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Study on Temperature Control and Crack Prevention of Concrete with Strong Constrained Area in Super–Strong BaseRock

Yang Feng[1,a],Song Jiadong[2,b], Wang Wanqin[3,c], Zhang Jingtao[3,d], Qiang Sheng[3,e]

[1]Henan Chushandian Reservoir Construction Administration,China

[2]Henan Hydraulic Engineering First Bureau, China

[3]Hohai University ,China

[a]yangfeng@hnsl.gov.cn, [b] 3263506148@qq.com, [c]1264084413@qq.com, [d]1251709535@qq.com, [e]sqiang2118@hhu.edu.cn

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Abstract. The concrete dam of Chushandian reservoir is made of normal concrete, whose strong constraint area of mass concrete cast in the spring is based on granite rock with elastic modulus of 55GPa.The super-strong baserock makes the temperature control and crack prevention of concrete very difficult. Based on hydration degree algorithm, numerical simulation was applied for a typical non-overflow dam section on a strong constraint area during construction and early working period. Concrete temperature field and stress field were obtained under such a special conditions. Then a reasonable quantitative standards of temperature control and cracking prevention were put forward, which may provide some reference to similar projects.

1. Introduction

Chushandian reservoir is a large flood-control projects on the Huaihe River, located in xinyang city, Henan province. The dam site is near the Chushandian village of 14km, west of Beijing-Guangzhou Railway, about 15km from xinyang city. 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.. The project is composed of multiple dam types. The main dam axis length is 3690.57 m, in which the earth dam length is 3261 m, and concrete dam section length is 429.57m (including connecting dam section), with a crest elevation of 100.4m.

Because the dam is made of normal concrete, which uses the large amount of cementitious material in per unit volume of concrete. The cement used in the non-overflow dam section is non-low-heat cement and the amout is large, especially the strong constraint area is located on the super strong baserock of 55GPa. Casting temperature and ambient temperature are high in the spring, which makes the mass concrete in the strong constraint area temperature control and crack prevention difficult [1,2].

2.Calculation Model and the Main Parameters

The whole finite element model is established for a typical non - overflow dam section. This paper focuses on the dam concrete in the strong constraint area, as shown in figure 2 and figure 3. The materials in dam upstream is C25 concrete, cover layer and downstream is C20 concrete, dam heart is C15 concrete.

Boundary conditions: In the temperature field simulation calculation, it is assumed that the bottom and the surrounding of the dam foundation are adiabatic boundary, and the other side is the heat exchange boundary [3,4]. In the calculation of the stress field, it is assumed that the bottom of foundation is hinged bearing, surrounded by connecting rod support, the upper structure are free. The first layer and the second layer are made of C20 concrete,whose casting thickness is 1.5m, the casting thickness of third layer made of C15 concrete is 3.0m.

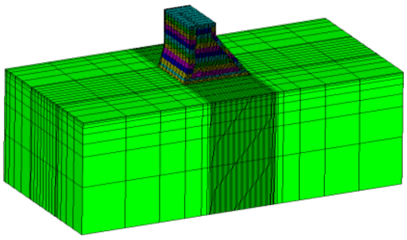

Fig1.Whole model

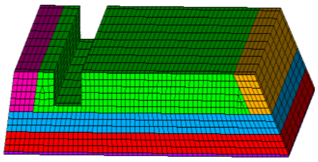

Fig2 .Concret in strong constraint area

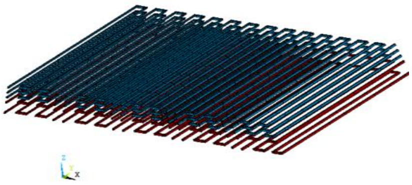

Fig3. Cooling pipes in strong constrained area

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 materials

Material	Thermal Conductivity λ (KJ/(m.h.℃))	Adiabatic temperature rise final value θ_0 (℃)	Temperature conductivity a (m^2/h)	Coefficient of linear expansion α $(10^{-6}/℃)$	Poisson's ratio μ	Density ρ (kg/m^3)	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
C25	9.546	41.5	0.00441	8.373	0.167	2357	31.7
Foundation	10.50	0.0	0.00548	7.00	0.20	2680	55.0

3. Calculation Results Analysis

Based on the hydration degree of temperature field and stress field simulation calculation program[5-8], after 23 cases of optimization, the following main conclusions are obtained. Due to space limitations, only the most optimal case results as shown in Figure 4 to Figure 7.

