Intelligent Automation And Soft Computing, 2019
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Vol. 25, no.4, 775–783
https://doi.org/10.31209/2019.100000081

Study on On-site Monitoring of Hydration Heat of Mass Concrete for Bridge Slab Based on Measured Data

Gao Xiaolong[1], Li Chunguang[2], Qiao Yunhong[3]

[1]Tianjin University, China
[2]CITIC-IDE (Beijing) Water Technologies Co., Ltd.
[3]Baotou City Drainage Industry Corporation

ABSTRACT
Plagued by consistent temperature cracks caused by hydration heat of mass concrete construction, a lot of research on concrete DAMS and other large hydraulic concrete, the theory also more deeply, and for large span bridge foundation pile caps, corresponding much smaller size of mass concrete, the related research is less. This article obtains from the cooling water pipes "embedded" scheme optimization, based on the new Tianjin Haihe river bridge project as the engineering background, construction of the concrete hydration heat temperature rise theory model was set up, with the help of theory formula, the numerical simulation and field measurement, the hydration heat of concrete control method is founded by the test.

KEY WORDS: Concrete, hydration heat, pipe cooling, cracks, temperature field, temperature stress, heat conduction, monitoring, construction control, actual measurement, numerical simulation

1 INTRODUCTION

WITH the rapid development of the economy, the demand for concrete technology in large structure is becoming higher and higher, and the concrete pouring project with large size and large amount is not uncommon. However, mass concrete construction brings a key technical problem-the control of temperature cracks. In 1915, the Arrow Rock Dam project in the United States, the Hoover Dam of the United States in 1933, the Togtoh Gore power station (Toktogul Hydropower Station) of the Soviet Union before 1977 and the project of the Three Gorges Dam (Three Gorges Dam), which attracted worldwide attention in 1994, are all demonstrating the mass concrete, these projects are all indicating that the construction of mass concrete has become a difficult problem in today's world. From the point of view of the internal stress of concrete, the temperature stress will be produced when the temperature difference in the surface of the concrete is more than a certain limit (Bobko C P et al., 2015; Silva WRLD et al.,2015; Lee M H et al.,2014; LIU Xinghong et al.,2010; Wenchao Liu et al.,2016.). If the temperature stress of the concrete exceeds the tensile stress of its own concrete, the concrete will produce cracks. These cracks are called temperature cracks. The relevant scholars at home and abroad have carried out a lot of research on this, how to control the temperature cracks of mass concrete in construction process has been plagued by many scholars (Heap M J et al., 2013; Conceicao J et al., 2014; LIU Wei et al., 2008).

Mass concrete first originated from the construction of concrete dams in hydraulic engineering. With the increase of productivity, it gradually developed into ship engineering, nuclear power engineering, and high-rise buildings. Japanese scholar Miyazawa et al. (2010) used blast furnace slag cement to control the heat of hydration inside mass concrete. The results show that blast furnace slag cement can effectively control the early temperature cracks in concrete; South Korea's Ha et al. (2014) focused on mass turbine concrete foundations. An automated temperature control system was proposed for construction. The experimental results show that the system can effectively control the generation of internal temperature cracks in mass concrete; American scholar Lawrence et al. (2012) studied the early strength to temperature cracks in mass concrete through tests and finite element analysis. The results show that the use of the finite element method can better predict the temperature field distribution of

CONTACT Gao Xiaolong adhi39@163.com

mass concrete. Around 1950, Zhu Bofang and others began to study temperature cracks in concrete. In 1958, a large number of construction temperature cracks occurred in the construction of Danjiangkou Reservoir (TIAN Yuzhe & ZHANG Tong, 2002). After a few years of summary design and construction experience, a preliminary domestic The temperature control measures provided the basic conditions for the smooth construction of the follow-up Three Gorges Project. The engineering community has studied many concrete hydraulic dams, such as concrete dams, and the theory has been deepened. However, for large-span bridge foundation platforms, the mass of concrete is much smaller, and there are fewer studies.

