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Study on Stress Field of Concrete with Large Foundation Defects under Fast Casting Condition

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Abstract. In the process of concrete dam foundation treatment, it is often encountered that the foundation defects are beyond the expected exploration. In order to ensure the quality of the project and the progress of the construction period, the stress field of the mass concrete in the foundation pit under the condition of fast filling is studied by numerical simulation method. Based on the calculation results and engineering experience, some comprehensive measures of temperature control and crack prevention are put forward: pipe cooling + reasonable angle arrangement of anti-sliding anchor bar + reasonable position of the limit of crack reinforcement layout. Which can provide some reference for solving similar engineering problems.

1 Introduction

The only flood control project in the Huaihe River Basin in the past Huaihe River Basin planning is Chushandian reservoir. It is given priority to with the flood control, combined with water supply, irrigation, both power generation.etc.. This project is located in Xinyang City, Henan Province, whose control basin area is 2900 km^2. The project contains some different dam type, including concrete gravity dam with a length of 429.57m, crest elevation is 100.4m.

It is extremely important that anti-sliding of concrete dam foundation for engineering safety. And the exploration work in the design stage can not cover all areas in a comprehensive and accurate manner. It is often found that local geological defects are more serious than exploration in the construction excavation process. In the process of foundation excavation, local geological defects in Chushandian reservoir are also found to be more serious. If the defects are not excavated and the concrete is casted, it will have some adverse effects on the future stability of the dam foundation[1]. Owing to the large depth of geological defects, excavation and backfilling workload is very large,the schedule will be delayed in long time,especially the flood season is coming soon. Although in the contradiction of schedule pressure and quality control, dam construction work must adhere to the quality first and schedule was taken into account in the same time.

In order to make a balance between project quality and schedule, it is necessary to study the stress field of the large volume backfill concrete under the conditions of rapid casting, and a reasonable solution on the basis of scientific analysis should be put forward .

2 Calculation Model and the Main Parameters

Due to the actual existence of two basic defects, shape of excavation casting pit is irregular and the decision making is hurriedly needed to support by the simulation calculation results. For rapid modeling and calculation, casting concrete was simplified as the trapezoidal. The maximum plane size is 54 * 48m, the deepest dimension is 17m. In view of the structural shape of the basic symmetry, so only half of the modeling (model of concrete size is 54m * 24m * 17m) is created.

The foundation casting concrete grid model is shown in figure 1 to figure 3. The total number of nodes in the model is 66465, and the total number of elements is 61506.

Boundary conditions: In the temperature field simulation calculation, it is assumed that the bottom and the surroundings of the foundation are insulated boundary, and the other side is the heat exchange boundary[2,3]. In the calculation of the stress field, it is assumed that the basement of the ground for the hinge seat, surrounded by connecting rod support, the upper surface are free.

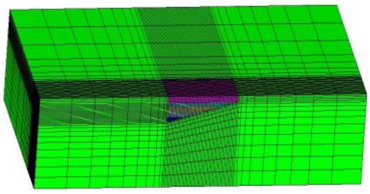

Fig1. Whole grid model

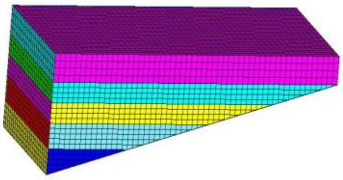

Fig2. Concrete grid model

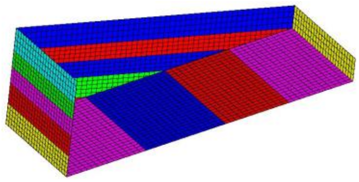

Fig3. Interface grid model

The annual average daily temperature variation is calculated as follows:

$$T_a(t) = 15.7 + 13 \times \cos\left[\frac{\pi}{6}(t-6)\right], \quad t \text{ for the month} \tag{1}$$

The main thermodynamic parameters are shown in Table 1.

