

# Application of Skip-bin Casting Method in Mass Concrete

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**Abstract:** With the increasing scale of large-scale civil and industrial construction projects, the problem of controlling temperature cracks is of vital importance in order to ensure the integrity and durability of mass concrete foundation footings. This paper is based on an actual project of construction of a large volume concrete skip bin method, using Midas FEA NX to carry out finite element simulation of the construction process under the skip bin casting of the project, and study the temperature field derived from the simulation, and it is found that the temperature of this large volume concrete project is maximum at about 48h after the concrete casting, and the location is in the center of the concrete.

**Keywords:** Mass concrete; skip bin method; finite element analysis; temperature field.

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## 1. Introduction

With the development of modern industrialization and urbanization, more and more large-scale infrastructure projects such as dams, bridge piers, nuclear power plants, large foundations, etc. require the use of mass concrete, and more and more rely on the use of mass concrete. Therefore, understanding the characteristics of mass concrete and controlling the cracking of mass concrete is extremely critical to ensure the stability and durability of the structure in use.

Barn-hopping method is a mass concrete construction method, which is mainly used to control the temperature rise of concrete and the temperature cracks caused by it in dams, foundations, pillars and other structures. This method achieves the purpose of controlling temperature rise and stress and preventing cracks by separating the concrete casting layers so that each part can carry out the hydration reaction separately, and by setting a gap for a period of time to allow time for each part to dissipate heat and reduce the temperature difference inside the concrete[1-2]. The jumping method was first proposed by Prof. Wang Tiemeng, and the jumping construction has many advantages, such as reducing the risk of temperature cracks, allowing optimization and control of the construction process, improving the structural integrity and reducing the internal temperature difference and thermal stress.

The skip method requires high control of pouring intervals and precise temperature monitoring and pouring schedules. In the implementation of the more complex, so the jumping method of pouring needs to be more comprehensive research. Large volume concrete jump warehouse method construction technology is currently less research, there are only local specifications to guide the construction, construction more dependent on engineering experience, and less foreign academic research, mainly domestic scholars research. Foreign scholars Hobusch[3] conducted on-site monitoring of extra-long walls using different crack control measures and compared the temperature and strain development process of the wall. The riser cooling method using water cooling during the pouring period is more suitable for early cracking structures that are only sensitive to temperature changes. The effects of temperature and confinement were taken into account, and it was concluded that the jump-bin method

construction method was the most effective measure. Jin Yating[4] combined the actual cases of the project, compared the similar projects using the back pouring belt construction method, the structural integrity of the structure is improved, and concluded that the jumping silo method ensures the quality of the project while accelerating the progress of the project. Zheng Haojie[5] believes that the combination of skip bin method and cooling water pipe can play a better temperature control effect, which can effectively reduce the risk of cracking in the early stage of large volume concrete. Zhou Bamboo shoots, Zhou Qinglei[6-7] to the actual project as a basis, to further explore the jumping warehouse method construction engineering in the technical difficulties, process, and construction process problems and the corresponding solutions to guide the actual project. Li Dong[8] successfully deduced the formula for calculating the relaxation stress of mass concrete, and based on the results of the deduced stress calculation formula for the foundation slab constructed by the skip bin method in a commercial housing project as an example, he formulated the corresponding crack control measures, and these measures showed significant effects in the application of the actual project. Hu Dongkang, Zhao Guangshu, Shi Weizhong[9-11] and others simulated the construction process of one-time casting and skip-cast method using finite element software Midas FEA. The study shows that the skip-cast method can reduce the concrete cracks to a certain extent, and the reasonable skip-cast method can achieve better results in the actual project, which has a certain reference value for the actual project. In recent years, the construction of skip-bin method has achieved excellent crack control effect in domestic large volume concrete projects[12].

## 2. Summary of Work

This project is a theater project in a city, the total building area is about 30,000m<sup>2</sup>, the underground building area is about 10,000m<sup>2</sup>, and the above ground building area is about 20,000m<sup>2</sup>. The thickness of the foundation slab of this project is 1,000mm, which belongs to the large area mass concrete structure. The raft slab concrete is C35P8, and the total amount of raft slab concrete is about 9000 square meters. The layout plan and concrete mix of the project are shown in Figure 1.

