Discussion on Construction Analysis of Concrete Computer Intelligent Temperature Monitoring

Mengmeng Li

1 City Institute Dalian University of Technology, Dalian, Liaoning, China, 116600

*Corresponding author e-mail: mengmeng@dlut.edu.cn

Abstract. In order to effectively monitor the temperature changes of the concrete during the construction phase, to avoid cracks caused by temperature. An intelligent computerized temperature monitoring method for concrete is proposed. Through the computer intelligent temperature monitoring system, the temperature changes during the construction phase can be obtained to better map the temperature distribution. The experimental results show that the computer-based intelligent temperature monitoring method for concrete proposed in this paper can effectively monitor the change of concrete temperature.

Keywords: Construction Period, Concrete, Arch Dam, Temperature, Data Analysis

1. Introduction

With the rapid economic development, various tall buildings or structures emerge in an endless stream\(^{1, 2}\), and various mass concrete components have been widely used. In the construction of mass concrete, temperature monitoring is very important, through temperature monitoring\(^{3, 4}\). Take necessary maintenance measures to prevent temperature cracks in concrete and ensure the quality of mass concrete construction. Computer intelligent temperature measurement and monitoring technology is a fully automated computer temperature measurement and monitoring, convenient and accurate\(^{5}\). It provides convenient and reliable guarantee measures for the construction of large-volume concrete, and has a high promotion and application value\(^{6}\).

This paper proposes a new method of analyzing the monitoring data of the computer intelligent temperature monitoring system for concrete arch dams. The computer intelligent temperature monitoring is analyzed from the three aspects of the change law and characteristics of the measured value of the computer intelligent temperature monitoring system, temperature difference and temperature field. The system monitoring data more reasonably reflects the temperature behavior of the concrete arch dam during the construction period. The example results show that the computer intelligent temperature monitoring system is arranged reasonably and the temperature control measures are effective. This method has guiding significance for the construction of concrete arch dams.

2. Analysis method
2.1. The changing laws and characteristics of the measured values of the computer intelligent temperature monitoring system

Analysis of computer intelligent temperature monitoring system data, statistics of corresponding characteristic values, and analysis of change laws can all evaluate the dam temperature field conditions. The change pattern of the measured value of the computer intelligent temperature monitoring system can also be seen visually and intuitively. The temperature change process of the temperature measured at each measuring point of the concrete arch dam during the construction process provides a basis for further formulation and modification of temperature control measures. The characteristic values such as the maximum temperature, the minimum value, and the amplitude of the temperature are analyzed to analyze the design requirements of the characteristic value. Therefore, the change law and characteristics of the measured value of the computer intelligent temperature monitoring system are the basis of the temperature data analysis of the concrete arch dam.

2.2. Temperature difference analysis

According to the causes and laws of mass concrete cracks, the temperature control standard of the dam block is mainly realized by limiting the temperature difference between the foundation, the temperature difference between inside and outside, and the temperature difference between the upper and lower layers. Therefore, in temperature monitoring, the occurrence of dam cracks can be judged by the design standard of temperature difference.

The basic temperature difference refers to the difference between the maximum temperature of the concrete and the stable temperature or quasi-stable temperature in the foundation confinement area within the height range of the pouring block 0.4L (L is the length of the pouring block). The control of the temperature difference of the foundation is to prevent the temperature of the foundation of the dam from being too high, and the larger temperature stress caused by the restriction of the foundation when the temperature is lowered causes the foundation to penetrate the crack. The basic allowable temperature difference is:

\[
\Delta T = [\overline{(1 - \mu)\sigma}][R(y)E\alpha K_p K]
\]

In the formula, \(\mu\) is the Poisson's ratio of concrete; \(\sigma\) is the 28d strength of concrete age; \(R(y)\) is the foundation restraint coefficient of different elevations, which can be obtained from the literature look-up table; \(E\) is the concrete elastic modulus; \(\alpha\) is the linear expansion coefficient of concrete; \(K_P\) is the concrete creep relaxation coefficient; \(K\) is the safety factor. The internal average temperature and surface of the dam body or cast block concrete

The temperature difference is called the temperature difference between the inside and outside of the concrete. Controlling the temperature difference between inside and outside can prevent surface cracks. The temperature difference between inside and outside is:

\[
T_o = 3\sigma/(2K_pE\alpha)
\]

When continuous pouring is continued on the old concrete surface with the age of the foundation confinement zone exceeding 14d or the age of leaving the constraint zone exceeding 21d, the newly poured concrete within 1/4L above the old concrete surface is controlled according to the temperature difference between the upper and lower layers, and the temperature difference between the upper and lower layers is the new and old. The temperature difference of concrete stipulates that the allowable temperature difference between the upper and lower layers of concrete is 15-20°C.