In this paper, based on the construction project of the foundation of the new Tianjin Haihe super bridge, the numerical simulation method is used to simulate and optimize the various construction conditions of the concrete integral casting process of the bearing platform, and the optimum formula of the "pre-buried cooling pipe" is obtained. In order to facilitate the real-time understanding of the temperature changes within the concrete, based on wireless sensors to establish a concrete remote monitoring platform, and in coordination with the control of the flow rate of the cold tube to achieve real-time control of temperature control of mass concrete.

2 THERMAL CRACKING MECHANISM OF CONCRETE HYDRATION

2.1 Definition of mass concrete

ACCORDING to JASSA, “The minimum size of the structural section is more than 80 cm, and the difference between the highest temperature in the concrete caused by the heat of hydration and the outside air temperature is expected to exceed 25°C, which is called mass concrete.” The American Concrete Association (ACI) only qualitatively described the concept of mass concrete, specifically stating that "a volume that is so large that it must take measures against the heat of hydration of the cement and the corresponding volume changes it brings in order to minimize cracking of a type of concrete.". At present, the definition of mass concrete in China is mainly based on the interpretation of the specification, and JGJ55-2011 “Design Procedures for Mix Proportion of Ordinary Concrete” is defined as “the larger volume that may be caused by the heat of hydration of cementitious materials. Temperature stress causes structural damage to harmful cracks." At present, mass concrete does not have a uniform definition, and its definition is only a relative concept. Structures larger than 1m in size are mass concrete. Although the size is not greater than 1 m, if no measures are taken to control, harmful cracks will be generated. It should also belong to mass concrete, and quantitative and qualitative analysis should be combined to understand the meaning of mass concrete. For example, a pool with a thickness of only 20-30 cm; an underground tunnel with 20-40 cm; a vertical wall with a thickness of 20-50 cm; and a raft foundation with a thickness of about 100 cm, strictly speaking, should not be considered large in terms of geometric dimensions. Volumetric concrete, but from the perspective of temperature shrinkage crack control should be "mass concrete".

2.2 Hydrothermal temperature field

Cement hydration reaction is a complex physical and chemical process, under the influence of hydration heat, concrete can be regarded as continuous homogeneous medium contains heat source, according to Fourier heat conduction theory, the concrete temperature field within the age and space function, the three-dimensional unsteady heat conduction differential equation of temperature field are as follows:

$$\frac{\partial T}{\partial \tau}=\frac{\lambda}{c\rho}\left(\frac{\partial^2 T}{\partial^2 x}+\frac{\partial^2 T}{\partial^2 y}+\frac{\partial^2 T}{\partial^2 z}\right)+\frac{m}{c\rho}\frac{\mathrm{d}Q}{\mathrm{d}\tau} \qquad (1)$$

In the formula, T is temperature; °C; t is time, d; x, y, z are rectangular coordinates; ρ, c, λ are concrete mass density, specific heat capacity and thermal conductivity, kg/m^3, kJ / (kg · °C), kJ/(m·h·°C); m is the mass of cement per unit volume of concrete, kg; Q is the cumulative heat of hydration of cement per unit mass when the age is t.

The expression of Q is:

$$Q(t)=Q_0\left(1\text{-}e^{-pt}\right) \qquad (2)$$

where, Q_0 is the final hydration heat generated by unit mass cement, kJ; P is constant, which is related to cement variety, specific surface and casting temperature.

The initial condition of concrete heat conduction is:

$$T|_{t=0}=T_0=\text{constant} \qquad (3)$$

The boundary conditions of concrete and air and solid contact surfaces are:

$$-\lambda\frac{\partial t}{\partial n}|_s=h_c\left(t-t_f\right) \qquad (4)$$

where, t_f is the air temperature, °C; h_c is the thermal convection coefficient between the solid variable cross-section and the fluid, kJ/(m^2·h·°C).

2.3 Hydration heat temperature stress field

In the finite element analysis, taking into account the influence of constraint degree and creep on the early-age concrete thermal stress, the time is discretized according to the calculus method, and the stress field at each node t is obtained by the incremental method (XIANG Yanyong et al., 2005).

$$\sigma(t) = -\alpha \sum_i K(t,\tau_i) R_i E_i \Delta T_i \tag{5}$$

where, i is the i-th time period; α is the thermal expansion coefficient of concrete, 1/℃; $K(t_i, \tau)$ is the stress relaxation coefficient; R_i is the constraint coefficient, its value is related to the ratio of length to height of the component and the ratio of the elastic modulus of the concrete; E_i is the elastic modulus, MPa; ΔT_i is the temperature difference between concrete inside and outside, °C.

2.4 Judgement of crack cracking

According to the temperature stress prediction and judgment of concrete cracking, using cracking risk factor assessment, it is generally believed that when the cracking risk coefficient reaches 0.7, the possibility of concrete cracking is already very high.

$$\eta = \frac{\sigma_1}{f_t} \tag{6}$$

where, i is the cracking risk factor; σ is the first principal stress of concrete, MPa; f_t is the tensile strength of concrete, MPa.

2.5 The equivalent heat conduction equation of tube cooling

The temperature field after the completion of the mass concrete can be regarded as a spatial unstable temperature field with the hydration heat acting as the internal heat source. The calculation of the temperature field is actually a solution to the heat conduction equation of the unstable temperature field in the space under the given initial conditions and boundary conditions. In practical engineering, the surface of concrete is exposed to air or water. In the process of cooling, the effect of water pipe cooling and the change of external temperature exist simultaneously. Therefore, the actual temperature field is calculated by the equivalent heat conduction equation of water pipe cooling, then the heat conduction equation (1) can be further written as:

$$\frac{\partial T}{\partial \tau} = a\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) + (T_0 - T_w)\frac{\partial \phi}{\partial \tau} + \theta_0 \frac{\partial \varphi}{\partial \tau} \tag{7}$$

where, T is the concrete temperature, °C; T_0 is the initial temperature of concrete, °C; T_w is the cold water inlet temperature, °C; τ is time, h; a is the coefficient of thermal conductivity, m^2/h; ϕ is the water cooling function; θ_0 is the final hydration heat at $\tau \to \infty$, kJ/kg; $\varphi(t)$ is the water-cooled temperature rise function, calculated according to the type of adiabatic temperature rise function selected; λ is the thermal conductivity, kJ/(m·h·℃).

The right side of equation (7) can be divided into two major parts. The first part is $a\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right)$, it represents the temperature change caused by heat flow through the concrete boundary. The rest shows the average temperature change caused by water pipe cooling and concrete adiabatic temperature rise under exterior adiabatic conditions.

Considering the above boundary conditions, equation (7) is discretized by finite element method in the space domain, and the following equation can be obtained:

$$[C]\left\{\frac{\partial T}{\partial \tau}\right\} + [K]\{T\} = \{F\} \tag{8}$$

$$[C] = \int_\Omega \rho c [N]^T [N] \mathrm{d}\Omega \tag{9}$$

$$[K] = \int_\Omega [B]^T [D][B] \mathrm{d}\Omega + \int_\Omega \lambda [N]^T [N] \mathrm{d}\Gamma \tag{10}$$

$$\{F\} = \int_\Omega \overset{g}{Q} [N]^T \mathrm{d}\Omega + \int_{\Gamma_q} q [N]^T \mathrm{d}\Gamma_q + \int_\Gamma \lambda T_a [N]^T \mathrm{d}\Gamma \tag{11}$$

where, $[C]$ is a specific heat matrix; $[K]$ is the heat conduction matrix; $\{F\}$ is the thermal load vector; $[N]= [N_i,N_j,\cdots,N_r]$ is the form function matrix; $[B]$ is the derivative matrix of the shape function in the natural coordinates; $\overset{g}{Q}$ is the total heat source rate per unit volume, kJ/(m^3·h); q is the water velocity of the cold pipe, m^3/s; Γ_q is the convection boundary of the cold pipe; Γ is the general convective boundary.