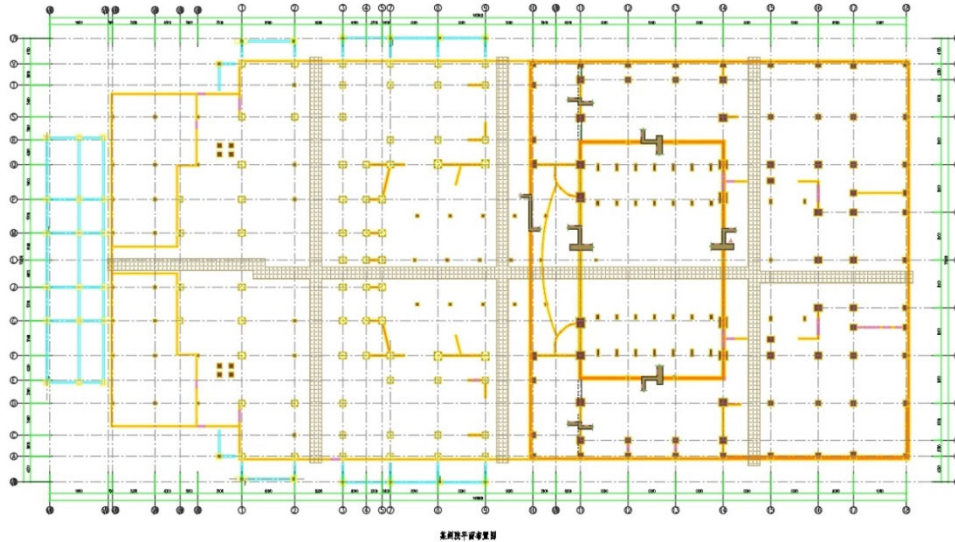


Figure 1. Floor plan of a theater

### 3. Parameter Setting and Modeling

In this project, the selected concrete design strength grade is C35, impermeability grade P8. In order to solve the problem of temperature difference caused by the high heat generation of concrete, and reduce the resulting temperature

stress, thereby reducing the possibility of cracks in concrete, the use of part of the fly ash instead of cement cementitious materials to reduce the heat of hydration, the concrete specific proportion is shown in Table 1.

Table 1. Concrete mix ratio

materials	concrete	fine aggregate	coarse aggregate	water	fly ash	weight
Amount of material used	330	750	1100	156	70	2406
weight ratio	0.1372	0.3117	0.4572	0.0678	0.0291	/

Finite element software is able to simulate and analyze the generation, transfer and effects of the heat of hydration of concrete to predict and control the temperature distribution and stress state inside the concrete in order to take appropriate preventive or mitigation measures. In this paper, Midas FEA NX, a software in the field of construction, is used, which has the functions of heat of hydration analysis, static analysis, slope analysis, etc., and is able to accurately simulate the temperature field and stress field during the construction of mass concrete. At the same time Midas FEA NX software, can do the same model multiple times to adjust the parameters of the calculation, so that the subsequent analysis does not need to be re-modeled, which is conducive to saving analysis and calculation time.

Basic assumptions of the model:

- Concrete and surrounding foundation soil are assumed to be isotropic and ideal materials;
- It is assumed that the thermal conductivity, specific heat capacity, specific gravity, and foundation temperature of concrete are constants that do not change with time;
- According to related research, the effect of reinforcement in the foundation footing on the temperature and stress fields of concrete can be neglected [93], so in order to simplify the calculation of the model, the effect of reinforcement in the foundation footing on concrete is not considered;
- It is assumed that the pouring of each bin block in the model is completed at one time;
- The specific parameterizations are shown in Table 2.

