Study on Monitoring Rock-Sand Concrete Temperature and Fitting Formula of Hydration Heat

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ABSTRACT: Rock-sand comes from rock which is broken by machine has bad grain gradation. It possess more power mix in gradation and angularity on gradation surface compared with river sand. Because of the character, rock-sand concrete need more cement slurry to cover with sand surface, however with setting and hardening of concrete temperature is higher than common concrete. According to temperature monitoring on rock-sand concrete, mapped ‘age -temperature’ curve, then through MATLAB to simulation, fitting hydration heat formula and fixing characters, at last the result of simulation via ANSYS have a good match with monitoring test.

1 INTRODUCTION

With the super-micro power and active material added to concrete, there are many types of concrete make up, especially the development of HPC (high performance concrete). It is payed attention to HPC from file named several opinions about application of high performance concrete issued by ministry of housing and urban-rural development of the People’s Republic of China and ministry of industry and information technology of the People’s Republic of China. The high durability is the main feature of HPC, so HPC needs special material to make up for common material shortage performance, in this condition hydration heat result calculated by traditional very different monitoring test, the new method to compute hydration heat is necessary. This paper introduced according matlab and ANSYS software to calculate temperature inside of concrete nearly with test.

2 METHODOLOGY

2.1 Monitoring temperature of rock-sand mass concrete

In order to get some parameters monitoring temperature of rock-sand mass concrete is studied, the concrete volume is 1.2×1.2×8.0m³, but the height of 3.3m underground, 4.7m height of bulk on the ground [1]. Because of horizontal direction size is small, the heat in concrete which is outside of ground will release to air, so the EPS is used to cover concrete, it will get better result of simulation core concrete temperature. Example of concrete size shown in figure 1, at the point of 1 detail drawing shown in figure 2.
This paper study on concrete strength grade is C40P10, in order to reduce adiabatic temperature rise of concrete, use micro-powder to replace cement and then enhance the self-density of concrete, at last improve the performance of concrete. C40P10 concrete mix at Table 1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Water</th>
<th>Cement</th>
<th>Rock-sand</th>
<th>Gravel</th>
<th>Mix material1</th>
<th>Mix material2</th>
<th>Additive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Pure water</td>
<td>P.O42.5</td>
<td>Medium sand</td>
<td>5-25mm</td>
<td>Micro powder1</td>
<td>Micro powder2</td>
<td>Water reducer</td>
</tr>
<tr>
<td>Consumption (kg/m³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>192</td>
<td>265</td>
<td>890</td>
<td>923</td>
<td>90</td>
<td>60</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Before concrete construction the thermal sensors were settled on three points at the vertical, there are three sensors at every situation \(^{[2,3]}\). The temperature sensor’s location shown in figure 3 After 20 days of temperature monitoring draw the picture of concrete age and temperature variation shown in figure 4.

![Figure 3. The temperature sensor’s location.](image)

![Figure 4. Picture of concrete age and temperature variation.](image)

Fig. 4 displayed temperature in core concrete relationship with concrete age, as the influence of retarder, temperature rise rate is slow (about 3°C/d) after concrete construction, once the retarder affect failure, the temperature rate skip high, nearly 23°C/d, almost 8 times than before, and after 36 hours of reaction the temperature at highest values, the peak temperature is 53°C. The test also state sensors at different place the temperature value is different, even upside of concrete covered by EPS, the temperature differential also 10°C. The sensors numbered A,B,C underground were not interfered with air temperature, so the temperature curve is smoothly in the monitoring process.

2.2 Simulation of concrete thermal field

The simulation of ANSYS software procedure is producing full scale model, applying suitable method to dividing mesh, putting in definite solution condition, and the calculating the result\(^ {[4]} \). There are two significant impacts on simulation; one is dividing mesh, the other is definite solution condition. As the initial conditions are different, so the results of simulation are different, at the condition it will get wrong guidance and have a heavy engineering accident. The simulation model shown in figure 5.

![Figure 5. The simulation model.](image)
2.3 Adjust parameters of hydration heat formula

The concrete adiabatic temperature rise formula is double exponential as Equation (1). \( \tau \) which is time parameter get the derivative through MATLAB software, and the result is rate of hydration thermal production as Equation (2) \(^{[5]}\). Write the equation to APDL language put in ANSYS, the result of core concrete temperature extracted through simulating, the temperature variation curve shown in Figure 7.

\[
\theta(\tau) = \theta_0 \left(1 - e^{-a\tau}\right) \tag{1}
\]

In which \( \theta_0 = (265 + 0.25 \times 150) \times Q_0 \), \( Q_0 \) is the last hydration of concrete, in this paper after 60 days hydration \( Q_0 = 461 \text{kJ/kg} \), \( a, b \) is constant, the value is 0.36 and 0.74.

\[
\frac{d\theta(\tau)}{d\tau} = ab\theta_0 \tau^{(b-1)} e^{-a\tau^b} \tag{2}
\]

Figure 6. Temperature variation curve.

Figure 7. The temperature variation curve.

Through simulation of the temperature field of concrete by heat formula on conventional hydration temperature monitoring point extraction with the same position of the temperature sensor, draw the curve of temperature and time, based on the existing hydration heat formula, adjust \(^{[1]}\) according to the monitoring data of temperature field, the modified formula of formula (3) ANSYS, will be adjusted formula input in Fig.8 temperature variation curve

3 RESULTS

After the hydration heat formula adjustment, the test temperature monitoring curve (Figure 8) concrete temperature peak in the corresponding parts of the time was second days after pouring, the peak temperature reached 51.5 degrees, the difference is only 2.8%, the maximum deviation of temperature controlled at less than 5%. Through monitoring and simulation analysis of concrete, using this formula there are restrictions, the raw materials of concrete, admixture types and properties, concrete pouring and curing conditions on the rate of hydration heat simulation results of numerical simulation for influence, so just play a guiding role, not as a real reaction the construction site.

Figure 8. The contrast curve.

4 CONCLUSION

(1) In the experiment, the wireless monitoring system is used to monitor temperature inside of concrete, the construction process can take measures in time to ensure the quality of concrete pouring.

(2) According to the monitoring data to adjust the existing heating rate by using the MATLAB software, in this case the concrete mix ratio, simulation and field monitoring of the cement heat.

(3) After the adjustment formula is brought into ANSYS, the simulation and field monitoring are in agreement with the post process analysis. The minimum error is 2.8%, and the maximum temperature deviation is controlled within 5%.
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