By using the backward difference method in time domain (8), we can get the following results:

$$\left([C] + [K]\Delta\tau\right)\{T\}^{n+1} = [C]n\{T\} + \Delta\tau\{F\}^{n+1} \tag{12}$$

Based on equation (11), using node temperature values and thermal load vector $\{F\}$ for n periods, the node temperature values for the n+1 time period can be found.

3 OPTIMIZATION OF BRIDGE BEARING CONCRETE HYDRATED HEAT PIPE COOLING SCHEME

3.1 Project summary

THE Tianjin Binhai New Area West Outer Ring Expressway (Jinhan Expressway - Haijing Avenue) starts from Beijing Qinghe Farm (connected to Jin-Han Expressway) and ends at the northeast boundary of Dagang District. The length of the route is 37.629km. The design speed of the entire line is 100km/h. It is a two-way eight-lane road and the load is road-grade I. The line extends to the west in the long-term. The Haihe River Bridge is located in the central and southern part of the West Outer Ring Expressway, and the Haihe River crosses at an angle of 76°. The starting point for the bridge construction is the north bank of the sea, and the end point is near the Tianjin Avenue. The total length of the bridge is 1.64km, and it is divided into the main bridge and the approach bridge.

The route is 37.629km long, the designed speed of the entire line is 100km/h. It is a two-way eight-lane road, and the load is road-grade I. The line extends westwards in the long-term and connects with the second phase of Tianjin-Hong Kong Expressway and the high-speed Jinshi Expressway to form the high-speed ring line of the Binhai New Area. The Haihe River Bridge is located in the middle and southern part of the West Outer Ring Expressway, and is located about 550m downstream of the Dangjin Expressway (Changshen Expressway) coastal bridge and intersects with the Haihe River at an angle of 76°. The starting point for the bridge construction is the north bank of the sea, and the end point is near the Tianjin Avenue. The total length of the bridge is 1.64km, and it is divided into the main bridge and the approach bridge.

The Haihe River Bridge is three span variable cross-section continuous steel-concrete composite truss bridge, a total length of 330m, the arrangement of 95m+140m+95m span girder pier supports the middle span section height 12.0m, high 3.5m, high 3.0m connection side span piers, bridge deck width 43m, as shown in Figure 1. The main bridge is divided into two upper and lower parts, each of which consists of 6 trusses, and the transverse center distance of the truss is 3.56m.

Figure 1. Haihe Bridge Effect Picture.

The main bridge intersects with the Haihe River at an angle of 76°, and the width of the Haihe River at the bridge location is about 260m wide. The 1# and 2# piers are located in the main channel of the Haihe River. The bridge is located at the designed sea water level of 2.73m, the water depth is about 7m, and the measured water level during construction is about 1.50m. The measured site elevation at the site is -4.53~-1.45m, and the silt layer thickness is 2.0~5.2m. The top surface of the No. 1 and No. 2 piers of the main bridge is designed to have a top elevation of -7.0m, with a shoulder bridge to a width of 14.5m, and a horizontal bridge to a total length of 45.75m and a thickness of 4.0m. The platform shall be connected to a thin-walled column pier, with piers spaced 9m apart and an opening 5m wide. In order to ensure the smooth construction of the foundation water in the lower part of the main pier of the bridge, the construction of bridge foundations adopts the form of water cofferdam support and adopts the dry sealing construction method in combination with the site conditions, as shown in Figure 2.

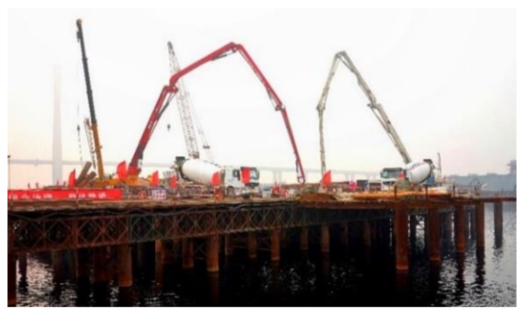


Figure 2. Construction of 2# pier bearing platform for Haihe special bridge.