Table 2. Main parameters of the finite element model

physical property	base plate	foundations
thermal conductivity (kJ/(m·h·°C))	9.5043	8.2
proportion (kg/m <sup>3</sup> )	2406	1900
specific heat (kJ/(kg·°C))	0.9275	0.81
convection coefficient (W/m·°C)	21.94	21.94
coefficient of thermal expansion	1×10 <sup>-5</sup>	1×10 <sup>-5</sup>
Mold temperature (°C)	20	/
Poisson's ratio	0.2	0.2
atmospheric temperature (°C)	20	20

#### 4 Analysis of numerical simulation results

In order to study the mass concrete temperature and its

temperature stress change rule during the construction process of jumping warehouse method, the first casting block

A2 and the latter casting block B2 were selected as the research object in this study. The location of the selected

measurement points is shown in Figure 2.

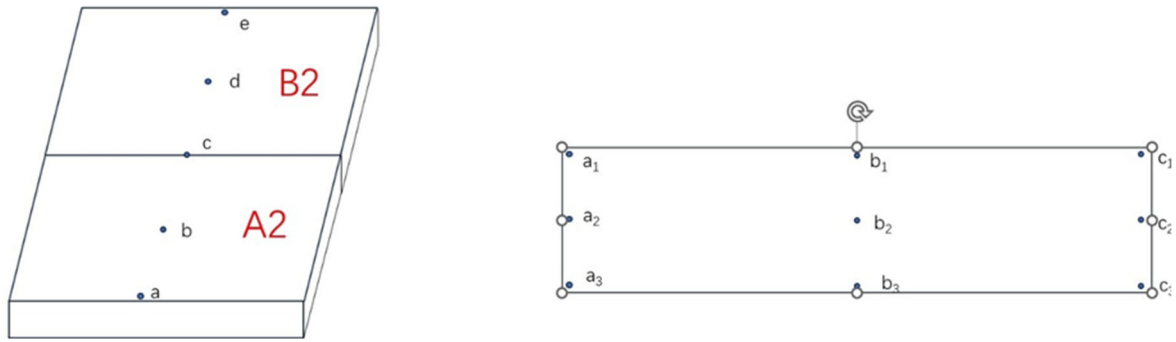


Figure 2. Layout of measurement points

The maximum temperature cloud at the center point of the A2 bin block is shown in Fig. 3, and the temperature time curve of the temperature measurement points b1, b2 and b3 is shown in Fig. 4. From Fig. 3, it can be seen that the first casting block in the pre-metamorphic heat due to the collision material and water occurring to produce a large amount of heat, so that the overall temperature of the concrete rises rapidly, and produces an obvious temperature gradient, which is manifested in the center of the concrete location of the higher temperature, the surface of the temperature is lower. The temperature of the concrete reaches a peak value of 50.93°C after about 2 days of pouring, from which it can be concluded that the hydration reaction rate is the fastest in the first two days after the concrete is poured, and at this time the release of heat of hydration also accumulates to the maximum value. As can be seen from Figure 4, from 2 to 3 days after pouring, the convection between the concrete and the outside

world is greater than the exothermic heat of hydration, the concrete began to gradually cool down, and the cooling rate of the surface measurement point b1 is much greater than the center of the measurement point b2, at this time, the concrete reached the maximum temperature difference between the surface and the surface of the temperature of 11.32°C. The concrete temperature reached a peak of 50.93°C in the first two days after pouring. After 3 days of pouring, the heat of hydration of concrete gradually tends to adiabatic temperature rise, and at the same time, because the concrete has been exchanging heat with the environment so that the temperature enters a rapid decline stage, the temperature is reduced to 34.85 °C on the 7th day, with the reduction of the overall temperature of the concrete and exothermic heat of hydration is completed, the temperature is slowly lowered and tends to the ambient temperature.



