

Temperature Control and Numerical Analysis for Mass Concrete Pile Cap of Hai-huang Bridge

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Abstract. In order to study the heat of hydration in massive concrete, this paper takes Hai-huang bridge for engineering background and uses the finite element analysis software of FEA to analyze the heat of hydration effect of the cushion cap. Comparing the measured data with the theory data, the results showed that the concrete crack was controlled effectively and ensure the construction quality by adopted reasonable temperature control measures. The results of the research prove that the measured data was consistent with calculation data, and it proves the accuracy of the finite element analysis. Finally, the study provides certain reference and guiding significance for similar project.

1. Introduction

With the continuous emergence of large span bridges, the demand for concrete technology of bridge structure is higher and higher, and the application of mass concrete is becoming more and more extensive[1-2]. However, the temperature cracks generated during the construction of mass concrete still cannot be underestimated. Many scholars at home and abroad have carried out a large number of researches[3-7]. In actual engineering, the concrete will produce a lot of hydration heat during the gradual hardening process. The concrete heat is directly in contact with the external atmosphere dissipates rapidly, but the internal heat is heated too fast and is not easy to dissipate[8]. This produces a temperature difference, resulting in a temperature stress. When the temperature stress is greater than the ultimate tensile stress of concrete, cracks will appear in the concrete, causing great damage to the structure. Therefore, relevant effective measures should be taken to reduce the hydration heat of concrete and monitor the structure.

This paper is based on Qinghai Hai-huang bridge for engineering support. The cooling is done by taking into the cooling pipe, and hydration heat of concrete temperature field is analyzed by the finite element software FEA, the corresponding measures were proposed to prevent cracking, it will have significant reference on the large mass concrete structure in the future.

Haihuang bridge is located in the east of the huangnan Tibetan autonomous prefecture of Qinghai province. The bridge is a control project for Zhangye to henan expressway. The overall length of the bridge is 1000m and the bridge is the cable-stayed bridge of semi-floating system of double tower and double cable, the main span is 560m, and the span is (104+116+560+116+104) m. The dimension of cushion cap is 42m (length) × 22.5m (width) × 6m (high), C40 concrete is used for pouring, and it belongs to mass concrete. The concrete pouring time is from October to November. Considering that the area of the bridge is the special climate zone of Qinghai plateau, the vertical distribution of temperature is obviously different, and the temperature difference between day and night is large in



winter. In order to avoid the temperature crack, the method of layered casting was adopted and the cooling pipe was installed.

2. Temperature monitor scheme

2.1. Arrangement of cooling pipe

In order to prevent the temperature crack in the concrete, the cooling pipe should be embedded in the concrete to reduce the temperature of the inner core concrete and the temperature difference between the inside and outside concrete. The cold water pipe is a steel tube with a diameter of 40mm and a thickness of 2.5mm. The flow rate should be no less than 0.7m/s and the outlet flow of the pipe should not be less than 338 liters/min. During the week of pouring concrete from the floor, water should be injected continuously from the inlet, and the outlet water of the outlet should be connected to the water storage tank for recycling.

2.2. Temperature monitoring method

It has been confirmed by the literature [9] that the ordinary cement concrete with is generally used to produce hydration heat after 20h, and then gradually start to decline after 150h, of which about 100h is the peak value of hydration heat. In addition, the ordinary concrete curing time should not be less than 21days. Therefore, the temperature was measured per every 4hours after 10 hours of pouring concrete. Measured on every 6 hours once the central temperature began to drop, the total temperature measured time is 30 days and ensure the temperature difference between the concrete and the inside is reduced obviously. The temperature measurement can stop when the concrete core temperature and external temperature difference is less than 25°C.

3. Finite element analysis

In order to simulate the state of the concrete cushion cap to transfer the heat to the foundation, the specific heat and heat conduction characteristics are given to the foundation to be more realistic. At the same time, considering the cushion cap and the foundation as the axisymmetric structure, a quarter cushion cap and foundation model can be established. The model USES eight node entity units. Considering the precision and efficiency of the calculation, the mesh size of the foundation is 0.75m, and the grid size of the cushion cap is 0.25m. In order to reduce the total number of units and nodes, the grid of the finite element model is shown in Fig.1.