3.2 Parameter calculation

Temperature crack analysis of concrete is a complex process and the age effect of concrete materials must be considered. With the progress of cement hydration, its mechanical properties (such as elastic modulus, tensile strength, etc.) and thermal properties (such as thermal expansion coefficient, thermal conductivity, etc.) have undergone significant changes. This article uses the equivalent age method to consider the age The effect of curing temperature on mechanical properties of concrete. The equivalent age calculation formula proposed by Hansen (HANSEN P F & PEDERSEN E J, 1977.) is used here:

$$t_e = \sum_0^t \exp\left[\frac{E_a}{R}\left(\frac{1}{293} - \frac{1}{273+T}\right)\right]\Delta t \tag{13}$$

where, t_e is the equivalent age at reference temperature, d; E_a is the activation energy, taking 22590 J/mol; R is the gas constant, and its value is

8.314J/mol·K; T is the average temperature and the temperature of concrete in time Δt , ℃.

1) Thermal parameters

The concrete strength grade of the platform is C35, cement uses P.O 42.5 cement, the amount of each component of cubic concrete is 280kg of cement, 144kg of water, 759kg of fine aggregate, 1047kg of coarse aggregate, 10kg of polycarboxylic acid superplasticizer, 24kg of preservative, 12kg of antifreeze, 40kg of fly ash, 80kg of mineral powder, and the specific heat capacity is 0.963 kJ/(kg·°C).

The calculation formula for hydration heat of cement is as follows:

$$Q(t) = Q_0\left(1 - e^{-at^b}\right) \tag{14}$$

where, t is age, d; $Q(t)$ is the hydration heat accumulated at the time of t ; Q_0 is the final hydration heat, and its value is 350kJ/kg; a and b are constants, a=0.36, b=0.74.

The thermal conductivity of concrete is calculated as follows:

$$k(t) = k_0\left[1.1 - 0.1\left(1 - e^{-0.36t^{0.74}}\right)\right] \tag{15}$$

where, $k(t)$ is the thermal conductivity of concrete at the time of t; k_0 is the heat conductivity of already hardened concrete, which is 8.50 kJ/(m·h·°C).

The concrete structure is attached with a template during the pouring period, and the equivalent thermal convection coefficient method is used to consider the influence of the template on the temperature field. The equivalent thermal convection coefficient of the concrete is calculated by the following formula:

$$h_{\text{free}} = \begin{cases} 5.6 + 3.95v & v \le 5\text{m/s} \\ 7.8v^{0.78} & v > 5\text{m/s} \end{cases} \tag{16}$$

$$h = \left(\frac{1}{h_{free}} + \sum \frac{l_i}{k_i}\right) \tag{17}$$

where, h_{free} is the template thermal convection coefficient, kJ/(m^2·h·°C); v is wind speed, which is 5.6m/s; l_i is the thickness of the concrete formwork, which is 0.02m; k_i is the thermal conductivity of the template, which is 0.837 kJ/(m·h·°C).

2）Mechanical parameters

The mechanical parameters mainly include thermal expansion coefficient, Poisson's ratio, elastic modulus, tensile strength and compressive strength. The thermal expansion coefficient of the concrete is 1×10^5/℃. The ratio of Poisson's ratio is 0.17. The curing temperature of concrete is 20℃ (t=t_e), and the formula of elastic modulus of concrete is:

$$E_c(t) = E_c(28)\left\{\exp\left[s\left(1 - \sqrt{\frac{28}{t_e - t_0}}\right)\right]\right\}^{n_E} \tag{18}$$

where, $E_c(28)$ is the elastic modulus of 28d concrete at an age of 31500MPa; t_0 is 0.2 d; s is 0.173; n_E is the test constant, which is 0.394.

