Research on Temperature Control of Mass Concrete of Fan Foundation

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Abstract. In recent years, wind power, as a new energy source, has its unique advantages. Under the push of the country, the number of wind power plants is increasing. Based on a wind power plant project in Shanxi Province, temperature field simulation is carried out for the construction of large volume concrete fan foundation, and field temperature monitoring and early acoustic emission monitoring experiments are carried out. The development trend of the temperature field inside the mass concrete is obtained, which reflects the temperature change inside the foundation in real time, and the rule between temperature and acoustic emission signal is found, which plays a certain guiding significance for the construction of mass concrete.

Keywords: mass concrete; Temperature monitoring; Acoustic.

1. Introduction

Wind power generation, as a kind of renewable energy with mature technology, low cost and abundant reserves, has high commercial development value, and is listed as an important strategic emerging industry, which is fully supported by the national renewable energy policy [1, 2]. In order to ensure the normal and smooth operation of the fan, the construction technology corresponding to it also needs continuous progress. In this paper, temperature control of mass concrete in fan foundation construction will be studied in combination with Gaojiapu wind Farm of Youyu, Shanxi Gaojiabao Wind Farm.

Large volume concrete section, the amount of cement, hydration heat released after cement hydration will make concrete produce large temperature stress and shrinkage stress, resulting in concrete surface cracks and penetration cracks, affecting the integrity of the structure, durability and waterproof impermeability. In this paper, a 3.2MW fan foundation is selected for construction simulation and temperature monitoring.

2. Projectoverview

The seismic fortification intensity of Youyu Gaojiapu wind turbine is 7 degrees. According to the Design Regulations for Wind Turbine Foundation (FD003-2007), the design grade of wind turbine foundation is 1 degree. Concrete strength grade: Base: C40; Cushion C15; Frost resistance grade F150. The total height of the fan base is 3.7m, the radius is 9.6m, and the radius of the operating surface is 3.25m.

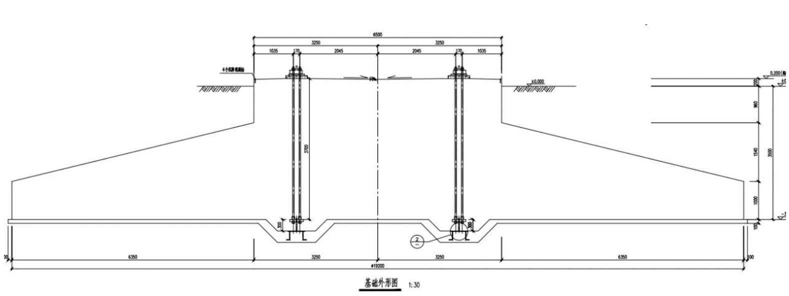


Fig. 1 Outline of foundation

3. Finite element simulation analysis of temperature field

3.1 Basic theory of heat conduction

The concept of temperature field [3] : Temperature field refers to the distribution of temperature in space region and time region, and its equation is $T = T(x, y, z, t)$。If the temperature change is not related to the time, at this point $\frac{\partial T}{\partial t} = 0$,the $T = T(x, y, z)$ It's called a stable temperature field, and if the temperature field stays constant in the z direction, $\frac{\partial T}{\partial z} = 0$,the $T = T(x, y, t)$ It's called a plane temperature field.

As shown in Figure 2, an infinitesimal hexahedron is taken from a homogeneous, isotropic material,The heat coming in from the left per unit time is,The heat coming out of the right-hand side can be expressed as， So the net heat flow into the hexahedron is.

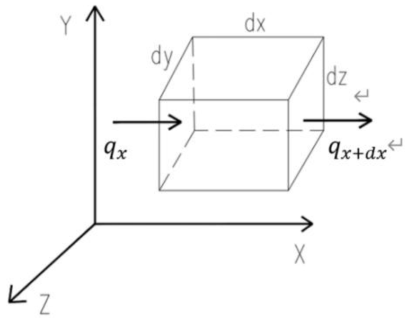


Fig. 2 Heat conduction cell

The relationship between temperature, time and space is considered in the establishment of the heat conduction equation. In order to determine the correct solution of the temperature field, it is necessary to know the initial conditions and boundary conditions. The initial conditions give the temperature distribution inside the concrete at the initial moment, and the boundary conditions give the heat conduction rules between the concrete surface and the surrounding media. Generally, the boundary conditions can be divided into four categories [4, 5].