2.3. Temperature field analysis

In order to study the distribution and change law of the temperature field inside the dam, the isotherm diagram in the concrete dam is drawn according to the measured value of the computer intelligent temperature monitoring system. The method is to spatially interpolate the discrete temperature measurement values, and then draw isotherms, and determine the working behavior of the dam from...
the spatial distribution of the temperature field.

3. Examples

3.1. Project overview and basic information

A hydropower station is located in the middle reaches of the Lancang River at the junction of Nanjian County and Fengqing County in the west of Yunnan Province, 1.5km downstream of the intersection of the main stream and the tributary Heihui River. The hydropower station pivot project consists of a concrete double-curved arch dam, a cushion pond behind the dam and a second dam, a spillway on the left bank, and an underground water diversion and power generation system on the right bank. Concrete double-curved arch dam crest elevation is 1245m, dam foundation floor elevation is 953m, dam crest length is 901.8m, arch crown beam crest width is 12.0m, bottom width is 72.9m, and maximum dam height is 292.0m. The scale of the project is large and the construction technology is complex. Temperature control and crack prevention have become the key to restricting the construction quality and schedule of the project. This paper only analyzes and studies the temperature monitoring data of the key monitoring dam section of the arch dam (#22). The monitoring arrangement of the computerized intelligent temperature monitoring system of #22 dam section is shown in Figure 1. The concrete Poisson ratio of the project is 1/6; the concrete age is 28d and the strength is 1.8MPa; the concrete elastic modulus is $2.592 \times 10^4$ MPa; the concrete linear expansion coefficient is $10 \times 10^{-6}$; the concrete creep relaxation coefficient is 1/2; the safety factor is 1.3.

![Figure 1. #22 dam section temperature detection layout (unit: m).](image)

3.2. The law and characteristics of the measured value change of the computer intelligent temperature monitoring system

The concrete temperature time process line is drawn from the monitoring data of the computer intelligent temperature monitoring system (Figure 2). Figure 2(a) is the first and second phase cooling process lines, and Figure 2(b) adds the mid-term cooling process line.

It can be seen from Figure 2(a) that the concrete temperature has gone through five stages: ①The first cooling stage. After the concrete is poured, the temperature gradually rises due to the heat of hydration. When the maximum temperature is reached, the water pipe cools and the temperature gradually decreases. Due to the rapid temperature drop, a few temperature drop rates exceed the design maximum temperature drop rate by 1℃/d; ②The end of the cooling Before the start of the second cold process. The temperature of all computerized intelligent temperature monitoring systems rebounded to varying degrees, with an average rebound of about 4.71℃; ③The second stage of cooling. With the implementation of cooling, the temperature gradually decreases, and the temperature drop is relatively rapid. A few temperature drop rates exceed the design maximum temperature drop rate by 1℃/d; ④The secondary cooling ends to the arch grouting process. The temperature rebounded
to a certain extent; ⑤ The temperature gradually stabilized after the rebound.

It can be seen from Figure 2(b) that the concrete temperature goes through four stages: ① The first cooling stage. The change rule is the same as that in Figure 2(a), but the maximum temperature exceeds the design allowable maximum temperature, indicating that the first-stage cooling control is poor, and it is recommended to start the first-stage cooling in time; ② The intermediate cooling stage. After the first cooling, in order to prevent the temperature from rising and reducing the temperature difference between the inside and outside, a medium-term water cooling was carried out. The temperature drop was relatively slow, and the temperature drop rate did not exceed the designed maximum temperature drop rate of 0.5 °C/d, but about 85% of the computerized intelligent temperature monitoring system The readings are not within the design allowable temperature range (18~20 °C). The water supply lasted about 2 months on average. It can be seen that the cooling effect of the medium-term water supply is poor. It is recommended to strengthen management and strictly control the water temperature and duration; ③ The second-phase cooling stage. The temperature drop is obviously slow, the temperature drop rate is lower than the design maximum temperature drop rate 0.5 °C/d, and the average water flow lasts about 3 months; ④ The concrete temperature tends to stabilize after cooling.

Figure 2. #22 dam section computer intelligent temperature monitoring system process line.