The calculation formula of concrete tensile strength is:

$$f_t(t) = f_t(28)\left\{\exp\left[s\left(1 - \sqrt{\frac{28}{t_e - t_0}}\right)\right]\right\}^{n_E} \tag{19}$$

where, $f_t(28)$ is the concrete tensile strength at an age of 28d, 2.20 MPa; n_t is the test constant, which is 0.658.

3.3 Arrangement scheme of tube cooling and temperature measurement points

The pile foundation of the main pier of Haihe River Bridge is supported by steel sheet pile cofferdam. The net size of steel sheet pile cofferdam is 46.95m×15.7m. The structural dimensions of the pile cap are double 22.855m× 14.5m× 4m, the top elevation of the platform is -7m, and the base height of the pile cap is -11m. According to the principle of " internal cooling and external insulation ", the large volume concrete of the pile cap is cooled by placing cooling pipes when pouring, and installing warm shed and covering heat storage outside the concrete. The cooling pipe of the cap structure is arranged in three layers along the vertical direction, and the interval is 1m. The cooling pipe adopts the thermal conductivity of the steel pipe with the diameter of 48mm, the wall thickness 3.5mm, the horizontal distance 1.0m, the maximum length of each cooling water pipe 150-200m, the cooling pipe inlet to be arranged centrally, so as to facilitate the unified management. The arrangement of the cooling water pipe is shown as shown in Figure 3.

The temperature difference between the inlet and outlet of the circulating cooling water is not more than 10℃, and the temperature difference between the water temperature and the internal concrete is not more than 20°C. In the water cooling process, through the buried temperature sensor, the concrete internal temperature and the cooling water temperature are monitored in real time to adjust the concrete curing strategy, especially to strengthen the insulation measures, to delay the temperature rate of the concrete and reduce the temperature gradient of concrete, so as to ensure that the concrete does not crack. In order to strengthen the heat dissipation effect, 4 water intake and 4 outlets are arranged for each layer of heat dissipation tube, as shown in Figure 4. The water intake is set in the middle of the cap because of the

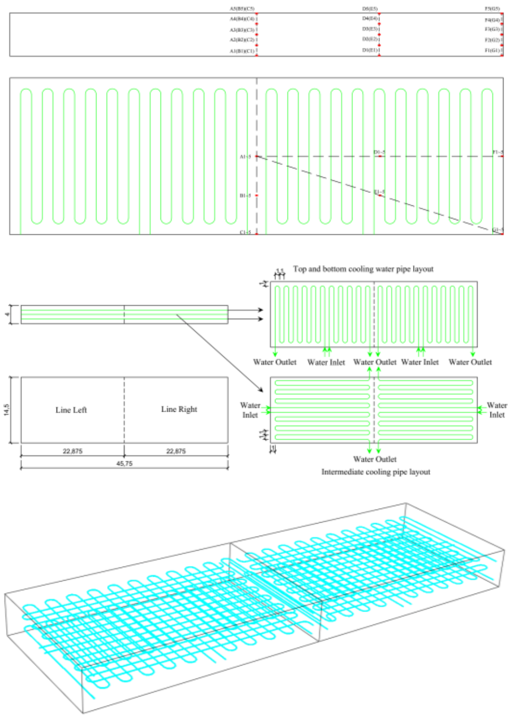


Figure 3. Layout of cooling pipe drawing.

Figure 4. Field cooling piping layout.

obvious aggregation of the hydration heat in the middle of the platform. The water inlet and outlet pipes of each floor are independent and connect to the top of the steel sheet pile cofferdam through the elbow. When the heat sink is installed, it is fixed to the erect steel bar with steel bar. The pipe elbow adopts the same type of steel pipe with the same material, and the pipe is connected with the casing for connection. Before placing the platform concrete, we need to carry out the closed water test, and we need to deal with the leaking place in time.