3.2 Simulation of basic temperature field

The size of the model is consistent with that of the fan foundation. According to the construction requirements and boundary conditions, the site is a one-time integral pouring, and solid brick 8 node 70 thermal analysis unit is intended to be used, and mapped grid is adopted [6]. The interior of the foundation is an adiabatic boundary, so only half structure is taken for analysis.

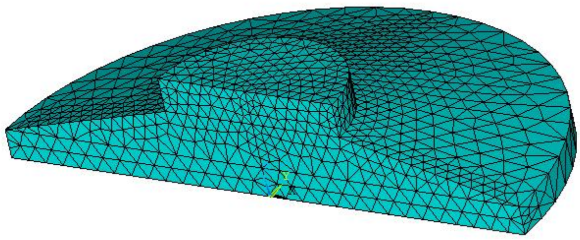
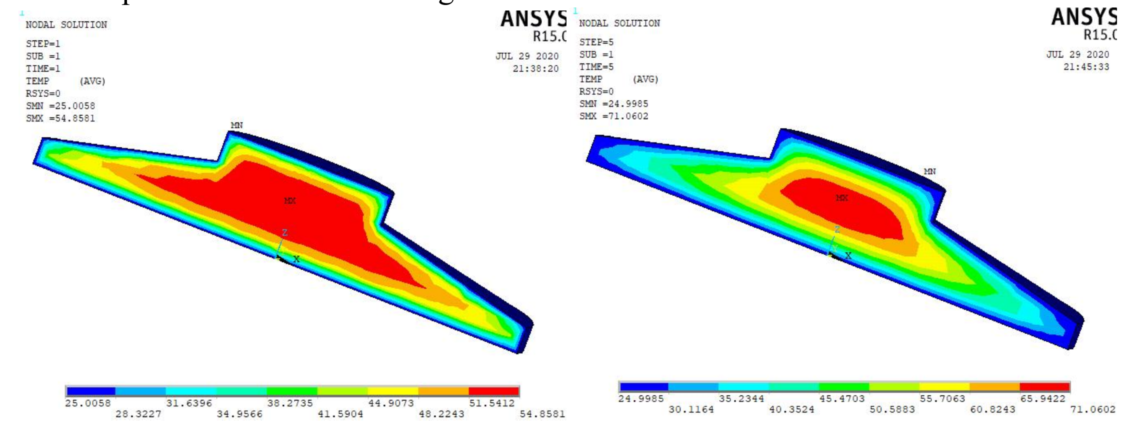


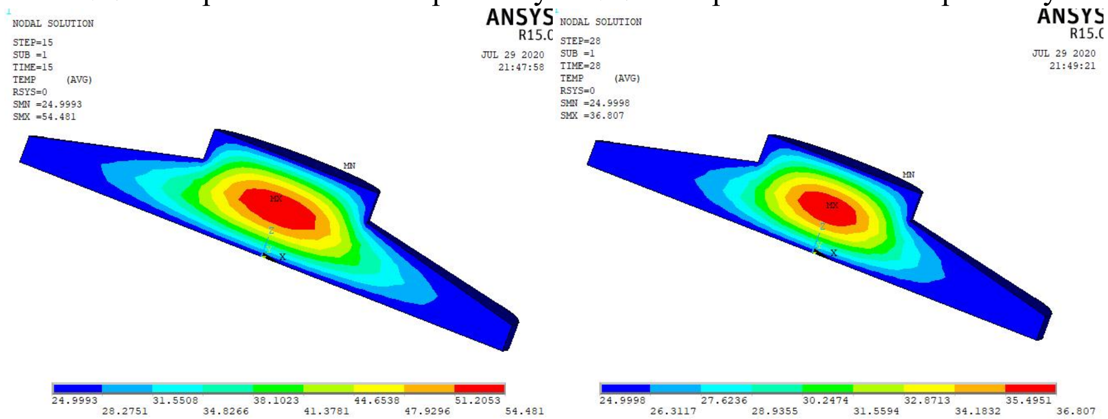
Fig. 3 Basic ANSYS Model Diagram

In order to simplify the calculation in the simulation, the following assumptions were made [7-9] : (1) Due to the construction in summer, the ambient temperature was selected to be 25℃, and the concrete molding temperature was selected to be 20℃, ignoring the influence of the change of ambient temperature on the temperature field of the foundation; (2) In the casting process, the temperature of each part will have an impact on the heat release rate of concrete hydration, but the impact is very small, so it is assumed that the heat release rate of cement hydration will not be affected by temperature, only related to the time effect.

