Concrete Cracking Control of Chamber wall in Jiepai Ship-lock Project

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Abstract. Based on analysis of crack problem of chamber wall ship lock expansion project in Jiepai province, the related research of countermeasures have been made, to solve the cracks occurs in the structure. The countermeasure of cracks are analysed by monitoring internal-external temperature and shrinkage stress of chamber wall. It is provided that the rational measures could make less cracks occur, including fiber lattice with curing of insulation and moisture materials and optimization of proportion mix. A series of investigations are carried out in situ and prove countermeasures of cracking control effectively. This paper states the technical details and developing of inner temperature and shrinkage in chamber wall by adopting above measures.

1. Introduction

Jiepai hydropower station project is the largest project in Jiangxi province, of which contains the upper for cast-in-situ concrete chamber wall with concrete strength of C40. The size of casting unit is of 17m×16.7m×2m, of which height of pouring concrete is about 2m, and cracks occurs easily on its surface during concrete construction, especially in mass concrete with growth of strength grade. It is huge problem to be solved [1]. According to technical specification for thermal cracking control of mass concrete of port and waterway engineering (JTS 202-1-2010), the control of cracks is not mean to control them within the specification requirements rather than eliminate generation. And the width and depth of cracks are illustrated in table 1.

| Zone          | Freshwater environment | Width (mm) |
|---------------|------------------------|------------|
| Above water zone | Fluctuation zone       | 0.25   |
| Underwater zone |                        | 0.4      |

Cracks mainly appear in vertical direction or horizontal direction, whose reason include difference of temperature, shrinkage and self-constriction in concrete. And binder materials adopted P-O42.5 cement, fly ash grade II, and ground slag. Aggregates adopted graded broken stone (5–40mm) and river sand. And concrete slump reach range of 70-110mm, initial setting time within 6h. The proportion mix is listed in table 2.
Chamber cracks mainly extended longitudinally, of which the location and width are illustrated in Figure 1. Cracks occurred after mould removal, which extended in incremental time. Two weeks later, the length of each crack extends vertically in entire surface, which has impact on the appearance and durability of the structure. so it is important problem to be solved, and this paper stated about the countermeasures of cracks [2].

2. Experiment
The countermeasures of cracks contains fiber lattice, optimize proportion mix and adopting insulation materials, which need to be applied synthetically, to achieve ideal effect of cracking control [3]. And the effect of cracking control and evaluation of countermeasures feasibility were investigated.

And internal temperature and environmental temperature monitoring by sensor, which are set according to the Figure 2.

2.1. Mix proportion optimized
The amount of binder materials has a great impact on the internal temperature of concrete, which could lead more internal restrain and cracks occurs. On the premise that the compressive strength can meet the requirements, reduce the amount of binder materials (or cement) appropriately. And binder materials should be double-doped with fly ash and ground granulated blast-furnace slag (GGBS) [4].

### Table 2 Proportion mix of concrete

| Compressive strength | Materials          | W/C | Cement | Fly ash | GGBS | Coarse Aggregate | Fine Aggregate | Water | Water reducer |
|----------------------|--------------------|-----|--------|---------|------|------------------|----------------|-------|---------------|
| Weigh(kg/m³)         | 0.46               | 235 | 55     | /       | 1108 | 708              | 136            |       | 6.4           |

Figure 1. Cracks location (caption centred).

Figure 2. Temperature monitoring by sensor
The setting time should be more than 10h by using adjusting retarded component. The optimized proportion mix are list in table 3.

Table 3 optimized proportion mix of concrete

| Compressive strength W/C | Materials                  | Weigh(kg/m³) |
|--------------------------|----------------------------|--------------|
|                          | Cement                  | 0.45         |
|                          | Fly ash                | 145          |
|                          | GGBS                    | 87           |
|                          | Coarse Aggregate       | 58           |
|                          | Fine Aggregate         | 1248         |
|                          | Water                   | 702          |
|                          | Water reducer           | 131          |
|                          |                          | 5.22         |

2.2. Adoption of fiber lattice

For the sake of the cracks occurred from in the pouring interface zone, and then extend vertically within 14d. The fiber lattice should be covered 2/3 length and 1/2 height at least and set in bottom of the chamber wall from interface zone before concrete pouring, as it is shown in figure 3. The fiber lattice could be set in covering layer, of which adopt cushion block to adjust rational position.

2.3. Adoption of Insulation materials

Due to the influence of internal heat of hydration, mass concrete restrained by volume, thickness, poor heat dissipation performance, construction method. The internal temperature tends to rise constantly, resulting in a large difference in the internal and external temperature difference in a short time. The high temperature could raise compressive strength rapidly, especially in tensile strength, which is benefit for cracking control.

Chamber wall adopted one-time casting, and its surface should be covered by insulation materials. In order to reduce the surface crack of concrete and improve the crack resistance of concrete. After completion of pouring, plastic film was used for covering, and water was sprayed for curing for 14 days.
3. Result
As can be seen from figure 3, the core temperature reaches its peak within 48h after pouring, and the maximum core temperature rise in the centre location is 73.8 °C (about 29.8 °C before the concrete mould). Due to environment condition, the temperature showed a trend of rising and falling periodically. The temperature at the top dropped relatively quickly and reached the natural temperature after a week. And 40mm in temperature in concrete change a little slower. After 7d, the core temperature still cannot be closed to environment temperature.

According to technical specification for thermal cracking control of mass concrete of port and waterway engineering (JTS 202-1-2010), it is stipulated that the internal temperature of concrete should not more than 70 °C, and the cooling rate should not be greater than 2°C/d. However, it can be seen from the temperature measurement curve that the temperature of the chamber concrete rises rapidly after pouring, and the maximum temperature of the chamber concrete reached more than 70 °C in 1d. The maximum temperature of the chamber concrete even reached to 73.8°C in 2d, which is more the specification but without cracks. The fall rate of temperature at the bottom and the centre of the chamber concrete was basically more than 2°C/d. After the initial setting time of concrete, the cement released heat with hydration, which raise the temperature inside [5]. With the temperature stress, the concrete generates compressive stress and expansive strength outwards. As the temperature gradually falls, the temperature of concrete will contract. After the optimization of concrete mix design, the dose of cementitious materials or cement are reduced, and the core temperature formed by internal hydration is also reduced as well, which make down the risk of internal constraint [6]. Moreover, the concrete insulation materials make the early strength of concrete increased rapidly, and tensile strength is larger, result in reducing the risk of cracking caused by external constraints [7].

According to the location of cracks in the early stage, cracks will occur when the tensile stress inside the concrete of the brake wall reaches the ultimate tensile strength of the concrete. The distribution of cracks are shown in the figure 6.
4. Countermeasures of cracking control
Concrete crack control is a comprehensive measure, which needs to be done well in all aspects, including material quality control, concrete proportion mix design, the use of fiber network and thermal insulation materials [8]. Above all, it is benefit for cracking control of concrete, and could be controlled well and project quality be improved, and the appearance of chamber wall concrete after 14d was Figure 7.

![Figure 7. Appearance of chamber wall](image)

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