In order to guide the on-site construction, provide reliable temperature instructions, and understand the internal temperature distribution of the entire pile, the interior of the concrete structure needs to be measured. The 1/4 layout of the cap can be selected due to the symmetry of the structure. Five layers of temperature measuring points are laid from the bottom of the platform to the top, and a total of 7 axes are arranged; To measure the temperature of the concrete surface layer, lay a layer at a distance of 0.05m from the bottom and top of the platform, and the specific layout and numbering are shown in Figure 5.

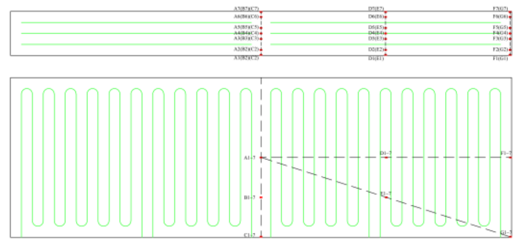
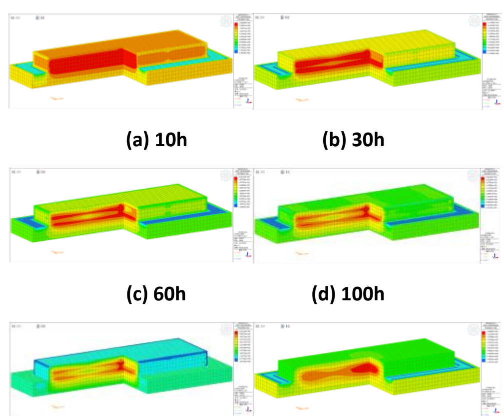


Figure 5. Layout of temperature measurement points.

3.4 Simulation of bearing temperature field

The Midas / Civil software was used to establish the finite element model such as the platform cap, foundation soil and cooling water pipes. According to the technical plan, the temperature field in the overall pouring process of the cap was simulated and analyzed with time, as shown in Figure 6. As can be seen from the figure, due to the large concrete volume of the pile cap and poor thermal conductivity, with the progress of the cement hydration, the heat of hydration in the center of the cap has accumulated continuously, and the temperature field has changed dramatically. After reaching the temperature peak, the temperature begins to decrease. The absolute value of temperature does not affect the cracking of mass concrete. The cracking is mainly related to the internal temperature gradient. The greater the temperature gradient, the higher the possibility of cracking. It can be seen from the temperature field cloud diagram that the temperature gradient within 1m below the surface of the cap is larger, and the temperature distribution inside the other areas is more uniform.



(a) 10h **(b) 30h**

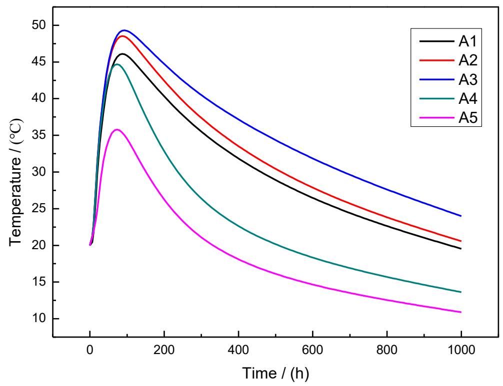
(c) 60h **(d) 100h**

(e) 130h **(f) 700h**

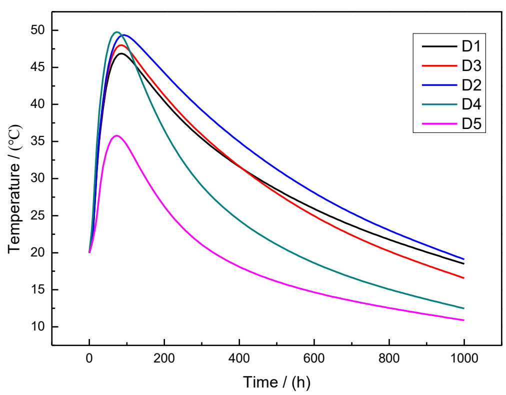
Figure 6. Temperature field nephogram of bearing platform.