The simulation lasted 28 days from the beginning of pouring to the end of the heat release of cement. The temperature field of each stage is shown as follows：



（a）Temperature Field Map on Day 1（b）Temperature Field Map on Day 5



（c）Temperature Field Map on Day 15 （d）Temperature Field Map on Day 28

Fig. 4 Temperature Field Simulation Diagram

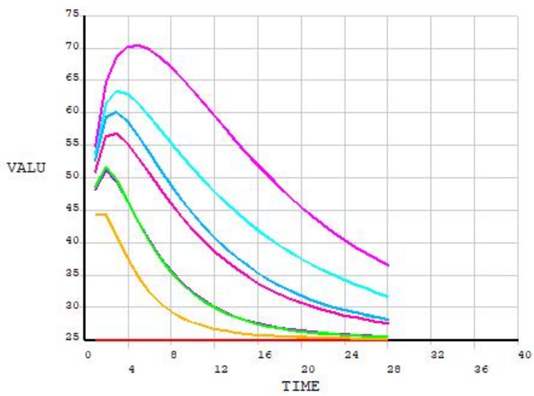


Fig. 5 Simulated temperature curves of different measurement points on the foundation

The temperature variation trend at each position of the fan foundation is basically the same. The temperature rises rapidly after concrete pouring is completed, and gradually decreases after reaching the peak temperature. The cooling rate gradually slows down with time. At the same time, according to the temperature field simulation diagram, it can be found that the temperature in the center of concrete is the highest, and the temperature decreases gradually from the inside out. This is because the hydration heat in the center of foundation is difficult to emit, and a lot of heat is concentrated in the center of the structure, while the concrete surface is in contact with the air, so the heat dissipation is good.

The highest temperature of the foundation appeared on the fifth day after pouring, the peak temperature of the core area was 70.5℃, and the highest temperature of the foundation calculated by hand was 72.4℃, which reflected the accuracy of the simulation results to a certain extent. The specific temperature field distribution should be measured on site. The temperature in the core area developed the fastest, rising rapidly to 53℃ on the first day after pouring, and reaching the highest temperature on the fifth day, with a cooling rate of 1.65℃/d.

It can be found from the temperature curve that the temperature difference between inside and outside is maintained at 25℃. According to the requirements of "Construction Standards for Mass Concrete", the temperature difference between inside and outside of mass concrete should not be greater than 25℃. In the field construction, measures should be taken for surface insulation to prevent the foundation cracking caused by tensile stress of concrete.Basic temperature monitoring.

In order to master the overall temperature distribution of mass concrete and timely discover the temperature changes in the arch foot foundation, the thermistor information acquisition system is used for temperature acquisition. Select a cross-section based on the structural characteristics. 15 temperature sensors are arranged in layers on the cross-section, with 8 temperature sensors on the innermost layer, 4 temperature sensors on the middle layer, and 3 temperature sensors on the outermost layer. Bind the temperature sensor onto steel bars of the same height using fine wire turns, and guide the test wire along the structural steel bars and tie it properly. The sensor distribution is shown in the figure:

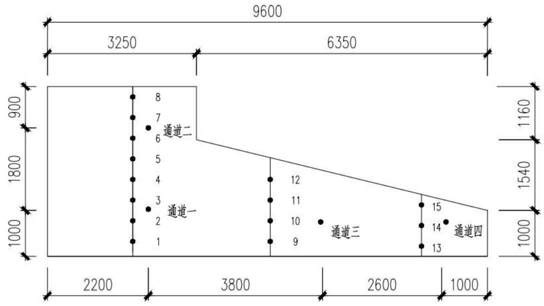


Fig. 6 Schematic diagram of temperature sensor layout plan

The temperature sensor adopts JMWT-32RT type temperature sensor, which is a thermistor type (NTC) temperature sensor. Temperature information is transmitted in real-time through wireless transmission. The wireless transmission module is a wireless modem embedded with a GSM/GPRS core unit, using a GSM/GPRS network as the transmission medium. It is an industrial grade communication terminal based on a mobile GSM short message platform and GPRS data service.

