NUMERICAL SIMULATION AND ANALYSIS OF THE EFFECT OF TEMPERATURE ON THE FISSION OF CONCRETE

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In order to further improve the crack resistance of concrete engineering, a numerical simulation method is constructed to study the effect of temperature on the fission of concrete. Based on the finite element method, the mathematical model is constructed, and the numerical calculation and image display are used to simulate and analyze the engineering problems. The temperature sensor is used to observe the whole variation law of typical temperature field, and the temperature of concrete entering and pouring is obtained. Thus, the temperature control real-time automatic acquisition system is set up. According to the temperature field and temperature stress distribution rules, the ideal temperature control curve model of concrete is proposed. Finally, the numerical calculation and experiment of the model are carried out. The results show that the maximum surface stress level decreases in varying degrees after different surface insulation measures are taken, and if the thermal insulation material's $\beta \leq$ *kJ/ (m2.h. ℃), the maximum surface stress of concrete can be reduced to 0.06 ~ 0.14 MPA. In this paper, it is shown that the negative effect of the large diurnal temperature difference on concrete surface insulation can be controlled.*

Keywords*: temperature, concrete; fission, effect, numerical simulation*

1. Introduction

Crack is a common and difficult problem in concrete engineering, and it is also the concentrated expression of concrete disease and defect (Ruiz G *et al*.2016). In the high-cold region, the natural conditions are bad, the dam mass concrete is prone to crack, flaw and fracture (Ren J *et al*.2016). Once the dam concrete cracks, it will not only affect the durability of the whole bridge dam and greatly reduce the service life of the dam, but also the maintenance cost will be very expensive. Therefore, in view of the climatic characteristics of the high-cold region, it is of great theoretical and practical significance to study the crack resistance of dam concrete in the high-cold region (Kallel H *et al*.2017). However, temperature is the main factor affecting the fission of concrete. It is very important for the study of crack resistance of concrete to analyze which fission effect of concrete is affected within which temperature range.

Numerical simulation is also known as computer simulation (Wei W *et al*.2017). By means of computer and the concept of the finite element or finite volume, the purpose of studying engineering and physical problems, as well as all kinds of natural problems, is achieved by means of numerical calculation and image display. Numerical simulation should actually be understood as the use of computers to do experiments where by establishing a mathematical model reflecting the nature of the problem (engineering problem, physical problem, *etc*.), a series of numerical values are obtained by using the high efficiency and high accuracy calculation method to calculate the program. Finally, the value is displayed in the form of images. The influence of temperature on concrete fission can be analyzed by computer simulation. In this paper, the effect of temperature on the fission of concrete is studied by numerical simulation.

The research of this paper is innovative in some aspects. The cracking of concrete in various parts of the dam is analyzed. It is found that the cracks are mainly composed of temperature cracks, dry shrinkage cracks and plastic cracks, as well as the special frost heaving cracks in the high-cold regions and the cracking of the protective layer caused by deicing salt in winter. In view of the bad natural environment characteristics in the high-cold region, the raw materials of the concrete of the Zangmu dam are tested and optimized by the numerical analysis method, which greatly improves its performance and effectively meets the requirements of the crack resistant concrete.

In this paper, the effect of temperature on fission of concrete is analyzed by the numerical simulation method, and a real time automatic collection system of temperature control is constructed. An ideal temperature control curve model is proposed based on the temperature field and temperature stress distribution rules of various dam types. The modeling principle and the realization process are analyzed. Finally, numerical simulation experiments are carried out on the model constructed in this paper. The experimental results are analyzed and summarized, and the validity of the numerical simulation analysis method is verified.

