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Study on Optimization of Semi-lateral Ventilation Mode of Fire in the Nantong Seyuan Road Tunnel

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Abstract

The fire field simulation tool FDS is used to simulate and compare the different fans operating conditions of the semi-transverse ventilation of the proposed Nantong Seyuan Road Tunnel. The fire source is located at the most unfavorable position of the main road and the ramp. The heat release rate is 20 MW and the grid size is 0.2 m. Considering the natural wind speed of 1 m / s and 2 m / s, the air volume of the single fan is 20 m^3 / s. The results showed that: (1) The flue gas temperature at the ceiling above the fire sources of all conditions was significantly higher than 100 ℃; when from the fire source area more than 10 m, the CO concentration was not more than 100 ppm and the height of the smoke layer was more than 2 m; (2) Opening the air feed fans was not conducive to reduce the flue temperature at the safe height. (3) Increasing the number of exhaust fans on both sides of the fire source was conducive to flue gas emissions; (4) when the exhaust fans were turned on, the addition of the ramp jet fan can not be significantly to reduce the flue gas temperature at the ramp. The aim of this study is to provide a theoretical basis for the optimization of the semi-transverse ventilation model of the fire in the Nantong Seyuan Road Tunnel.

Keywords: semi-lateral ventilation, mechanical ventilation, tunnel fire, numerical simulation, road tunnel.

Nomenclature

ρ	the density of the fluid medium	$\vec{P}$	the static pressure
u_i	the velocity component in the coordinate direction, where i = 1, 2, 3		
c_i	the pollutant concentration	Γ_i	the pollutant diffusion coefficient
$\overrightarrow{\rho u_i' c_j'}$	the turbulence-induced pulsating flow rate caused by the concentration of pollutant diffusion		
δ_x	the grid size, m	D^*	the fire radius, m
ρ_∞	the air density, kg / m^3	C_P	the specific heat capacity of air, J / (kg • K)
T_∞	the air temperature, K	g	the acceleration of gravity, m / s^2
S_c	the pollution source	Q	the heat capacity, kW
t	the time, s		

1. Introduction

With the rapid development of the national economy, all kinds of tunnels have emerged, but due to environmental constraints, tunnel safety operations are facing great challenges. When the fire occurs, high temperature flue gas is the main cause of casualties [1]. A reasonable fire and ventilation system can not only provide fresh air for the tunnel, eliminate harmful gases generated by the vehicles, but also inhibit the spread of fire smoke [2] in order to provide valuable time for personnel to escape and fire rescue, its design and operation is very important for the tunnel.

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This study employed the CFD (computation fluid dynamics) based FDS (fire dynamics simulator) [3] software， which developed by the U.S.NIST (National Institute of Standards and Technology), to simulate the fire accident smoke exhaust device at the exact time when accident occurs. Until recently, there is little information available in literature about the effect on smoke management and movement under semi-transverse ventilation. Yao et al. [4] found that semi-transverse ventilation can effectively control the spread of fire smoke. When the exhaust air rate is certain, the exhaust port interval of 20 m and 50 m has little effect on function of smoke control. Rafael Ballesteros-Tajadura et al. [5] investigated the Influence of the slope in the ventilation semi-transversal system of an urban tunnel. Li et al. [6, 7] and Fu et al. [8] Studies have shown that when the fire occurs in main tunnel, the ramp fan is best to stop running in order to help the main tunnel to achieve better flue gas control effect. In this paper, the FDS numerical simulation was used and the fire source was located at the junction of the middle of the main road and the ramp, which is the most unfavorable position. For different natural wind speeds and different number of fans, the temperature, CO concentration distribution and the height of the flue gas were analyzed, Which provides the basis for the control of fire smoke in tunnel.

2. Nantong Seyuan Road Tunnel

Seyuan Road Tunnel is a part of the rapid renovation project of Seyuan Road in Nantong City. It is 3170 meters to 6315 meters from the western section of the highway, which is recorded as K3 + 170 ~ K6 + 315. The tunnel length is 3145 meters and the buried section is 2620 meters. Each tunnel has three lanes, the tunnel width is 12 m and the height is 6 m. Due to environmental impact restrictions, the operation of ventilation will not be able to use the vertical ventilation. The north side of the tunnel is the built area and the south side is the outer protection zone of the scenic area, which is limited to high. In this condition, the high-altitude air towers used to exhaust the flue can not be built and the use of high-wind towers are also limited. Under the premise of satisfying the limit height and the fire problem, the decentralized mechanical ventilation scheme of the sub-belt exhaust shaft and the mechanical bidirectional axial fan is adopted. Axial fan normal spacing is 60 m and exhaust volume is 20 m^3 / s.

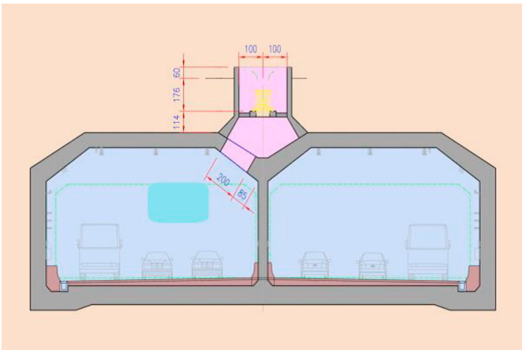

Figure 1 Schematic diagram of semi-lateral ventilation of Seyuan Road Tunnel

3. numerical model

3.1. mathematical model

Fire simulation software FDS uses the large-eddy simulation method to deal with the turbulent flow, and the approximate finite difference method is used to calculate the partial order equation of mass conservation, energy conservation, momentum conservation and component conservation to solve the gas density in each calculation unit, temperature and component volume fraction and other parameters. The general form of the equation is as follows:

Continuity equation:

$$\frac{\partial \rho}{\partial t}+\frac{\partial\left(\rho u_i\right)}{\partial x_i}=0 \tag{1}$$

Momentum equation: