Temperature control technology on construction of large volume concrete

Shilong Wang 1, a, Jian Xu 2, b, Rui Zhong 2, c

1 Department of Construction, Harbin Engineering University, Harbin, China
2 Department of Project management, Ninth Design & Research Institute, Shanghai, China.

a wangshilong@hrbeu.edu.cn, b jj7680@126.com, c zhongrui@ndri.sh.cn.

Abstract. After the pouring of large volume concrete, the internal hydration heat is accumulated and not easy to send out. However, the surface heat sending is faster, and then the temperature difference between inside and outside is bigger, so the compressive stress is generated in the interior of the concrete and in the concrete external tensile stress is occurred, which eventually led to temperature cracks in the concrete surface. In the north latitude of 45 degrees, Harbin, in order to avoid unfavourable factors during the large volume concrete pool construction, the appropriate and effective temperature control measures must be taken to prevent the temperature cracks harm to the safety and durability of the structure.

Keywords: Large volume concrete, hydration heat, temperature cracks, temperature control measures.

1. Introduction

Due to cement hydration heat of the large volume concrete is not easy to distribute, in the concrete internal, temperature rise is too high [1]. When the temperature difference between the inside and the outside of the concrete is larger than 25 ℃, inside the concrete, there is compressive stress, and tensile stress is generated on the surface. If the tensile stress exceeds the early tensile strength, concrete will be pulled crack, and the temperature cracks is taken [2, 3]. Due to Concrete bulky and shrink large, shrinkage cracks is easy to be produced. The amount of concrete is large, and heat capacity is high generated by cement hydration heat. Additionally, concrete is a poor conductor of heat, the heat inside the concrete within a short time is difficult to disperse. If the cooling rate is too fast, the concrete will have a greater temperature difference, and the cooling temperature difference can easily cause the overall deformation of concrete. However to large volume concrete, it is impossible to deform along with the temperature difference stress, what’s more, the combined effect of volume shrinkage deformation caused by water loss of concrete and the tensile stress acted by the constraints due to the foundation and other structural boundary conditions, it is easy to produce the through cracks. Therefore, it is critical to control the maximum value of the temperature rise and cooling rate in 5d ~ 14d after pouring the large volume concrete.

So the key issue of large volume concrete construction is how to control the generation of temperature cracks and shrinkage cracks, specifically, it is how to control the temperature difference between the outside ambient and the inside temperature when inside concrete, there is the highest peak heat caused by cement hydration heat and thus the shrinkage amount of concrete cooling. The solution to the problem is to control the release rate of hydration heat and temperature difference, cooling rate of concrete [4, 5].

2. Temperature estimation of large volume concrete

2.1 Adiabatic temperature rise calculation at any moment caused by the cement hydration heat[6]

\[ T(t) = \frac{CQ}{\epsilon\rho} (1 - e^{-\frac{t}{\tau}}) \]  

(1)
The formula of temperature rise of maximum concrete hydration heat

\[ T_{max1} = \frac{CQ}{c\rho} \]  

Where: C – specific heat of cement, \( \rho \) – density of cement, Q – heat of hydration of cement.

The measured data is put into the formula to get the maximum theoretical adiabatic temperature rise value \( T_{max1} = 37.3 \degree C \), for safety, the theoretical value is used to calculate.

2.2 Calculated adiabatic temperature rise at any moment

\[ T_{max2} = K \times \frac{CQ}{c\rho} \]  

Where: K – impact coefficient of volume thickness and Cooling conditions to temperature of large volume concrete; So get summer \( T_{max2} = 33.6 \degree C \).

2.3 Budget maximum temperature inside the concrete

\[ T_{max3} = T_j + T_{max2} \]  

Where: \( T_{max3} \) - Concrete maximum temperature (\degree C); \( T_{max2} \) – maximum temperature rise of concrete under various thermal impact conditions(\degree C), calculated by taking (3) results[7-9];

\( T_j \) - temperature of concrete into the mold (\degree C), according to the construction experience and temperature data, in summer, taken as 25.0 \degree C.

Therefore, to get the budget maximum temperature of the concrete internal in summer \( T_{max3} = 33.6 + 25.0 = 58.6 \degree C \).

3. Temperature control measures of large volume concrete

In order to effectively control the emergence and development of harmful cracks, comprehensive consideration must be taken from control hydration heat warming, slow cooling rate, reducing shrinkage, improve the ultimate tensile strength, and improve aspects of constraints and design structure. Combined with practical engineering some necessary measures must be taken[10].

3.1 Reduce hydration heat of cement

To chose the low or moderate hydration heat cement in concrete batching. According to the actual situation, P.O32.5 ordinary portland cement to be used to this project.

Take full advantage of the late strength of concrete or 60d strength, reduce the amount of cement of concrete per cubic meter. The test results showed that each increase or decrease 10kg cement, the temperature will be corresponding lift 1 \degree C caused by hydration heat.

