Fire Risk Analysis for Urban Traffic Link Tunnel

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Abstract: Law of fire smoke spread in the urban traffic link tunnel (UTLT) was used as a research subject under different ventilation and smoke extraction conditions. 6 fire scenarios were set to simulate by fire simulation software (FDS). By combining theoretical analysis with numerical simulation, the change of fire smoke temperature, spreading law and visibility were analyzed. The results prove that: semi-transverse ventilation in the range of 300 meters has a remarkable effect on controlling the spread of fire smoke. Fire smoke can be contained within the exhaust area when air change rate is 12 times per hour. This result will play a guiding role for smoke control system.

1. Introduction

UTLT generally located in underground space is a new kind of urban traffic distribution channel. It is an integral part of the urban underground space [1]. UTLT is different from the general tunnels. It has the distinguishing feature of multiple entrances and exits, narrow section, high traffic and complex structural design [2]. In case of a fire, the smoke spreads quickly in the UTLT, and the fire risk is high, which will cause great adverse social influence [3].

The research on fire smoke control in the UTLT by domestic and foreign scholars mainly focuses on transverse ventilation and longitudinal ventilation [4-6]. However, there are few researches on the influence of semi-transverse ventilation on the movement of fire smoke under different ventilation frequency. In order to get a reliable smoke control and exhaust plan, By combining theoretical analysis with numerical simulation, 6 fire scenarios are simulated by FDS. The results of the research can be used to determine the optimal air change rate so as to avoid the fire smoke spreading throughout the tunnel and to ensure the fire smoke within a certain range.

2. Model of UTLT

2.1 UTLT description

UTLT in this paper is 600 meters long on each side and 2,400 meters in length under the municipal road. The tunnel has a net width of 8.0m and a net height of 4.0m. Its main passage runs in one direction with two lanes. There are two ramps connected to ground on each side.The ramps are 4 m high, 4 m wide and 560 m long .

2.2 Fire model of UTLT

(1) Model of FDS

It is representative to make a typical UTLT as the research objective in this paper. According to tunnel design dimensions, the fire model is established by the software FDS, as shown in Figure 1.

(2) Fire heat release rate

Based on the characteristics of the research object, one fire can occur at a time in the tunnel because only except for cars and buses, no other vehicles are allowed. The maximum heat release rate which is equal to the heat release rate of one bus ignited is 20MW [7]. The heat release rate tends to t^2 growth pattern. The size of fire source is situated in the corner of tunnel .The entrance and exit of the UTLT act as a natural vent. The numerical simulation time is equal to 1200s.The temperature measuring point located 90m and 150 meters from the fire source and 2 meters high is set symmetrically. Temperature and visibility sections are set at a height of two meters.

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(3) Ventilation and smoke control conditions

There is a smoke zone for every 100 meters in UTLT. The entrances and exits on each side serve as natural air outlets. Each smoke zone has 4 exhaust outlets interval of 25 m. Smoke screen is 0.5 m high. Considering the Code for Fire Protection in Building Design, the distance between evacuation passages is 250~300 m in the UTLT [8]. Therefore, the smoke extraction area is set as three smoke zones where the fire occurs and the two adjacent smoke zone, totaling 300m.

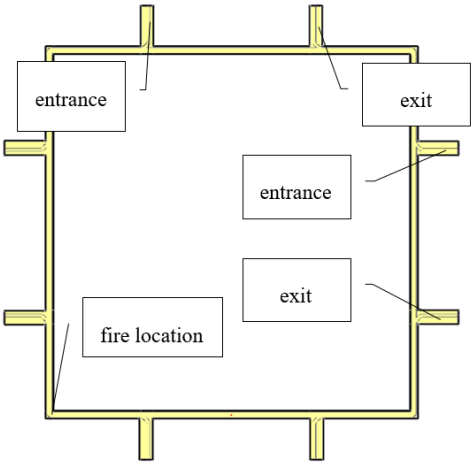

Figure 1. Fire model of UTLT in FDS

2.3 Fire scene

In order to research the fire risk of UTLT, 6 fire scenarios are built and simulated by FDS, as shown in Table.1.

