Temperature analysis of concrete gravity dam of Qianming Reservoir in China during construction

Shenghui Chen[1], Leilei Xue[2*], Xiaochen Xu[2]

[1] Jinyun County Water Conservancy Bureau, LiShui Zhejiang 321400;
[2] Zhejiang Guangchuan Engineering Consulting Corporation, Hangzhou Zhejiang 310020;

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

Abstract. In order to study the temperature process of concrete gravity dam in Qianming Reservoir during construction, temporary temperature monitoring was carried out. The reliability of the temperature monitoring data obtained by the dam permanent temperature monitoring system, such as the temperature during the construction period, the concrete temperature record of the construction unit and the local temperature history record, is demonstrated and some basic understandings are obtained. At the same time, according to the monitoring data analysis, put forward some concrete crack prevention measures. The main conclusions are as follows: (1) Temperature after embedding and maximum temperature of dam section 7# and 14# are higher than those of 8# and 11#, but the temperature rise of 8# and 11# is higher than that of 7# and 14#, The temperature difference in dam section 7# and 14# is the largest, while the temperature difference between dam section 8# and 11# is small. (2) After concrete pouring, the temperature of the dam body rises sharply. Most of the dam sections reach the highest level about 60 hours after pouring, and the highest temperature rise is about 30°C. The internal temperature of concrete is controlled within 45°C. During the heating stage, there is no significant difference between the upstream and downstream panels of the dam and the internal temperature of the dam. In the cooling stage, the relationship between the temperature of different parts at the same time point is that the internal temperature is higher than that of the upstream and downstream panels. The results can provide reference for gravity dam placement engineering in temperate areas.

Keywords: Construction period; Ravity dam; Ncrete; Tmperature

1 Introduction

The problem of temperature crack often exists in the construction process of mass concrete[1-2]. The dam concrete temperature control and crack prevention through all stages of dam construction, but in the construction stage is particularly important [3-4]. After the dam enters the construction stage, it is affected by the construction conditions and management level, and there are different degrees from the design condition[5]. Therefore, it is necessary to use monitoring data to feedback key parameters, according

Z. Ahmad et al. (eds.), *Proceedings of the 2023 5th International Conference on Structural Seismic and Civil Engineering Research (ICSSCER 2023)*, Atlantis Highlights in Engineering 24,
https://doi.org/10.2991/978-94-6463-312-2_7

to the actual progress and temperature control measures, timely feedback construction, optimization design, improve the quality of project construction [6-7]. In the process of concrete gravity dam pouring, due to raw materials, temperature control measures and other reasons, there will often be an obvious temperature rise phenomenon, especially high fly ash normal concrete and RCC [8-9]. Some positions rose above the maximum temperature of a cold session. In order to evaluate the influence of temperature on concrete gravity dam, this paper takes the concrete gravity dam of Qianming Reservoir in Zhejiang Province, China as the research object, and fully considers the external air temperature, thermodynamic characteristics of pouring materials, warehousing temperature, pouring layer thickness, interlayer intermittent and conventional thermal insulation measures to evaluate the temperature of concrete at various parts of the dam. It provides monitoring data and technical support for temperature control optimization of concrete gravity dam during construction.

2 Project overview

The dam site of Haoxi hdraulic project is located in Lishui City, Zhejiang Province, China. Qianming Reservoir is an integral part of Haoxi hydropower project. The project tasks are mainly flood control and water supply, combined with irrigation and power generation. Qianming Reservoir, with a total storage capacity of 34.13 million m^3, is a medium-sized project. The main hub buildings of the project are composed of barrage, drainage buildings, power generation diversion buildings, power plants and booster stations. The dam type of the barrage is the normal concrete gravity dam, the top elevation is 247.00m, the maximum dam height is 42.50m, the top length is 335.0m, and the top width is 5.0m.

3 Monitoring arrangement

Barrage is a normal concrete gravity dam. In order to test the temperature control effect of dam concrete and understand thermal parameters such as adiabatic temperature rise of dam concrete and surface heat release coefficient, concrete was observed in situ on the construction site to provide measured data such as temperature for the optimization of concrete mix ratio and the study of temperature control and crack prevention during construction.

In order to cooperate with the research of temperature control and crack prevention during the construction period of concrete, temperature monitoring was arranged in the dam section 7#, 14#, 8# and 11# during the construction and pouring of the dam as shown in the figure 1. Three temperature monitoring points were arranged in each bin of concrete, and one thermometer was arranged in each monitoring point. A total of 90 thermometers were buried. The temperature is in the range of -30~200°C, and the accuracy is 0.1°C. Automatic monitoring, reading once an hour.