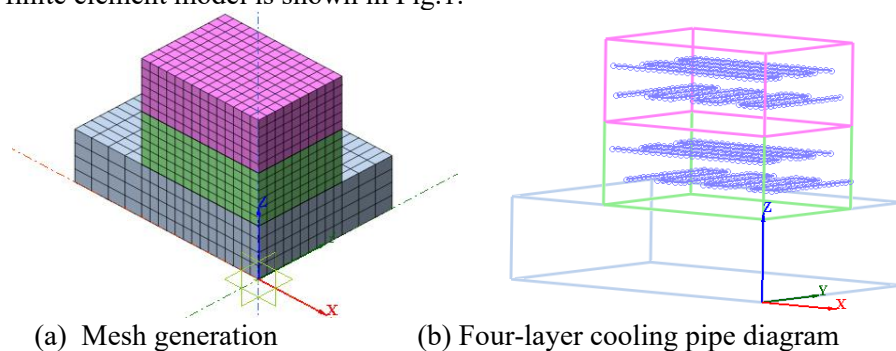


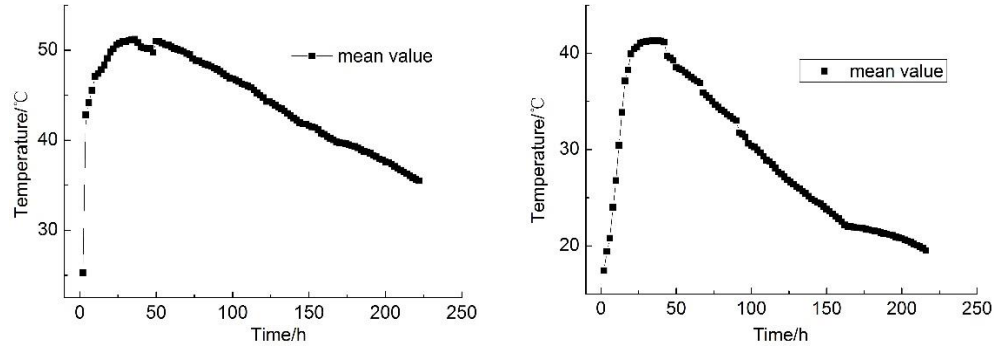
Fig.1 The finite element model of cushion cap

4. Comparison and analysis of measured value and theoretical value.

4.1. Analysis of measured results

The average temperature of the measured points is measured as the measured value of the layer, and the curve as shown in Fig.2~3. It can be found that the temperature of each layer shows the same trend, the temperature rises rapidly after pouring and then decreases slowly after reaching the maximum. This is mainly due to the combination of concrete hydration heat and cooling pipe heat dissipation.

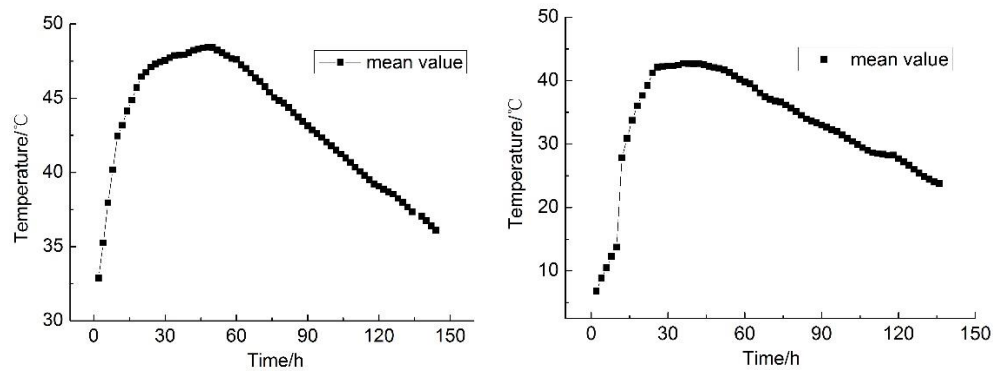
The maximum temperature is different with the measuring points, the mainly reason for that is the location of the measurement point and the external temperature of the casting have a great influence on it.



(a) The temperature of the first layer

(b) The temperature of the second layer

Fig.2 The average temperature curve of the measuring point section in the first time



(a) The temperature of the third layer

(b) The temperature of the fourth layer

Fig.3 The average temperature curve of the second casting of concrete

From the situation of the site, concrete after a winter, the concrete surface has no obvious harmful temperature crack, good quality, achieved the expected temperature control target.

4.2. Comparative analysis of theoretical value and measured value.

The maximum temperature curve and theoretical results of the inner center point of the cushion cap are compared and analyzed, as shown in Fig.4.