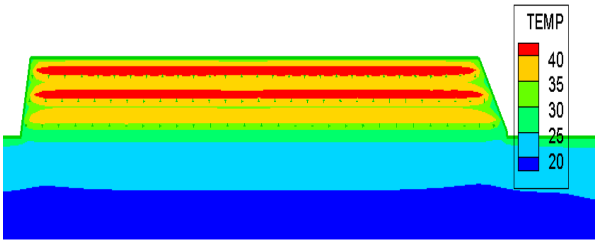

Fig.4 Temperature countour of the center section in the dam strong constraint area

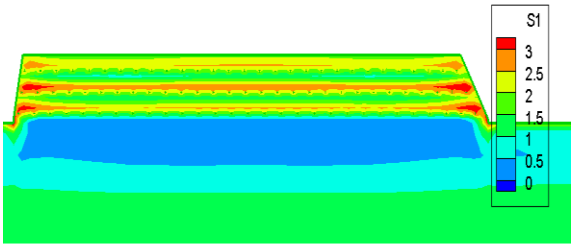

Fig.5 The first priciple stress countour of the center section in the dam strong constraint area

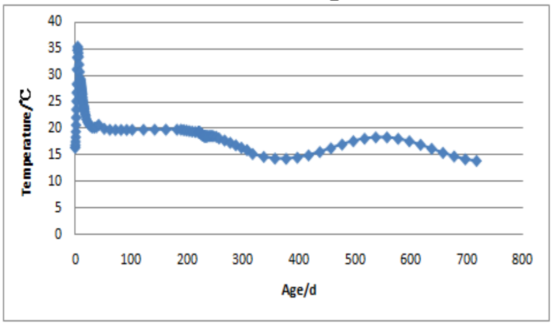

Fig.6 Curve of temperature at midpoint of strong constraining area

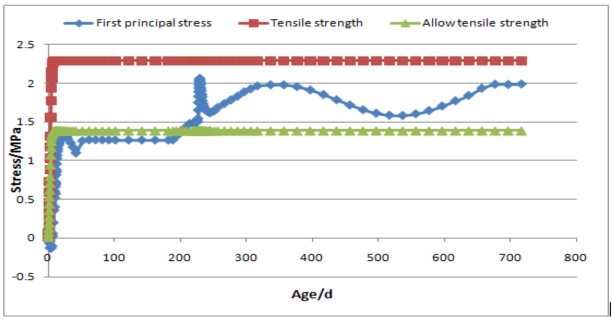

Fig.7 Curve of the first principal stress at midpoint of strong constraining area

(1) The baserock is granite with elastic modulus of 55GPa, whose strength is very large. It put great pressure on crack prevention for the strong constraint area of the dam. Another disadvantage is the strong constraint area casted in the spring, which make the casting temperature and ambient temperature very high. For the above two reasons, tensile stress generated by the strong constraint area is very large in the autumn and winter. If there is no crack prevention measures, C20 concrete highest temperature is expected to reach 38 ℃ ~45 ℃ in late March to early April, and the maximum temperature will reach 47℃～50℃ in mid to late April. When the temperature decreases, shrinkage happens in the concrete .The maximum tensile stress inside the concrete will reach about 4MPa, obviously more than the tensile strength of C20 concrete. And tensile stress in many areas of concrete is too large, it is supposed that more penetrating cracks or deep cracks will occur in the concrete.

(2) As the temperature rising slowly in the early age and average daily air temperature in spring increasing gradually, the internal and external temperature difference does not lead to excessive surface tensile stress. Therefore, early-age stage concrete surface covered with a layer of geomembrane cloth is enough.

(3) Depending on the pipe layout density comparison calculations (using river water for cooling), when the layout is 1m * 1m , the temperature peak is cut about 4 ℃. 1m * 0.5m layout is cut about 6 ℃. 0.5m * 0.5m layout is cut about 10 ℃. When the peak temperature decreases, the tensile stress peak value in the internal point of the first layer would decrease. But the maximum tensile stress on the 55GPa baserock can not be reduced to its tensile strength range if the water pipe cooling is the only measure used in the project.

(4) After pipe cooling + expansion agent were used, it is found that when the autogenous volume shrinkage deformation of the 60 microstrain was reduced to 6 microstrain, equivalent to reducing temperature about 6 ~ 7 ℃, crack would not happen.

(5) Trying the water pipe cooling + reducing the 31m long edge size to about 15m, the maximum tensile stress in the first layer would become 2.1MPa, which was under the tensile strength.

(6) Before the flood season, the internal temperature of the concrete is reduced to within 20 ℃ (with water pipe cooling), then the possibility of cracking in the strong restraint area during the flood period (water temperature 20 ℃) is small.

(7) Casting temperature in the calculation shows that if it exceeds 20 ℃, whatever measures can not make the tensile stress of concrete in the fall and winter lower than its tensile strength.

4. Recommended Temperature Control Indicators

(1) Casting temperature: No more than 20 ℃. If it is higher than 20 ℃, should not be casted.

(2) Maximum temperature in the concrete: The length of the casting block is needed to reduce. When the longest side of the casting block is not greater than 25m, the maximum temperature can not be higher than 35 ℃. When the longest side of the cast block is no more than 15m, the maximum temperature can not be higher than 40 ℃.

(3) Concrete temperature drop rate: No more than 2 ℃ / d.

(4) Internal and external temperature difference: No more than 25 ℃(the difference between the maximum temperature inside concrete and the minimum environmental temperature).

5. Conclusion

Compared with the ordinary concrete dam, there are two great difficulties in mass concrete temperature control and crack prevention work in the strong constraint area. First, the baserock elastic module is very large, reaching 55GPa. The second is the spring casting makes casting temperature and hydration heat temperature peak difficult to control.

The concrete temperature field and stress field in the strong constraint area shows that strict temperature control measures and temperature control index should be adopted to control the internal temperature peak. It will avoid cracks during the flood time,especially in autumn and winter.

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