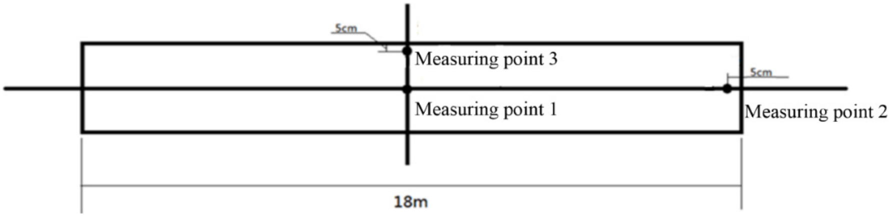


Fig. 1. Thermometer installation position diagram

4 Analysis of monitoring results

Temperature load is one of the main loads of concrete arch dam during construction and operation. The temperature change has great influence on the deformation and stress of the dam. In the design and construction of concrete arch DAMS, the internal temperature of concrete rises rapidly due to the large volume of concrete and the difficulty of releasing a large amount of hydration heat during solidification. When the cooling temperature of concrete decreases, the volume will shrink, and the dam volume deformation will be constrained, resulting in great shrinkage stress. If the ultimate tensile strength of concrete is exceeded, there will be shrinkage cracks. Such cracks sometimes run through the whole section and become structural cracks, leading to serious harm. Therefore, temperature control and crack prevention is the key factor restricting the construction quality and progress of the project. Temperature is an important load that gravity dam needs to pay special attention to. Many scholars have carried out field temperature monitoring test and simulation analysis of concrete, and obtained temperature rise rules of several concrete projects[10]. In order to further study the temperature variation law in the process of concrete gravity dam, temperature monitoring of different dam sections was conducted in 2018, and the results are shown in Table 1. The average temperature of each dam section varies from 12.32℃ to 25.23℃. The temperature in 7# and 14# dam section has the greatest degree of dispersion, while the temperature in 8# and 11# dam section has little difference. The maximum mean temperature varies from 29.46℃ to 42.07℃. Similarly, the maximum temperature of 7# and 14# is higher than that of 8# and 11#. The temperature rise of each dam section varies from 12.87℃ to 17.14℃, and the temperature rise of 8# and 11# is higher than that of 7# and 14#.

Table 1. Statistical table of characteristic values of concrete temperature after pouring

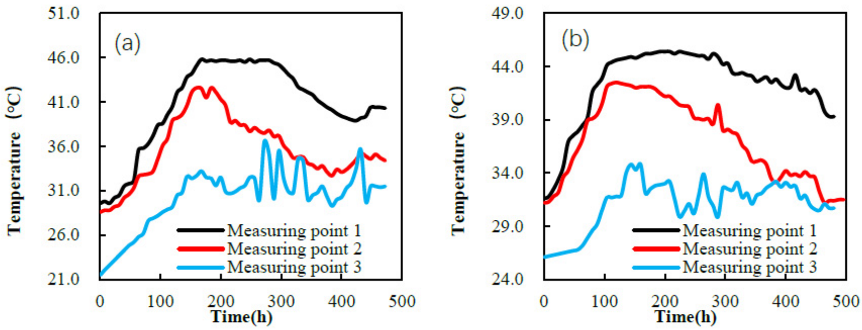
Statistical value		7#	8#	11#	14#
Temperature after embedding	index of variability	0.44	0.01	0.09	0.40
	standard deviation	10.65	0.12	1.15	8.34
	variance	113.39	0.02	1.33	69.50
	maximum	39.70	25.40	13.50	34.20
	minimum	5.40	25.10	10.60	6.20
	mean	24.24	25.23	12.32	20.75
	index of variability	0.16	0.03	0.07	0.16
	standard deviation	5.89	1.38	1.94	5.88

Maximum tempera-ture	variance	34.71	1.91	3.78	34.60
	maximum	46.70	43.50	32.70	46.20
	minimum	24.30	40.20	27.10	24.60
	mean	37.11	42.07	29.46	36.03
Tempera-ture rise	index of variability	0.49	0.08	0.11	0.40
	standard deviation	6.32	1.40	1.84	6.11
	variance	39.92	1.96	3.39	37.31
	maximum	26.50	18.40	19.70	25.40
	minimum	2.30	15.00	14.70	1.10
	mean	12.87	16.83	17.14	15.28

In order to more clearly represent the temperature variation in early age of concrete after pouring, the measured temperature process line inside concrete after pouring of dam section 14# is shown in fig.2. The results show that the temperature of the dam body rises sharply after concrete pouring, and most of the pouring silo at the end of the dam reaches the highest level about 60 hours after pouring, and then begins to decline slowly, with the highest temperature rising about 30℃. The internal temperature of concrete can be controlled within 45℃.