2. STATE OF THE ART

For concrete, temperature is the main factor that affects its cracking. In recent years, many scholars have carried out a lot of numerical simulation and other related research on it. Jiang H takes the construction of a high-rise foundation cap as an example and uses the finite element software ANSYS to simulate the temperature field caused by the hydration heat during the construction of the mass concrete of the cap, which is compared with the engineering measurement. It is found that the results are in good agreement with the expected (Jiang H.2016). Mi Z analyzes the effect of different curing conditions on the temperature field of concrete by using ANSYS software. The results show that the curing condition has a great influence on the surface temperature of concrete, proving the importance of maintenance in mass concrete construction (Mi Z *et al*.2018). Zhen C has established a spatial finite element model to simulate the shrinkage and creep characteristics of concrete-filled steel's frame tied arch bridge. The results show that concrete shrinkage and creep have no effect on the axial force of the whole section of the structure system, but it has great influence on the bending moment of the whole section of the structure (Zhen C *et al*.2018). Xue-Feng Liu establishes a plane finite element model to analyze the stress of concrete-filled steel frame tied arch bridge under the action of temperature load and dead load. The results show that changing the rise-span ratio has a great influence on the axial force of the structure under dead load and the internal force caused by the whole temperature change (Xue-Feng Liu *et al*.2018). Gangnant A establishes the spatial finite element model. It is found that the dynamic response of the bridge span structure is very obvious when the load moves through the bridge deck at the speed of 1~20m/s(Gangnant A *et al*.2016). Martins D J analyzes the temperature field distribution characteristics of a concrete shaking table foundation in early age by means of numerical simulation and field test. It is found that the temperature variation law of concrete at different test points is different (Martins D J *et al.*2016). Haeri H uses the nonlinear finite element method to simulate the temperature field of concrete members during fire. It is found that the calculated results are in good agreement with the experimental data (Haeri H *et al.*2016). Zhu X simulates the failure process of concrete under uniaxial compression by using the finite element analysis system MFPA2D,. The results are compared with those of physical tests, verifying the feasibility of the numerical simulation method (Zhu X *et al.*2018). Dong W uses the finite element numerical simulation method to determine whether the anti-crack ring can be used to study the cracking resistance of concrete during temperature deformation. The results show that the crack resistant ring can be used to study the crack resistance and temperature deformation of concrete (Dong W *et al.*2016). Zden K P adopts the finite element software to simulate the temperature field of the super-long prestressed concrete beam. The correctness of the calculation method and the theory is verified by comparing the calculated values with the measured values (Zden / k P. 2016).

To sum up, the problem of concrete fission caused by temperature has been widely concerned by scholars at home and abroad. Many scholars have put forward and verified many numerical simulation methods through empirical analysis. However, most of the literature is aimed at a certain project or a certain aspect of a specific project. The research results are not generalized and universal, so they cannot form effective standards and norms, and the related work is still in the exploration stage. Therefore, it is of great significance to analyze the effect of temperature on concrete fission in this paper.

3. The Numerical Simulation Analysis Method Based on the Effect of Temperature on Concrete Fission

3.1 Temperature Control Real-time Automatic Acquisition System

The inner temperature of the dam: the LN-TC01 temperature sensor is used; three thermometers are embedded along the central axis of the dam segment, which are 1/4,1/2, and 3/4 from the upstream surface respectively; monitoring frequency is once every half an hour, and the average of the temperature inside the dam is determined. This arrangement can effectively reduce the temperature difference between the upper and lower reaches, and at the same time, it can effectively guarantee the survival rate of the instrument and observe the whole variation law of typical temperature field and the law of temperature change in confinement region. Temperature gradient: LN-TC06-I and LN-TC06-II digital temperature sensor groups are used and the monitoring frequency is once half an hour. This scheme can effectively observe the variation law of temperature gradient of warehouse surface in different seasons, the temperature change law of the bottom hole and adjacent parts, the temperature gradient of upstream and downstream surface and so on. Temperature: LN-TC01 temperature sensors are used which are placed in the dam toe, with one on the left bank, one on the right bank and one on the riverbed; the average value of the three thermometers is taken, and the monitoring frequency is once every half hour. Aggregate temperature: concrete aggregate temperature test recorder (supporting wireless transmission module) is used; monitoring frequency is twice per vehicle. Warehousing and pouring temperature: LN2026-TM temperature test recorder (support wireless transmission) is used to monitor the temperature of concrete storage and pouring.