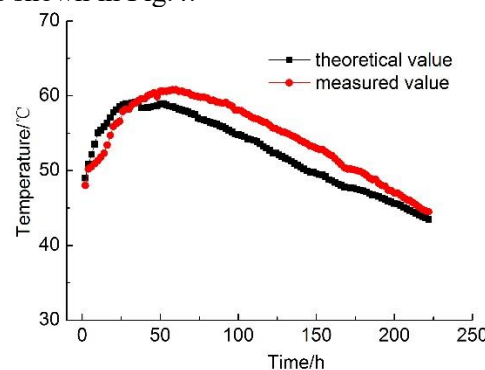


Fig.4 Comparison curve of measured and theoretical values

The results of finite element model are agree well with the measured data by comparing the curves in the diagram which indicates that the calculation results of the finite element model are basically correct. The measured value in the initial stage of hydration heat is smaller than that of the finite element calculation, and the maximum temperature of the measured value is slightly higher than that

of the finite element calculation. This is mainly due to the finite element model of the cooling water inlet temperature for a fixed value, in the actual operation process, the water is according to the measured data in a timely manner to adjust the temperature change, the previous low, gradually increased.

In addition, the water flow and the external environment temperature are set to a fixed value in the finite element model. However, the parameters are variable in practical engineering, so that there is certain error between calculated value and measured value.

5. Conclusion

(1) According to the temperature control monitoring of the mass concrete of 21# main tower of hai-huang Bridge, the temperature indexes meet the corresponding specifications. It is proved that the temperature control measures adopted are effective, which not only guarantees the construction quality of concrete, but also provides reference for the hydrothermal control of similar projects.

(2) Using FEA to simulate the hydration heat of large volume concrete, the results show that the simulation results agree well with the measured data. However, in the actual project, both the water flow and the external environment are all variables, these factors are not considered in the FEA simulation in this paper, therefor there is a certain deviation between the calculated value and the measured value.

(3) From the perspective of site construction, there was no obvious harmful temperature crack on the concrete surface after a winter, its quality is excellent and it reaches the expected temperature control target.

References

- [1] Chen Guilin, Jiang Wei, Liu Wenchao. A review of recent advances in controlling temperature cracks in mass concrete construction [J]. *Journal of natural disasters*. 2016,25, (3):159-165.
- [2] Bobko C P, Zadeh V Z, Seracino R. Improved Schmidt method for predicting temperature development in mass concrete[J]. *ACI Materials Journal*.2015,112(4): 579-586.
- [3] Lawrence AM, Tia M, Ferraro CC, et al. Effect of early age strength on cracking in mass concrete containing different supplementary cementitious materials: experimental and finite element investigation[J]. *Journal of Materials in Civil Engineering*, 2012, 24(4):362-372.
- [4] Liu Xinghong, Zhou Chuangbing, Chang Xiaolin. Simulation of mass concrete temperature cracking propagation process [J]. *Rock and Soil Mechanics*, 2010, 31(8):2666-2671.
- [5] Liu Wei, Dong Biqin, Li Weiwen. The study on thermal stress and temperature crack of underground mass concrete [J]. *Industrial Construction*, 2008, 38(7): 79-82.
- [6] GB50496-2009. Code for Construction of Mass Concrete[S]. *Beijing: Building Industry Press of China*, 2009.
- [7] Li Cheng, Tao Fuxian, Liu Mengwei. Temperature control and numerical analysis for massive concrete of cushion cap based on MIDAS [J]. *Journal of Sichuan University of Science and Technology (Natural Science Edition)*, 2014, 24(4):78-81.
- [8] Yu pei, Zhang Ruimin, Yuan Yinshu. The finite analysis of bridge deck mass concrete temperature field based on MIDAS [J]. *Journal of Tianjin Chengjian University*. 2015,21(4): 273-277.
- [9] WANG Tiemeng. Control of Cracking in Engineering Structure [M]. *Beijing: Building Industry Press of China*, 2007.
- [10] WANG Weibin. Crack Control and Construction Technology of Mass Concrete [D]. *TianJin: Tianjin University*, 2004.
- [11] Wang Jun, Hao Xianwu, Li Feng. Finite element analysis of hydrated heat temperature field of massive concrete considering pipe cooling [J]. *Journal of Guangxi University (Natural Science Edition)*, 2013, 38(4): 929-935.
- [12] Liu Muyu, Xu Liming, Wang Feng. Temperature Controlling and Monitoring for Mass

- Concrete Construction of Huangpu Bridge [J]. *Journal of Huazhong University of Science and Technology (Urban Science Edition)*. 2008, 25(1):12-16.
- [13] Song Fuchun, Liu Ce. Analysis on hydration heat of massive concrete with pipe water cooling [J]. *Journal of Shenyang Jianzhu University (Natural Science Edition)*, 2015, 31(1):95-101.