To use coarse aggregate, try to use a particle size of 5 ~ 31.5mm, well-graded coarse aggregate; Pulverized fuel ash and other admixtures, or mixing the appropriate water reducing agent, retarding agent, improve the workability of concrete. To lower water-cement ratio in order to reduce the amount of cement and reduce heat of hydration heat[11].

3.2 Reduce the temperature of the concrete into the mold

For pouring concrete, to choose a more suitable temperature and try to avoid the hot weather. In summer, pieces of ice should be added to concrete or using groundwater mixing concrete and aggregates should be set up sun protection measures.

Mixing the appropriate retardation type water reducing agent.

When the concrete into the mold, ventilation and heat dissipation measures should be taken to accelerate heat dissipation.
3.3 Strength temperature control during construction

After the concrete pouring, do well in insulation moisture curing of concrete. Thus slowly cooling, give full play to the characteristics of concrete creep to lower the temperature stress.

Take a long conservation, set reasonable removal time, so delay the cooling time and speed to give full play to "stress relaxation effect" of concrete.

Strengthening temperature monitoring and management, implementing information control, always monitor the temperature changes inside the concrete, to ensure temperature difference between internal and external is less than 25 °C, temperature differences between the base surface and the substrate surface is controlled within 20 °C.

Reasonable arrangements for the construction program is able to control temperature rise being evenly during pouring process. And avoid excessive accumulation of concrete mixture to appear much height difference.

3.4 Improve constraint condition, reducing temperature stress

Stratified or chunked to pour concrete with a reasonable set of horizontal or vertical construction joints, which is advantageous to prevent the accumulation of hydration heat.

Setting a post pouring belt on appropriate positions can relax relax the constraints extent and reduce the heat accumulator of each length of pouring concrete, ultimately to reduce the temperature stress.

4. Temperature measurement and control of large volume concrete

4.1 The actual process of temperature measurement is as following steps:

Step 1: Layout design of measurement points;
Step 2: Prepare thermometer and wire;
Step 3: Put up temperature measurement workplace;
Step 4: layout measurement points in construction site;
Step 5: Temperature line connection with thermometer;
Step 6: Thermometer for checking;
Step 7: Start temperature measurement;
Step 8: Monitoring thermometer;
Step 9: Temperature data processing;
Step 10: Drawing the bitmap of time - temperature location - temperature field;
Step 11: Summary of temperature data.

4.2 Points layout and control of temperature measurement

Generally, before large volume concrete construction, temperature measurement points should be pre-arranged, the specific principles are: the most appropriate points are Corners and easy to ventilate location, and center position of the concrete. The arrangement of the measuring points should be evenly distributed, preferably equidistant gap so easy to calculate the cooling rate and temperature distribution inside the concrete. Specific distribution methods should refer to the figure1 below:

Fig. 1 Schematic arrangement of measurement points
4.3 Temperature monitoring frequency

In general, test should be started 10h after finishing pouring concrete, and then a test every 4h, verification at any time during the testing process. Thus continues until the concrete temperature began to fall to the stability point, about 14d. Generally, during and within 7d after pouring concrete, to measure and read once on more than 2h; 7d later, to measure and read once no more than 4h; 14d later, to measure and read once no more than 8h; after, to measure and read once no more than 24h. High-frequency test is required to record the whole process of concrete temperature control.

To this project, it is required to start temperature monitor work since 10h after finishing pouring concrete. And test once every 2h, each cycle is 7d, total test time is 14d, and test frequency should be adjusted according to actual engineering cooling situation.

To test the temperature into mold of concrete once no more than 8h during pouring large volume concrete, make a record of work.

4.4 Analysis of test results

Temperature test results are primarily basis to the analysis on temperature and changes of large volume concrete interior. To winter construction, it may be lower than -10 °C at the edge, and may be higher than +40 °C at the center. It is necessary to carry out insulation of the edge in order to achieve internal and external temperature difference does not exceed 25°[12].

In general, the temperature indicators is preferably not greater than the following values:
The maximum temperature rise is no more 35°C than the temperature of pouring into the mold
The temperature difference between the inner and the surface (without concrete shrinkage equivalent temperature) is no more than 25 °C.

Cooling rate is no more than 1.2 °C / d.

Calculated temperature stress \( \sigma \) should be met:

\[
\sigma \leq \frac{f_a}{k}
\]  

(5)

5. Summary

The key issue of large volume concrete construction is how to control the generation of temperature cracks and shrinkage cracks. In the north latitude of 45 degrees, Harbin, it is particularly difficult to large volume concrete pond construction. Combined with the actual situation, the five kinds of temperature control measures of large volume concrete are given. The engineering actual test results prove the feasibility and effectiveness of these methods. Techniques and methods used on this engineering is can be referred to deal with other similar problems.

References