3.2 Modeling of the Ideal Temperature Process Curve

The temperature field and temperature stress distribution rules of various dam types are studied synthetically. The ideal temperature control curve model of coagulation with different parts, different material zoning and different casting is proposed. The ideal temperature control curve has the characteristics of minimum temperature stress under the condition of the same temperature control standard. The normal concrete gravity dam is usually composed of longitudinal joints, which need joint grouting. The concrete cooling is divided into the first, medium and second stages, as shown in Fig. 1.

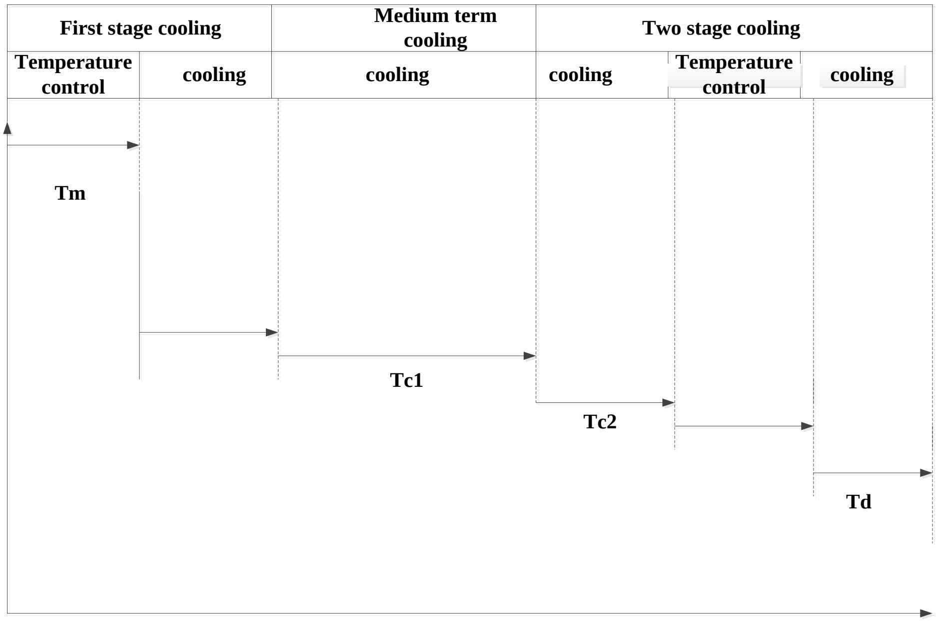

Figure 1 Ideal Temperature Process Line

After the concrete has entered the actual cooling stage, it can be seen from the ideal process line that the first stage of cooling consists of five stages: two stages of temperature control and cooling, the middle stage of cooling, the second stage of cooling and the second stage of temperature control. First stage temperature control: the main purpose of the temperature control stage is to cut the peak so that the maximum temperature inside the concrete is controlled within the design allowable range (or below the maximum temperature value of the ideal temperature curve). At this stage, if the pouring temperature exceeds the standard, the maximum temperature must be controlled as far as possible by other measures or parameter adjustment on the basis of the control measures and parameters corresponding to the ideal cooling curve. At this time, moderate lowering of cooling water temperature or increasing the flow of water can be adopted to control. Generally speaking, the effect of lowering the cooling water temperature on the maximum temperature is more significant than that of increasing the flow rate. Therefore, it is a better choice to reduce the cooling water temperature. If the pouring temperature is obviously lower than the design requirement, it can be controlled by the proper delay of water flow, or by using high temperature water and low flow rate. The adjustment of water temperature during construction may be required by the water use requirement of refrigeration units and the system. Priority should be given to low-flow or delayed water flow to achieve control. First stage cooling: The purpose of the first stage cooling of concrete is to reduce the internal temperature, reduce the temperature difference between the inside and outside, and avoid the appearance of large cracks of the early age concrete due to the relatively large internal and external temperature difference.