Table 1 Thermal and mechanical parameters of the material

material	Thermal Conductivity λ (KJ/(m.h.℃))	Adiabatic temperature rise final value θ^0 (℃)	Temperature conductivity a(m²/h)	Coefficient of linear Expansion α (10^{-6} /℃)	Poisson's ratio μ	Density ρ (kg/m³)	Final elastic modulus E_0 (GPa)
C15	9.663	34.0	0.00445	8.363	0.167	2350	28.8
C20	9.613	39.5	0.00444	8.378	0.167	2353	30.3
foundation	10.50	0.0	0.00548	7.00	0.20	2680	55.0

3 Calculation Results Analysis

Based on the temperature field and stress field of the hydration degree of simulation program[4], the following conclusions are obtained through comparative calculation and analysis of four cases. Figure 4 to Figure 7 for the different cases of the casting concrete block at the center of the temperature and stress duration curve. It can be seen that only under the case of figure 6 to ensure that the tensile stress of the casting block is lower than the tensile strength.

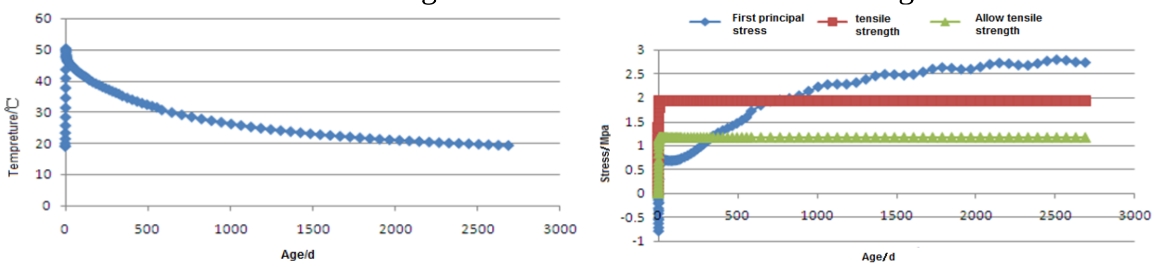

Fig 4. Temperature and first principal stress curves of concrete center point without temperature control measures under 3d intermittent

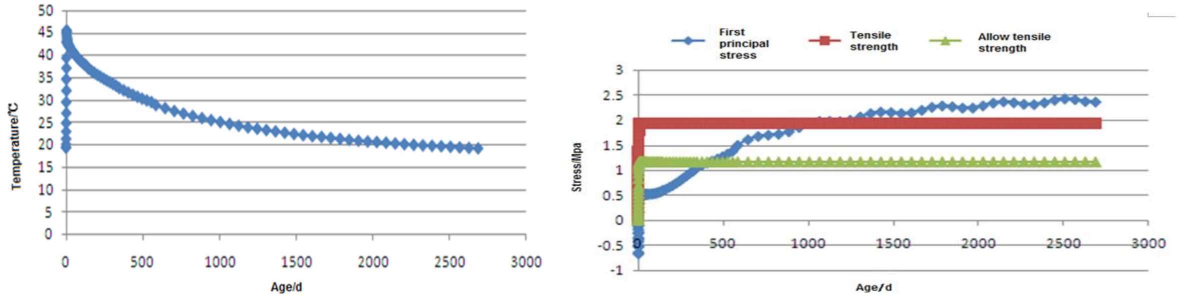

Fig 5 . Temperature and first principal stress curves of concrete center point with pipe cooling under 3d intermittent

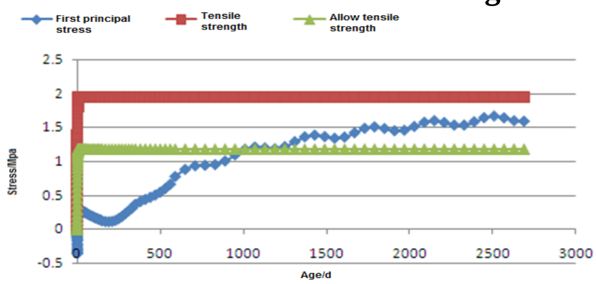

Fig.6 The first principal stress curve of the center point under 1d intermittent with pipe cooling

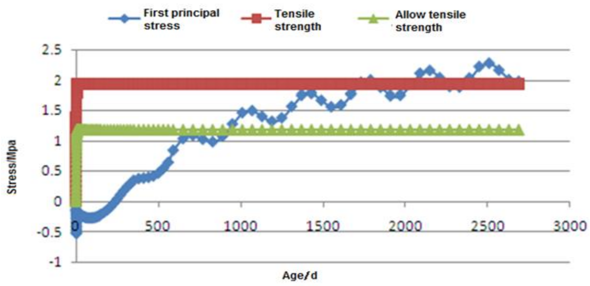

Fig.7 The first principal stress curve of the center point under 1d intermittent with pipe cooling and side anchorage