Figure 3. Sections of bin block A2 (48h)

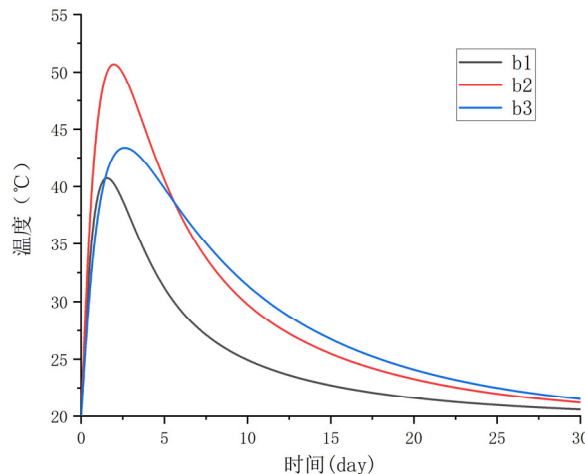


Figure 4. Temperature time curve at measurement point b

The cloud diagrams of the profiles of A2 bin block and B2 bin block are shown in Fig. 5, and the time course curves of temperatures at the center temperature measurement points b1, b2, b3, d1, d2, and d3 are shown in Fig. 6. From the cloud diagram 5, it can be seen that the maximum temperature appeared 48 hours after the completion of the pouring of the post-cast block, and this maximum temperature was the same as the maximum temperature of the first-cast block. And the temperature of the concrete pouring surface close to the post-cast block increased, which surfaces the influence of the post-cast block on the first-cast block. Further from Figure 6. it can be seen that the temperature trends at the center points of the

post-cast block and the precast block are generally similar, both of which increase rapidly and then decrease slowly and gradually approach the ambient temperature. The maximum temperature and the rate of temperature rise of the center measurement points b and d are almost the same, which indicates that the heat transfer from the post-cast block to the first casting block has a very small effect on the temperature of the center point of the first casting block. This is because the measurement point d is far away from the first casting block, as well as the first casting block has already had sufficient heat release in the first seven days.

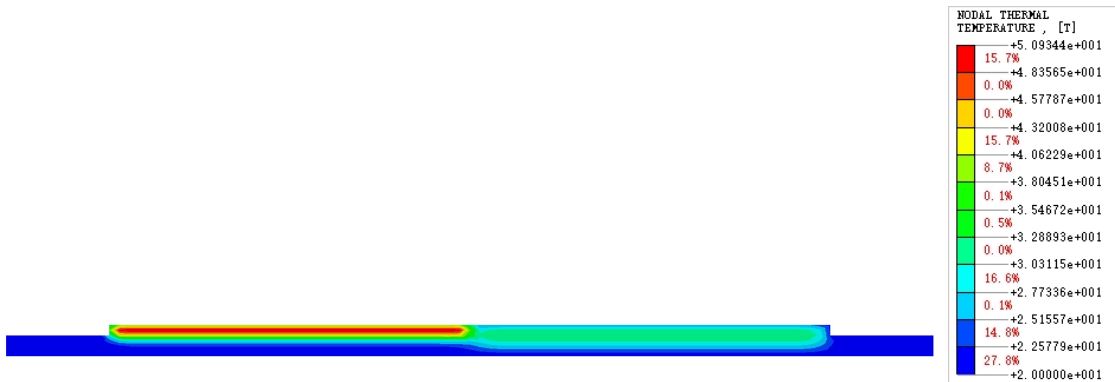


Figure 5. Sections of bin blocks A2 and B2 (216h)