The temperature measurement of the fan foundation starts from the completion of pouring and ends at 28 days after curing. The temperature is collected every half an hour, and the number of temperature measurements is gradually reduced when the temperature drops to a certain extent. Based on the temperature monitoring results, select measurement points 1, 3, 5, 8, 10, and 15 to draw temperature curves.

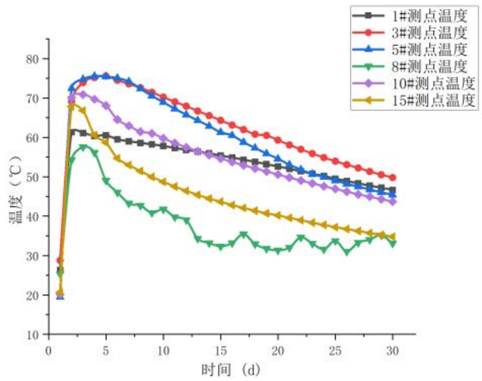


Fig. 7 Measured Temperature Curve of Each Measurement Point

From the temperature change curve, it can be observed that after the completion of concrete pouring, the temperature rises rapidly and reaches its maximum temperature within 60-80 hours. The highest temperature of the foundation was measured at 5# measuring point at 76.5 ℃ at 83h, and the changes were slow after reaching the peak temperature at each point, with a high-temperature temperature plateau lasting for about a day. During the cooling stage, measuring points 8# and 15# are located on the surface and have a faster heat dissipation rate, while the cooling rate of each internal point is relatively flat. The closer it is to point 1#, the slower the heat dissipation rate. On the seventh day, after the backfilling of the foundation pit is completed, except for the top surface of the foundation, the temperature drop rate at other locations tends to be consistent. Due to the influence of environmental temperature on the top surface above the horizontal plane, there are temperature fluctuations, but the overall trend is gradually decreasing.

4. Early age acoustic emission monitoring of mass concrete

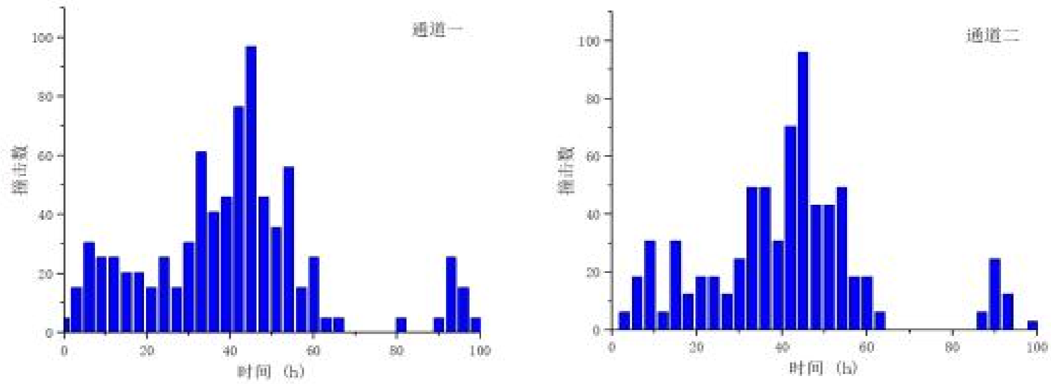
4.1 Introduction to acoustic emission technology

When structures or components are affected by internal forces or external forces, damage, deformation, stress concentration and other changes will occur in the interior of materials or structures, resulting in uneven distribution of energy. When energy accumulates to a certain extent, it will be released in the form of elastic waves, which is called acoustic emission [10]. The acoustic emission instrument uses acoustic emission sensors to receive these elastic waves and convert them into electrical signals, which are amplified by preamplifiers to capture useful acoustic emission signals [11].