(1) For the foundation defects casting concrete, the depth of concret is 17-19m, the long side reaches 52m. 18 ℃ casting temperature condition was taken in April. If there is no pipe cooling measures, its internal maximum temperature is 52 ℃. If reasonable measures of cooling pipes were adopted, the maximum internal temperature can be controlled at about 46℃. The entire casting concrete near the center of the tensile stress can be reduced from 2.2MPa to 1.7MPa.

(2) The maximum tensile stress near the bottom of the backfill concrete and the baserock surface is 3.3MPa under the condition of no temperature control and crack prevention. In the pipe cooling + short intermittent conditions are still 2.2MPa, which more than C15 concrete tensile strength, the expansion depth of about 2m cracks will be produced.

(3) If the layered casting was adopted, the maximum tensile stress under intermittent period 3d condition was produced about 2.9Mpa. The maximum tensile stress under intermittent period 1d condition was produced about 2.3 MPa.

(4) If arrangment of anchor bar in the contact surfaces of rocks and concrete is unreasonable, the seam surface will tend to open. The casting concrete as a whole in a five surface (sides and bottom) under constraints, the maximum tensile stress near the seam will reach about 3.3MPa, that is, concrete near the seam surface will be local damage.

4 Temperature Control and Crack Prevention Measures

(1) For the long side more than 50m and the depth of 17-19m casting concrete, short intermittent rapid construction in thick layer was needed to implement owing to the tight schedule. There is no time to heat dissipation in the warehouse surface. This problem can be resolved through the pipe cooling. It is recommended that the distances of the pipe in the C15 concrete is 1.5m * 1.5m, the pipe layout in the C20 concrete is 1.0m * 1.0m. The cooling water in the pipe is river water, and the maximum flow before the peak temperature is 6 m^3/h. After the peak, the temperature drop rate should not be faster than 0.3 ℃/d.

(2) Let the intermittent be about 1d. Put appropriate amount of expansion agent.

(3) For the seam between the concrete and the rock, should be allowed to open because of concrete temperature drop shrinkage. Thus, the external constraints of concrete will reduce and the

probability of concrete cracking from the inside will also reduce. For these seams, if arrangements of the anchor rebar connect the rock and concrete (anchor rebars were to meet the requirements of the dam anti-sliding stability), the seam is difficult to open because of the strong tensile capacity of steel, but the inside of the concrete is easy to crack. Considering the poor bending resistance of the steel bars, in order to allow the seam to be opened, the angle of the reinforcement should be as perpendicular to the direction of the contraction of the concrete or to the large angle. After the concrete temperature drop shrinkage is basically completed, it can be grouted.

(4) As the casting concrete under the constraints of baserock are the strongest, so tensile stress of the bottom is the largest. Tensile stress in this area can not be controled in safe range even the pipe cooling measures was used. This area is still some extension within the concrete cracks in the depth of about 2 m. It is recommended to arrange 2 to 3 layers of limit-crack steel bars above the bottom surface of 0.1m ~ 0.5m to share some tensile stress. Meanwhile, pre-embedment grouting pipes are put near the seam. After the concrete temperature drops to bedrock temperature (18°C), the cracks around the bottom in the concrete can be grouted.

5 Conclusion

Due to the excavation process in the construction of concrete dam foundation, local geological defects are found out are more serious. It needs to completely dig and refill, which put great pressure on the pre-flood period. In order to ensure the construction of the schedule and avoid the occurrence of penetrating cracks in the refill concrete, the rapid casting of large volume casting concrete were implemented.

Based on the simulation analysis, and combined with the engineering experience, the scheme of temperature control and crack prevention in this special case is put forward. Pipe cooling + reasonable angle arrangement of anti-sliding anchor bar + reasonable position of the limit-crack reinforcement layout are mainly measures. At the time of submission, there aren’t any harmful cracks showed in the refill concrete, nor did it affect the upper dam concrete. Measures in this paper may provide some reference to similar projects.

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