is a potential risk of seepage damage to the dam. The phenomenon proves the accuracy of the analysis of monitoring data, the analysis of monitoring data can be found in a timely manner the safety of the dam, while effective measures should be taken to eliminate the seepage potential, and continue to strengthen the monitoring and monitoring of the safety of the dam.

References
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