The control of temperature process in this stage can be controlled mainly by reducing the flow rate of water or increasing the cooling water temperature. How to select can be determined according to the actual situation of the field and the real time feedback analysis. First-stage abnormal cooling condition treatment: If all possible preparatory temperature control measures are taken during the construction period and the temperature exceeds the standard, then the necessary control of the temperature drop rate is needed. Generally speaking, a daily cooling requirement of not more than 1 ℃ is required in the specification. According to the engineering experience in recent years, the daily cooling can be controlled according to 0.5 ℃ / day, and the cooling time can be extended moderately until the concrete intersects with the ideal process line again, and then controls along the ideal process line. Medium-term cooling: the main purpose of medium-term cooling is to reduce the difference between internal and external temperatures or to reduce the range of secondary cooling in the later stage. Generally speaking, the cooling time is relatively long. The daily reference cooling range can be obtained by time interpolation according to the difference between the first cooling target temperature and the medium-term cooling target temperature, generally not exceeding 0.3 ℃ / day. If the concrete does not reach the target temperature at the beginning of the medium-term cooling period, the daily water flow can be appropriately increased and can be controlled by no more than 0.5 ℃ / day. If the medium-term cooling of concrete begins below the start temperature of the medium-term cooling, the flow rate may be reduced moderately, for example, control according to the standard of 0.1∽0.2℃/ day. It is important to note that the late concrete should try to avoid water outages in order to reduce the risk of cracking caused by low temperature water cooling after reopening of the water supply. If there is a water shutdown, the cooling water temperature should be appropriately higher during recooling, and then the cooling water temperature is reduced slowly, and flow should be controlled from small to large. Second stage cooling (late cooling): The temperature drop rate should not be too high; the daily reference cooling range can be obtained by time interpolation according to the difference between the cooling target temperature and the medium-term cooling target temperature, generally not more than 0.3 ℃ / day. If when the second phase of cooling begins, the concrete does not reach the target temperature, then the daily water flow can be increased properly and can be controlled by no more than 0.5 ℃ / day. For the second phase of cooling, it is necessary to try to avoid the situation of intermittent water supply to reduce the risk of cold impact cracking. Even if water is forced to be cut off (such as on-site power outages or equipment maintenance, etc.), a small flow rate should be adopted when reopening water and then step by step increasing the flow rate. The water temperature should also be gradually reduced. Second stage temperature control: The purpose of the second stage temperature control is to prevent the later temperature rising and reduce the opening and closing degree of the joint, thus affecting its irrigability. The rate of residual hydration heat emission of concrete during the second stage temperature control is relatively small. Hence, in this case, it is relatively good to adopt the method of reducing the flow rate of water flow to control the temperature.

For highway engineering, there are many ways to control the temperature on site, and the main factors affecting the cooling process include cement hydration reaction (usually expressed by adiabatic temperature rise formula), water pipe layout, cooling water temperature, flow rate, water pipe pressure difference and other key factors. Cement hydration reaction characteristics (adiabatic temperature rise) are generally relatively stable. Once the cooling pipe is embedded in concrete, its layout will not change. Therefore, these two factors are basically fixed factors.In theory, the water pipe pressure difference can also be adjusted, which depends on the configuration power of the refrigeration unit.Generally speaking, on the premise of reducing faults and improving the life of units, after deducting the loss of resistance along the way, the pressure difference is generally kept relatively constant, and the change of pressure difference does not directly affect the change of temperature. Its influence is reflected in the influence on flow, so adjusting the pressure difference of water pipes is equivalent to adjusting the flow parameters.