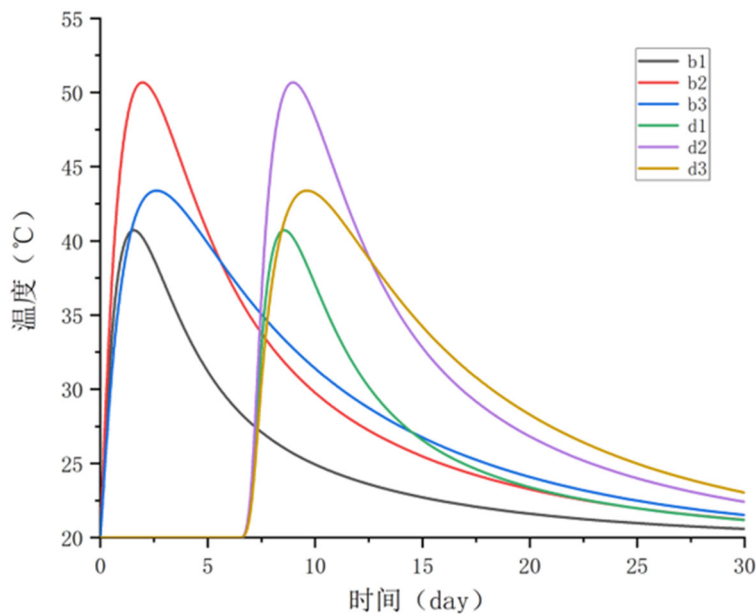


Figure 6. Comparison of temperature at measurement points b and d

According to the cloud figure 5, it can be seen that for the hopping method, the interface between the new and old concrete is the location most affected by the hydration heat of the post-cast block, and the temperature time curve of the temperature measurement points c1, c2 and c3 is shown in Figure 7. Measurement point c2 reaches the temperature peak value of 39.92°C in about 2 days of pouring, due to the measurement point in the first 7 days constantly convection with the outside world, so that the temperature is fully released and tends to be close to the ambient temperature, and at this time, the maximum temperature value is 23.44°C. After

7 days of pouring, due to the hydration heat effect of the concrete after pouring and heat transfer to the concrete of the first pouring block, the temperature of the measuring point began to show an upward trend until the 9th day to reach the peak temperature of 38.59 °C, and then entered the overall cooling process, the rate of cooling down with the time to decline, the temperature gradient after pouring the block began to reduce the temperature of the measuring point by decreasing the temperature tends to be the ambient temperature.

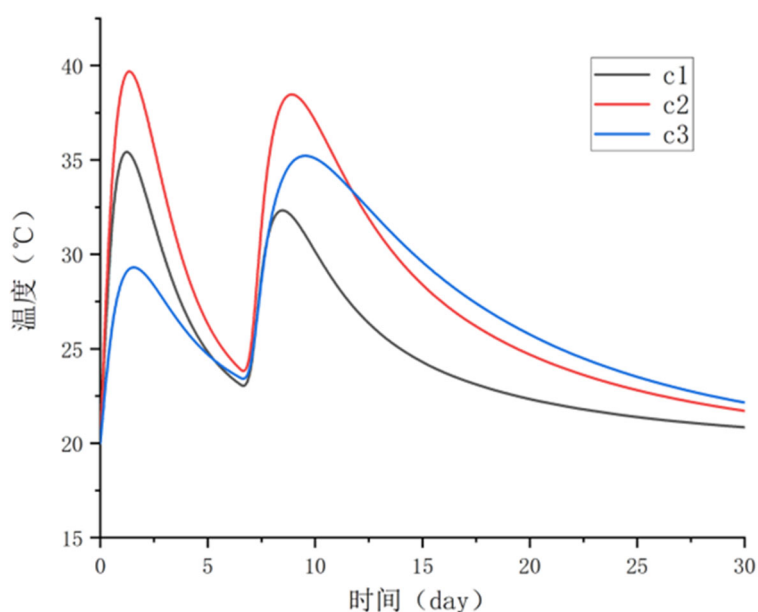


Figure 7. Temperature development curve at measurement point d

In summary, the maximum temperature of the concrete is 50.93°C, the temperature rise value is 30.93°C, the maximum temperature difference between the interior and exterior of the concrete is 11.32°C, and the overall cooling rate of the concrete silo block is less than 2°C/d. Therefore, the results of the simulated temperature field comply with the requirements of the temperature control indexes of the relevant specifications.

#### 4. Summary

In this chapter, the numerical simulation of temperature field is carried out in combination with the construction process of an actual mass concrete foundation slab by jumping warehouse method, and the development law of temperature in the process of heat of hydration of mass concrete is obtained. The temperature peak of the first casting block and the center of the second casting block of the skip-cast construction both reached the peak about 48h after the end of the casting, and then began to decline and gradually converge to the ambient temperature, and the temperature peak, the trend of change and the law are basically the same. The temperature of the combined surface of the old and new concrete was greatly affected by the post-cast block, and the temperature continued to rise after the post-cast block was poured, and the temperature began to fall until it was close to the ambient temperature when the heat of hydration of the post-cast block was basically finished.

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