In the heating stage, there is no big difference between the upper and lower panels of the dam and the internal temperature of the dam. This is because the heating stage is short and the heat loss is not much. The heat dissipation environment of different parts does not have a great impact on the temperature.

In the cooling stage, the cooling trend of different parts is basically the same, but the relationship between the temperature of different parts at the same time point roughly follows the rule that the inner panel is larger than the upstream and downstream panel. This is because when it comes to the cooling stage, the heat dissipation environment of different parts plays a dominant role in the temperature. The heat dissipation environment inside the dam is the worst, so the temperature inside the dam is higher than that of the upstream and downstream panels.



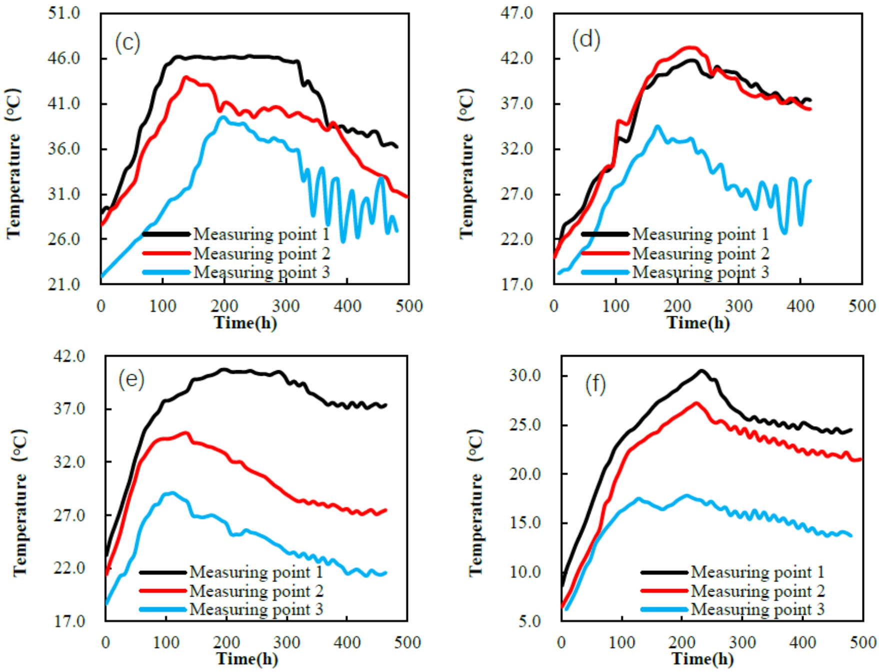


Fig. 2. Measured temperature process line inside concrete after pouring of 14# dam section (Figure a,b,c,d,e,f respectively represent temperature process line of No. 1,5,6,7,9,14 warehouse of 14# dam section)

5 Improvement measures

Through the analysis of monitoring data, the following concrete crack prevention measures are proposed.

(1) Optimize the concrete mix ratio and improve the cracking resistance of concrete

The purpose of selecting concrete raw materials and optimizing concrete mix ratio is to make concrete have greater cracking resistance. Specifically, it is required that the adiabatic temperature rise of concrete is small, the tensile strength is large, the ultimate tensile deformation capacity is large, the thermal strength is relatively small, the linear expansion coefficient is small, the autogenous volume deformation is the best micro expansion, at least the low shrinkage.

(2) Reduce the concrete warehousing temperature

The higher the temperature outside, the higher the pouring temperature of the concrete. However, higher concrete temperature will accelerate the hydration reaction of cement, shorten the time for concrete to reach the highest temperature, thus reducing the available heat dissipation time, which is not conducive to reducing the maximum temperature of concrete and reducing the temperature difference. In general, the pouring temperature of concrete should not be greater than 28°C. By means of aggregate precooling and ice mixing, the exit temperature of concrete is reduced, while the transportation distance is shortened as much as possible, so as to reduce the warehousing temperature.