4. Experimental Design and Analysis

4.1 Data sources

A 3D model with length × width × height = 40m × 25m × 10m is established to study the temperature difference between day and night at 15 °C, 20 °C, and 25 °C at different ages. Moreover, under the temperature drop of 15 °C and 6 °C in two days, the fine mesh is used for simulation. As shown in Fig. 2 / 3, the mesh size of the surface layer is 5Cm~10cm, which is divided into 46,000 units and 53,004 nodes.

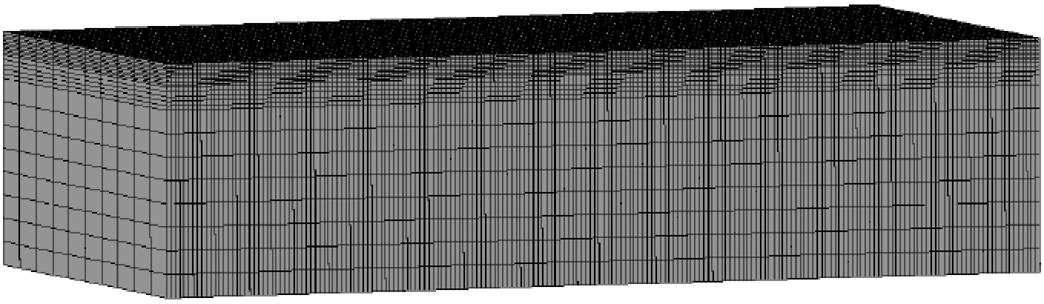

Figure 2 Computational Grid Diagram

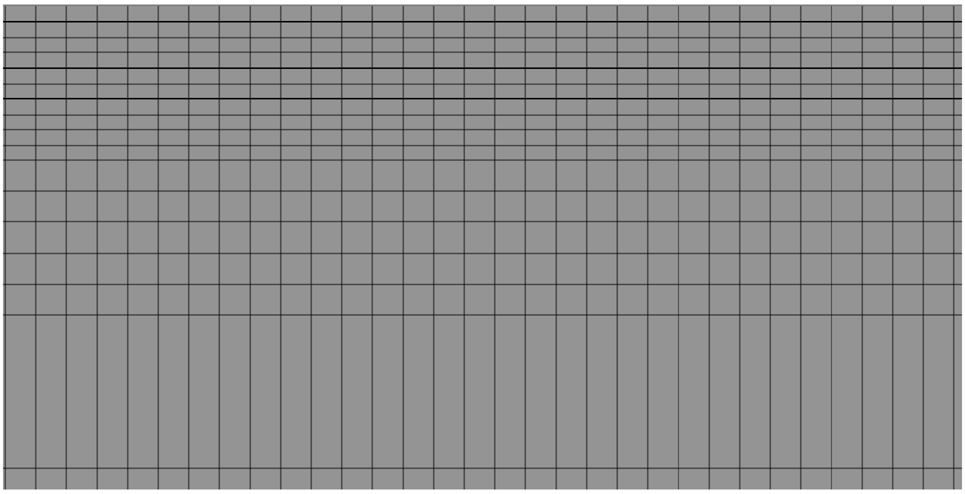

Figure 3 Locally Computed Mesh Diagram

4.2 Analysis of Calculation Results

4.2.1 Calculation and Analysis of Diurnal Temperature Difference Stress

When the third-grade matching C9025 concrete encounters day and night temperature difference of 15 °C, 20 °C, and 25 °C, the maximum tensile stress on the concrete surface of two working conditions, namely when there are surface protection measures（β=10kJ/（m2.h.°C）,5kJ/（m2.h.°C）, and 3kJ/（m2.h.°C）and there are not is shown in Table 4-1. The distribution of tensile stress along the depth of the concrete surface without heat preservation is shown in Fig. 4-3 when the third-grade C9025 concrete encounters 20 °C of day and night difference. The surface thermal insulation coefficient of concrete is 10kJ/ (m2.h. °C), 5kJ/ (m2.h. °C), and 3kJ/ (m2.h. °C), respectively, corresponding to the thermal insulation board of lcm, 3cm, and 5cm.