4 ANALYSIS OF ON-SITE MONITORING RESULTS

BASED on the above-mentioned platform concrete pouring and pipe cooling construction plan, the concrete of the main pier platform is poured, and the internal temperature of the platform is monitored in real time in the process of pouring and postconservation, and a corresponding tube cooling strategy is monitored in conjunction with monitoring the temperature to ensure the temperature difference between each part of the platform is not too large. Here, the measured data of the five vertical measuring points in the center A of the cap and the five vertical measuring points in the middle of the center D are taken as examples. The actual measured data is shown in Figure 7.



(a) Temperature change curve at the point of A axis



(b) Temperature change curve at the point of D axis

Figure 7. Measured temperature curve.

The maximum measured temperature at the A-axis point is 49.25°C, and it appears at the 90th to 100th hour after the pouring. The maximum temperature measured at the D-axis point is 49.65°C, and it appears at 80-90 hours after the pouring. The trend of the measured temperature history curve basically agrees with the calculation result, but there is a difference in the temperature value and the appearance time of the temperature peak. This is because the theoretical adiabatic temperature rise curve is used in the calculation, and the relevant boundary conditions are properly simplified. The flow is assumed to be uniform, while the actual flow is uneven, and the actual water temperature varies slightly with temperature and is not a constant value. In-situ cast concrete also has natural conditions (including sunlight, wind speed changes, etc.). In the process of cooling pipes, there are several interruptions due to power outages and instrument problems. Therefore, there are differences between measured values and calculated values in the temperature field. During the actual construction, the concrete is poured from the bottom upwards, and the upper layer concrete starts hydration and heat reaction later than the bottom concrete. In the calculation, it is assumed that once the concrete is poured and each height of the concrete starts the hydration heat reaction at the same time, the measured temperature curve and the calculated temperature curve are there is a time difference in the time of occurrence of the temperature peak.

5 CONCLUSION

COMBINED with the construction of the new foundation project for the foundation of Haihe River Bridge in Tianjin, a theoretic model for the temperature rise of the concrete hydration heat was established, and the temperature field changes during the entire construction process of the platform were simulated with the aid of finite element software. Finally, the theoretical and numerical models described above were obtained from measured data. The test was conducted and the following conclusions were obtained:

1) Taking into account factors such as convection boundary conditions, cement hydration and heat release, and time-dependent enhancement of concrete strength, the established theoretical model and Midas model can accurately calculate the temperature caused by the hydration effect of cement during the three-dimensional massive concrete placement - The stress coupling problem, compared with traditional calculation methods, is more concise and the calculation results can be intuitively reflected.

2) The monitoring results are in good agreement with the calculated results. The trend of the measured temperature history curve is basically consistent with the calculated results, but there is a slight difference in the temperature values and the appearance time of the temperature peaks. The established finite element model can better simulate the characteristics of early hydration temperature field changes of mass concrete, and provide reference for engineering application.

3) The massive concrete hydration reaction will lead to a higher temperature rise of the concrete. The closer to the center of the concrete, the higher the temperature rise. The concrete surface and bottom are in contact with the atmosphere and the ground, respectively, and can effectively release and transmit heat with a small temperature rise. However, the bottom of the concrete is closed and the temperature decreases slowly.

4) Cooling tube cooling measures can effectively reduce the temperature rise of the concrete and prevent early cracking of the concrete.

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7 DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

8 NOTES OF CONTRIBUTORS

Gao Xiaolong is a Ph.D. student at Tianjin University. His current research interests include municipal engineering, environmental engineering water treatment and concrete structure construction.

Li Chunguang is an engineer of CITIC-IDE (Beijing) water technologies co., Ltd. His current research interests include municipal engineering, concrete structure construction, domestic sewage and industrial wastewater treatment.
Li Chunguang, Beijin,China , email: uqoo04@163.com

Qiao Yunhong is an engineer of Baotou City drainage industry Corporation. Her current research interests include municipal engineering and concrete structure construction.
Email: yphg55@163.com