3.3. Temperature difference analysis

(1) Basic temperature difference control. Substituting the basic parameters and data into equation (1) can get the basic allowable temperature difference of different elevations. The calculation results are shown in Table 1. It can be seen from the table that the temperature control of the basic temperature difference can meet the basic allowable temperature difference requirements.

Table 1. Basic temperature difference statistics table.

| Elevation/m | Temperature/°C | Temperature difference/°C |
|-------------|----------------|--------------------------|
|             | Highest        | Stable                   | Basis | Basic permission |
| 955.25      | 24.6           | 21.1                     | 3.5   | 12.0            |
| 959.00      | 27.9           | 20.9                     | 7.0   | 14.0            |
| 974.75      | 28.6           | 20.1                     | 8.5   | 17.0            |

(2) Internal and external temperature difference control. Substituting the basic parameters and data into equation (2), the temperature difference between inside and outside T0=20.7 ⁰C is obtained by
calculation. Two intelligent computerized temperature monitoring systems T-15 and T-13 inside and outside at 974.8m elevation are selected, and the observation results and the temperature difference between inside and outside are plotted in Figure 3. It can be seen from the figure that the temperature difference between inside and outside meets the requirements.

Figure 3. The measured temperature difference between inside and outside at an elevation of 974.8m.

(3) Temperature difference control between upper and lower layers. Table 2 is a statistical table of temperature difference between upper and lower layers. It can be seen from the table that all meet the requirements of the specification.

Table 2. Statistical table of temperature difference between upper and lower layers.

| Pouring date | Elevation/m | Fresh concrete temperature/℃ | Average most | Lower average | Temperature difference between upper and lower layers |
|--------------|-------------|-------------------------------|--------------|--------------|------------------------------------------------------|
| 2006-02-09   | 955.4       | 24.63                         | 21.05        | 3.58         |
| 2006-04-04   | 959.1       | 27.58                         | 20           | 7.58         |
| 2006-06-23   | 947.9       | 28.18                         | 22.6         | 5.58         |
| 2006-10-27   | 1004.7      | 25.53                         | 14.14        | 11.39        |
| 2007-02-03   | 1030.1      | 20.46                         | 12.7         | 7.76         |
| 2007-09-05   | 1061.4      | 28.53                         | 16.8         | 11.73        |
| 2007-12-03   | 1085.1      | 25.42                         | 15.27        | 10.15        |
| 2008-03-23   | 1111.6      | 23.21                         | 18.02        | 5.19         |
| 2008-05-23   | 1123.8      | 25.91                         | 23.6         | 2.31         |
| 2008-07-07   | 1136.9      | 33.03                         | 23.5         | 9.53         |
| 2008-12-12   | 1159.1      | 26.31                         | 15.37        | 10.94        |

4. Conclusion
The use of concrete computer intelligent temperature monitoring in the concrete construction process can complete the temperature during concrete construction. The proposed computerized intelligent temperature monitoring method for concrete arch dams can accurately reflect the concrete temperature changes during construction. The experimental results show that the construction technology has the advantages of advanced equipment, high degree of automation, advanced technology, accurate temperature monitoring, convenient construction and fast installation speed.

References
[1] Salazar, F., & Toledo, M. A. (2015). Discussion on "thermal displacements of concrete dams: accounting for water temperature in statistical models". Engineering Structures, 171(SEP.15), 1071-1072.
[2] Zhou, H., Zhou, Y., Zhao, C., Wang, F., & Liang, Z. (2018). Feedback design of temperature control measures for concrete dams based on real-time temperature monitoring and construction process simulation. KSCE Journal of Civil Engineering, 22(5), 1584-1592.
[3] Su, H., Li, J., Hu, J., & Wen, Z. (2013). Analysis and back-analysis for temperature field of concrete arch dam during construction period based on temperature data measured by dts.
IEEE Sensors Journal, 13(5), 1403-1412.

[4] Danping, Z., & Jin, D. (2011). The data mining of the human resources data warehouse in university based on association rule. Journal of Computers, 6(1), 139-146.

[5] Xie, J., & Yan, J. B. (2018). Experimental studies and analysis on compressive strength of normal - weight concrete at low temperatures. Structural Concrete, 19(4), 1235-1244.

[6] Yangbo, L., Dahai, H., & Jianshu, O. . (2012). Fast algorithms of the simulation analysis of the thermal stresses on concrete dams during construction periods. Physics Procedia, 24(Part B), 1171-1177.