Table 1 Statistical Table of Maximum Tensile Stress on Concrete Surface (Unit: MPa)

Cooling type	Surface protection measures（β）	Age（d）				
		3	7	14	28	90
Diurnal temperature difference 15°C	No heat preservation	0.43	0.53	0.62	0.72	0.87
	10kJ/（m^{2}.h.°C）	0.14	0.17	0.20	0.23	0.28
	5kJ/（m^{2}.h.°C）	0.07	0.08	0.10	0.11	0.14
	3kJ/（m^{2}.h.°C）	0.04	0.05	0.06	0.07	0.09

Table 1 Statistical Table of Maximum Tensile Stress on Concrete Surface (Unit: MPa)

Cooling type	Surface protection measures（β）	Age（d）				
		3	7	14	28	90
Diurnal temperature difference 20°C	No heat preservation	0.58	0.71	0.83	0.95	1.16
	10kJ/（m^{2}.h.°C）	0.18	0.22	0.26	0.30	0.37
	5kJ/（m^{2}.h.°C）	0.09	0.11	0.13	0.15	0.18
	3kJ/（m^{2}.h.°CC）	0.06	0.07	0.08	0.09	0.12
Diurnal temperature difference 20°C	No heat preservation	0.72	0.88	1.04	1.19	1.45
	10kJ/（m^{2}.h.°C）	0.23	0.28	0.33	0.38	0.46
	5kJ/（m^{2}.h.°C）	0.11	0.14	0.16	0.19	0.23
	3kJ/（m^{2}.h.°C）	0.07	0.09	0.10	0.12	0.14

