Study on Temperature Control of Ventilation System in Construction Period of High Ground Temperature Tunnel

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Abstract. As China's infrastructure continues to advance, tunnels will encounter increasingly complex geological conditions during construction. High geothermal heat seriously affects not only the normal construction of tunnels but also the physical and mental health of construction workers. Due to the existing cooling measures have poor effect and high energy consumption, so the cooling effect of the ventilation system is neglected. This paper studies the influence of ventilation system on the temperature inside the tunnel under different air supply volumes, and the distribution of temperature inside the tunnel. The numerical results show that the ambient temperature in the tunnel decreases gradually with the increase of air supply volumes at the same air temperature, but it will not change with the increase of air supply at a certain temperature. This study provides the theoretical basis for optimizing the ventilation and cooling system, it will provide a better construction environment for tunnel workers.

1. Introduction

There are many high temperature tunnels in the process of tunnel construction in the mountainous and hilly western China. Table 1 lists some existing high temperature tunnels in China. The research on high temperature tunnel mainly focuses on the influence of surrounding rock temperature field and high temperature on surrounding rock stress lining structure.

Table 1. Formatting sections, subsections and subsubsections.

| Tunnel Name                  | Length(km) | Temperature(°C) |
|------------------------------|------------|-----------------|
| Heishuibai hydropower station tunnel | 2.3137     | 45.2            |
| Gaoligongshan railway tunnel  | 39.608     | 75.2            |
| Luquan factory diversion tunnel | -          | 76.2            |
| Gonggeer power station tunnel  | 18         | 82.2            |

Xie Qiang used finite element method to calculate the underground temperature field in the tunnel area in view of the possible thermal damage in the construction of Qinling tunnel. On this basis, the characteristics of the underground temperature field of the tunnel were analyzed, and the surrounding rock temperature of the tunnel was predicted and partitioned [1]. L. ruybach predicted the Loetschberg tunnel and proposed a specific cooling scheme [2]. Lu [3,4], Prashant [5], Suneet [6] obtained the analytic solution of the transient temperature field of the circular tunnel by using the superposition principle and the separation variable method. Bonaicina [7] obtained the numerical solution of one-
dimensional nonlinear temperature field with phase transition. Oda M [8] studied the basic mechanical properties and micro-fracture process of rocks under the action of temperature, and finally obtained the change rule of basic mechanical properties of rocks with temperature and the failure mechanism of rocks. Alm O [9] observed in detail some mechanical properties of granite after heat treatment at different temperatures, and studied the micro-fracture process of granite under the action of temperature.

These studies have ignored the effect of ventilation system on the cooling of tunnel construction. Therefore, numerical simulation software is used in this paper to study the temperature distribution and diffusion of tunnel ventilation system in high ground temperature tunnel. This study takes Nige tunnel as the object. The left length of the Nige tunnel is 3366m and the maximum depth is about 640m. At present, the temperature of the surrounding rock near the face of the tunnel is about 57 °C, the temperature of the initial lining rock is about 52 °C.

2. Temperature Measurement programs in Nige Tunnel

This study takes Nige tunnel as the object. The left length of Nige tunnel is 3366m and the maximum depth is about 640m. We tested the temperature of air in Nige tunnel on site. Figure 1 shows the change curve of air inside the tunnel with the distance of the palm surface. The gas temperature is about 42~45℃ within 10 meters from the face of the palm. The gas temperature at 60m away from the face is about 36~40℃. The gas temperature at 100m away from the face is about 31~35℃.

![Figure 1 Curve of gas temperature changing with distance from palm face and the measured figure](image)