As one of the nondestructive testing techniques, acoustic emission testing can monitor the damage performance of structures in real time, continuously and online. It is widely used in petrochemical industry, mechanical engineering, fracture mechanism of composite materials and other fields[12].

4.2 Acoustic emission monitoring results

In order to fully grasp the internal hydration situation of mass concrete and collect acoustic emission signals as much as possible, self-made piezoelectric ceramic plate sensor was used in this experiment, and high temperature resistant BNC signal transmission line was selected. Similar to the arrangement of temperature sensors, the four sensors are arranged in the same plane, and two sensors are arranged vertically in the inner layer of the center, one in the middle layer and one in the outer layer, with the same height from the bottom. It is bound inside the steel cage with fine iron wire. In order to avoid affecting the concrete construction, internal wiring of the cage bottom is adopted. The sensor distribution is shown in Figure 6:



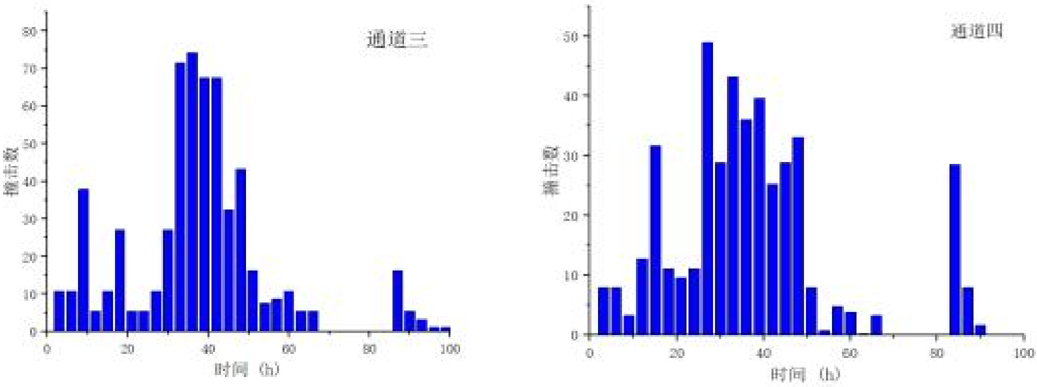


Fig. 8 Variation of the impact number of each channel over time

Through the comparative analysis of acoustic emission experiment results and temperature monitoring results, it can be found that the temperature of channel 1 is higher than that of channel 3, and more acoustic emission signals are collected. The heating process of channel 1 is long, and the acoustic emission signal is generated continuously before the temperature reaches the peak. The position of channel three is relatively outside, and the temperature rises rapidly. After reaching the peak temperature, the temperature gradually drops, and the acoustic emission signal also decreases gradually.

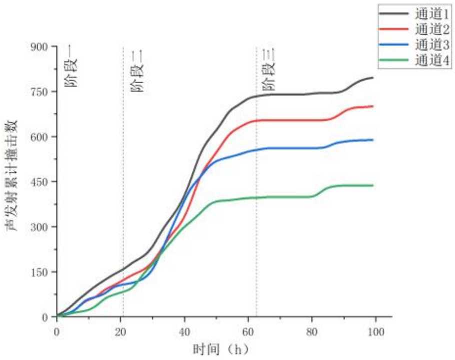


Fig. 9 Variation of AE cumulative impact number over time in hydration process of each channel

Through the comparative analysis of the experimental results and temperature monitoring results of channel 1 and the same channel, as shown in Figure 4.22, it can be found that channel 1 is closer to the core area than Channel 3, and the pre-heating process is faster. When the temperature of channel 3 reaches its peak, channel 1 is still in the heating stage, and the heating rate slows down. At this stage, more AE signals are collected in channel 1 than in channel 3. After reaching the peak temperature in channel 3, the growth rate of AE events increases significantly, indicating that the temperature decreases slightly at this time, but the hydration activity in concrete is still vigorous. The temperature decrease is because the hydration heat release rate and heat dissipation rate basically maintain a balance. The heating process of channel 1 is long, and acoustic emission signals are generated continuously before the temperature reaches the peak. When the acoustic emission signals collected in channel 3 grow slowly, the cooling rate of the measuring point starts to increase, indicating that hydration activities in concrete begin to weaken at this time. Due to the setting of the signal acquisition threshold, only a few signals are collected by the acoustic emission instrument.