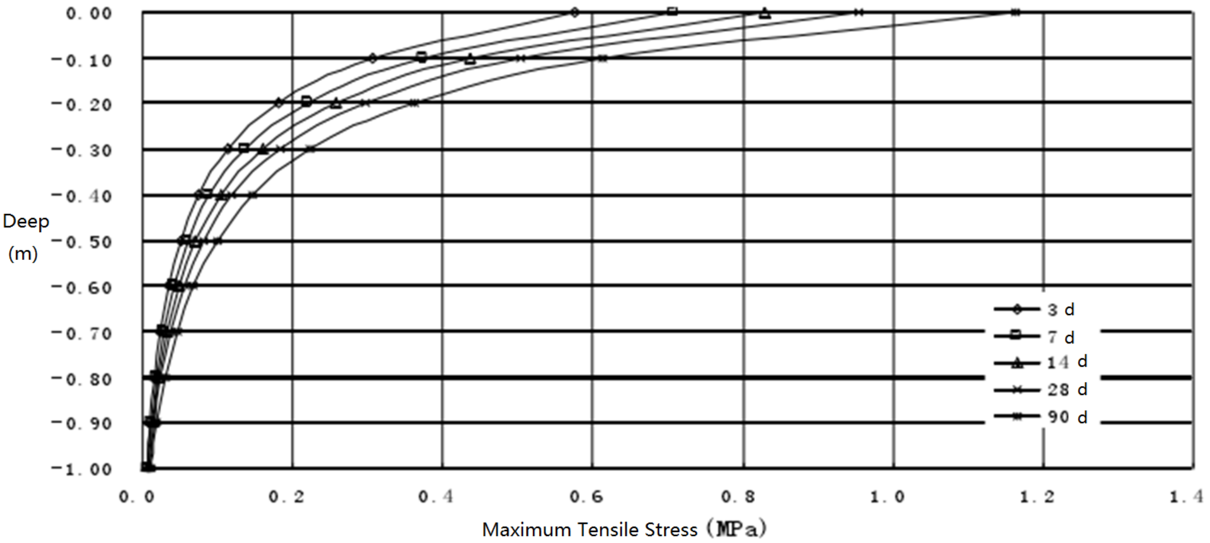

Figure 4 No insulation measures

To sum up, the maximum surface stress of three-grade matching C9025 with three temperature differences of 15 ℃, 20 ℃ and 25 ℃ is 0.87 MPA, 1.16MPa and 1.45 MPA, respectively. The areas where the stress exceeds 0.4MPa are mostly within the range of 30cm below the surface. After taking different surface insulation measures, the maximum surface stress level of concrete decreased to 0.06 ~ 0.14 MPA when the heat insulating material's β ≤ kJ/ (m ~ 2 ·h ·℃). It can be seen that even if the temperature difference between day and night is relatively large, the adverse effects can be controlled in a smaller range as long as the work of surface heat preservation is done well.

4.2.2 Analysis of Sudden Temperature Drop Stress

Under the influence of the cold wave of 15 ℃ for 2 days and 6 ℃ for 2 days and different surface measures, the maximum tensile stress of concrete at different ages is listed in Table 4-2. When the cold wave is smaller and the surface insulation work is done well, the adverse stress is effectively controlled, but under the action of the larger cold wave, even if the surface insulation measures are done well, there will still be obvious auxiliary stress. In addition, influence by the depth of the cold wave, the greater the cold wave, the deeper the influence range is; Without heat preservation, the influence depth of the cold wave, which falls 6 ℃ or 10 ℃ in 2 days, is about 0.6 ~ 1.0 m (the stress value is higher than 0.4MPa).

Table 2 Maximum Tensile Stress on Surface of Different Cooling and Cold Waves and Surface Measures (Unit: MPa)

Cooling type	Surface protection measures（β）	Age（d）				
		3	7	14	28	90
Diurnal temperature difference 15℃	No heat preservation	1.40	1.64	1.88	2.15	2.60
	10kJ/（m^2.h.℃）	0.74	0.87	0.99	1.13	1.37
	5kJ/（m^2.h.℃）	0.43	0.51	0.58	0.66	0.79
	3kJ/（m^2.h.℃）	0.28	0.34	0.39	0.44	0.53
Diurnal temperature difference 20℃	No heat preservation	0.56	0.65	0.75	0.86	1.04
	10kJ/（m^2.h.℃）	0.30	0.35	0.40	0.45	0.55
	5kJ/（m^2.h.℃）	0.17	0.20	0.23	0.26	032
	3kJ/（m^2.h.℃C）	0.12	0.14	0.15	0.18	0.21

5. CONCLUSION

Cracking is a problem that often occurs in concrete engineering and is difficult to solve. There are many factors affecting the cracking, and temperature is the most important factor. In this paper, the numerical simulation method is used to analyze the effect on concrete cracking. Through the establishment of concrete temperature control information real-time automatic collection subsystem and concrete temperature control information transmission subsystem, the concrete anti-cracking dynamic intelligent temperature control software control system is formed. The 10# section of the dam of Zangmu is selected as the engineering support. First, the concrete of 1-2 irrigation areas is selected for the field experiment, and the applicability of the software control system is verified. According to the experimental results, the system function is improved and perfected. Through establishing the ideal temperature process curve model of concrete temperature control and crack prevention, according to the characteristics of typical climate and difficult surface crack prevention of Zangmu engineering, the research is carried out in combination with the actual situation of the project. This paper analyzes and studies the concrete surface insulation and crack prevention of Zangmu dam. The results show that by numerical simulation and calculation of the temperature difference between day and night at different ages of dam concrete, different surface heat preservation measures and temperature stress of pouring concrete in different seasons, it is found that the long-period stress and short-period stress on the surface of dam concrete have superposition effect. Considering that the actual thermal insulation effect is usually weaker than that of theoretical insulation effect, there should be more room for temperature control design. However, the study of this paper still has some shortcomings. In this paper, the emphasis is placed on the mechanical properties of concrete materials. The next step should be to analyze the durability of concrete materials, especially in the freezing resistance of pebble concrete in Xinjiang high-cold areas.

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