3. Numerical model

3.1. Model description

According to the relevant parameters of Nige tunnel, the exposed rock face near the face of the face, the initial support area and the second lining area are divided into three sections. The modeling and calculation consider the surrounding rock-tunnel wall-wind flow coupled heat transfer, and establish 50 around the tunnel. m thick rock formation, so the total length of the model is 350 m. The simulated tunnel section is consistent with the geometrical dimensions of the construction drawings. The air duct is 12 m away from the face and the diameter of the air duct is 1.8 m. The geometric model is shown in Figure 2.
3.2. Numerical calculation model
In the calculation, the surrounding rock conditions of the tunnel are set uniformly according to the actual conditions: the temperature of the fixed surrounding rock is constant, and according to the actual situation of the site, the surrounding rock temperature near the face of the tunnel is set to 57 °C, and the temperature of the initial lining is 52 °C. The lining rock temperature is 47 °C. In the initial stage of calculation, the environment inside the tunnel and the temperature of the surrounding rock are first kept consistent, and then the ventilation is started. The calculation model is shown in Figure 3. In order to obtain suitable air volume and air temperature, the following eight calculation conditions are set in the numerical calculation. The detailed design is shown in Table 2. The wind speed at the inlet of the air duct in the table characterizes the air supply.

4. Study on the influence of different ventilation parameters on the temperature inside the tunnel
4.1. Nige tunnel ventilation
Nige tunnel adopts the single-head press-in ventilation of the pipeline, which is basically not restricted by the construction conditions. It only needs to match the ventilation equipment reasonably due to the
length of the air supply and the required air volume, but due to the influence of the high ground
temperature, and the pressure of the pressurized ventilation air. Too long will cause the ventilation
efficiency to drop and the total required air volume to be too large, and the temperature inside the
tunnel will become higher and higher as it approaches the face. Therefore, we adjust the ventilation
parameters to observe the changes in the temperature field inside the tunnel under different ventilation
parameters.

4.2. Numerical calculation and analysis of results under different working conditions
When calculating various operating conditions in Table 2, the air supply volume is set to 12.7 m$^3$/s,
25.4 m$^3$/s, 38.1 m$^3$/s, 50.8 m$^3$/s, and the air inlet temperature of the air duct is 28 °C. At the end of the
calculation, draw a section every 10 m, take the average temperature on the section as the temperature
of the section and plot the temperature. As shown in Figure 4.

![Figure 4](image)

Figure 4 Curve of average temperature with time at different sections under different working
conditions

It can be seen from Figure. 4 that in the first working condition which air supply volume is 12.7
m$^3$/s, the vicinity of the face of the face is stable from about 56 °C to 36 °C; away from the face of the
face, the high temperature energy near the face of the face is taken out, and the temperature is raised
first. The process of post-cooling is finally stabilized at about 39 °C; the temperature of the face rock
layer is gradually stabilized from 57 °C to 48 °C.

In the second working condition which air supply volume is 25.4 m$^3$/s, the vicinity of the face of the
face is stable from about 56 °C to 34 °C; away from the face of the face, the high temperature
energy near the face of the face is taken out, and the process of first heating up and then cooling down
is experienced. Finally, it is value stable at about 38 °C; the temperature of the face rock layer is
gradually stable from 57 °C to 44 °C.

In the third working condition which air supply volume is 38.1 m$^3$/s, the vicinity of the face of the
face is stable from about 56 °C to 33 °C; away from the face of the face, the high temperature energy
near the face of the face is taken out, and the process of first heating up and then cooling down is
experienced. Finally, it is value stable at about 37 °C; the temperature of the face rock layer is gradually stable from 57 °C to 42 °C.

In the fourth working condition which air supply volume is 50.8 m³/s, the temperature near the face of the face is stable from 56 °C to 33 °C, and the difference from the third working condition is not large; away from the face of the face, the high temperature energy near the face is taken out, and the temperature is raised first. The process of post-cooling is finally stabilized at about 36 °C; the temperature of the face rock in the face is reduced from 57 °C to 40 °C, and the cooling trend is obvious.

Change the air supply volume, and make the curve of the average temperature of the face rock face, the face near the face and the tunnel as a whole under different working conditions. As shown in Figure 5.

5. Conclusion
When the air supply volume is 38.1 m³/s, the temperature near the face is 34.9 °C, and the overall temperature of the tunnel is about 37 °C. This condition is the best condition for the cooling effect of the above four working conditions when the air inlet temperature of the air duct is 28 °C.

According to the air inlet temperature of the air duct at 28 °C, the numerical calculation results under different working conditions can increase the wind speed of the inlet of the air duct within a certain range, and the temperature in the tunnel can be balanced to improve the cooling effect, but the wind is increased after exceeding a certain value. The influence of the inlet air velocity on the tunnel cooling temperature is getting smaller and smaller.
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