According to acoustic emission positioning technology, signal source positioning is performed on the signals collected in channel 1 and Channel 2, and Figure 4.23 is obtained. It can be found that signals are concentrated in the central position in the process of signal collection, which is related to the high temperature in the central position and the more intense hydration process. The bottom signal is slightly more than the top signal, which is also related to the more moderate temperature change at the bottom. Part of the AE signals collected at the later stage of the top may be due to the influence of environmental temperature, and the temperature of the operating surface at the top of the structure changes greatly, resulting in small cracks, which are then received by the AE signal acquisition system.

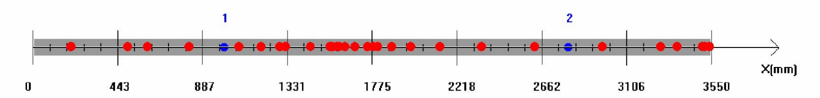


Fig. 10 Linear positioning diagram of AE signals

5. Crack control measures for mass concrete

In order to prevent cracking of mass concrete structure under the influence of temperature stress, a series of technical measures should be taken in the construction process besides temperature stress calculation and temperature field simulation before construction.

There are many cracking factors of mass concrete, but its essential reason can be attributed to the temperature change of newly poured concrete caused by excessive temperature stress beyond a certain limit. Therefore, in order to prevent and effectively control the generation and development of concrete temperature cracks, ensure the quality of concrete after pouring, the main task is to strictly control the range of concrete temperature change, try to reduce the temperature difference between the inside and outside of concrete, avoid the temperature of the central part of the concrete too fast and too high, at the same time, but also pay attention to delay the cooling speed of concrete, In the control of temperature stress at the same time, we should constantly improve the crack resistance of concrete and the tensile strength of concrete itself, so as to prevent and control the occurrence of temperature cracks of large volume concrete.

6. Conclusion

(1) ANSYS finite element simulation software was used to simulate the temperature field of mass concrete foundation, and it was found that the highest temperature of foundation appeared on the fifth day after pouring at 70.5℃, and the highest temperature of hand-calculated foundation was 72.4℃. The difference between the simulated maximum temperature and the theoretical calculation value was 2.6%.

(2) By monitoring the temperature field of mass concrete, the temperature inside the fan foundation changes with time degree. It is found that the highest temperature in the inner core area of the foundation is 74.8℃ at 85h after pouring, and the vertical temperature comparison shows that the closer to the center, the higher the temperature is. In the cooling stage, the cooling rate of the concrete core area is the slowest and increases from inside to outside. The top plane of the foundation is in a fluctuating state under the influence of ambient temperature and sunlight, and the overall trend is decreasing.

(3) By comprehensive comparison of the monitoring results of concrete temperature field and acoustic emission, it can be seen that the temperature of concrete will rise sharply in the early stage of pouring, and fewer acoustic emission signals will be collected at this time. When the temperature reaches the peak, the AE signal increases gradually. When the concrete is in the cooling stage, the acoustic emission signal gradually becomes stable. At the same time, similar to the results measured in the laboratory, the hydration process of mass concrete can be divided into three stages according to the signal acquisition rate of each time period: incubation period, acceleration period and stable period. The difference is that the time of each stage is more delayed, the duration is longer, the number of signals collected is more, the amplitude of the signal is also larger. According to acoustic emission positioning technology, it can be found that in the process of signal acquisition, signals are concentrated in the central position, which is related to the high temperature in the central position and the more intense hydration process. There are slightly more signals at the bottom than at the top, which is also related to more moderate temperature changes at the bottom.

In the construction of the mass concrete foundation, due to accurate calculation and strict construction organization plan on site, no harmful temperature cracks appeared in the foundation, and the temperature control effect was good, which laid the foundation for the smooth progress of the subsequent construction. On the premise of meeting the strength of concrete, cement with low hydration heat can be adopted to control the mold temperature, strengthen the foundation surface insulation, control the surface heat dissipation rate and other measures to control the hydration heat and prevent temperature cracks.

Acknowledgments

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