(3) warehouse surface insulation

When concrete is poured in summer, if only the entry temperature is lowered, the effect of lowering the maximum temperature may be affected due to external heat recharge. In the early stage of pouring, the temperature is higher than the temperature of concrete, so the heat recharge cancels out the effect of pre-cooling aggregate, adding ice and other measures. Therefore, appropriate insulation measures should be taken for warehouse surface.

(4) Others

Take measures such as warehouse surface insulation, water pipe cooling, surface protection, surface moisturizing, warehouse surface spray and reasonable template selection to prevent cracks.

Through the reasonable analysis of the monitoring data, the anti-crack measures are put forward to ensure the construction quality of the mass concrete, the concrete construction does not appear to endanger the structure safety cracks.

6 Conclusion

This paper analyzes the temperature of Qianming concrete gravity dam during the construction period by combining the temporary monitoring data, the construction temperature data recorded by the construction unit and the data measured by the permanent monitoring thermometer. The analysis of these data deepens the understanding of the temperature process of concrete gravity construction period, which is summarized as follows: (1) The temperature and maximum temperature of dam section 7# and 14# are higher than those of 8# and 11#, but the temperature rise of 8# and 11# is higher than that of 7# and 14#. In addition, the temperature dispersion of 7# and 14# is the largest, while the temperature difference of 8# and 11# is not much. (2) The temperature of the dam rose sharply after the concrete was poured. Most of the dam sections reached the highest about 60 hours after the concrete was poured, and the highest temperature rise was about 30°C. The internal temperature of concrete is controlled within 45°C. In the heating stage, there is no big difference between the temperature of the upstream and downstream panels of the dam and the temperature inside the dam. In the cooling stage, the cooling trend of different parts is basically the same. However, the relationship between the temperature of different parts at the same time point roughly follows the rule that the temperature inside the dam is higher than that of the upstream and downstream panels. In addition, a comprehensive quality inspection was carried out on the dam during the acceptance, and no cracks were found. The results of drilling and coring also showed that the concrete quality was good. The results can provide reference for gravity dam pouring engineering in areas with mild temperature.

Reference

1. Cross W F, Covich A P, Crowl T A, et al. Secondary production, longevity and resource consumption rates of freshwater shrimps in two tropical streams with contrasting geomorphology and food web structure[J]. Freshwater Biology, 2010, 53(12):2504-2519.
2. Jia C, Shao A, Ren Q. Analysis of temperature field of high concrete dams with cooling measures during construction[J]. Shuili Fadian Xuebao/Journal of Hydroelectric Engineering, 2010, 29(5):64-69.
3. Wang Z, Tao L, Liu Y, et al. Temperature Control Measures and Temperature Stress of Mass Concrete during Construction Period in High-Altitude Regions[J]. Advances in Civil Engineering, 2018, 2018(PT.6):1-12.
4. Wang H B, Qiang S, Sun X, et al. Dynamic Simulation Analysis of Temperature Field and Thermal Stress of Concrete Gravity Dam during Construction Period[J]. Applied Mechanics and Materials, 2011, 90-93.
5. Yu N, Chen C, Mahkamov K, et al. Selection and testing of phase change materials in the physical models of buildings for heating and curing of construction elements made of precast concrete[J]. Solar Energy, 2021, 226(1–2):309-318.
6. Liu Y J, Ding L, Zhao Y J, et al. Analysis of temperature control mode of concrete construction in winter[C] Applied Mechanics and Materials. Trans Tech Publications Ltd, 2013, 368: 847-850.
7. Su H, Li J, Hu J, et al. Analysis and back-analysis for temperature field of concrete arch dam during construction period based on temperature data measured by DTS[J]. IEEE Sensors Journal, 2012, 13(5): 1403-1412.
8. Su H, Li J, Wen Z. Evaluation of various temperature control schemes for crack prevention in RCC arch dams during construction[J]. Arabian Journal for Science and Engineering, 2014, 39: 3559-3569.
9. Yangbo L, Dahai H, Jianshu O. Fast algorithms of the simulation analysis of the thermal stresses on concrete dams during construction periods[J]. Physics Procedia, 2012, 24: 1171-1177.
10. Alembagheri M. A study on structural safety of concrete arch dams during construction and operation phases[J]. Geotechnical and geological engineering, 2019, 37(2): 571-591.