Table. 1. List of fire scenarios

Fire scenarios No.	Air change rate
A	smoke management system failure
B	10 times per hour
C	12 times per hour
D	14 times per hour
E	16 times per hour
F	18 times per hour

3. Results

3.1 Simulation results

In fire scenario A, the smoke management system failed. The software simulation results show that distance of fire smoke spread over an area of 300m at 291s. The maximum spread distance exceeds 405m at the end of the simulation, as shown in Figure 2. 150 meters away from the fire, visibility dropped to 10m at 330s and the temperature rose to 60℃ at 940s.The distribution of temperature and visibility field on the height of 2 m at 1200s is obtained, as shown in Figure 3 and Figure 4.

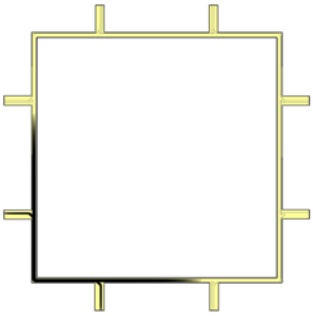

Figure 2. The spread of fire smoke at 1200s in fire scenario A

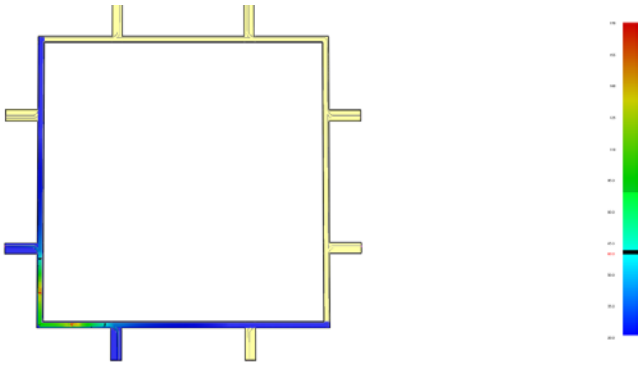

Figure 3. The distribution of temperature field at 1200s in fire scenario A

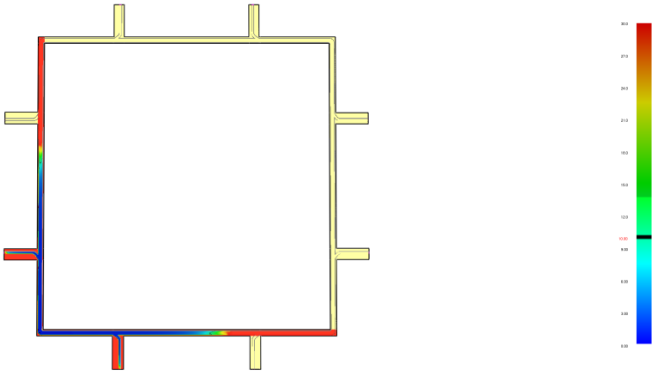

Figure 4. The distribution of visibility field at 1200s in fire scenario A

3.2 Different air change rate on simulation results

The temperature variation curve at 90m and 150m are obtained as shown in Figure 5 and Figure 6. The comparison results show that the temperature is lower the farther from the fire source than the closer to the fire source. The smoke management system has remarkable effect on controlling the spread of fire smoke. When air change rate is 12 times per hour, the fire smoke can be controlled within 300m to ensure safety in other areas. This is great for evacuating people in case of a fire. With the increase of the number of air changes, the temperature of fire smoke decreases correspondingly, but the temperature drops to a small extent. At this time, the effect of increasing the number of air changes is not obvious. When the smoke management system is working normally, the temperature will tend to be stable at the later stage of simulation.

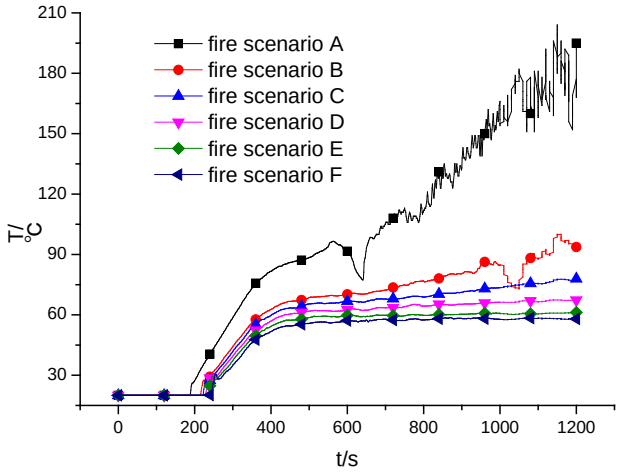

Figure 5. Temperature variety curve at 90m

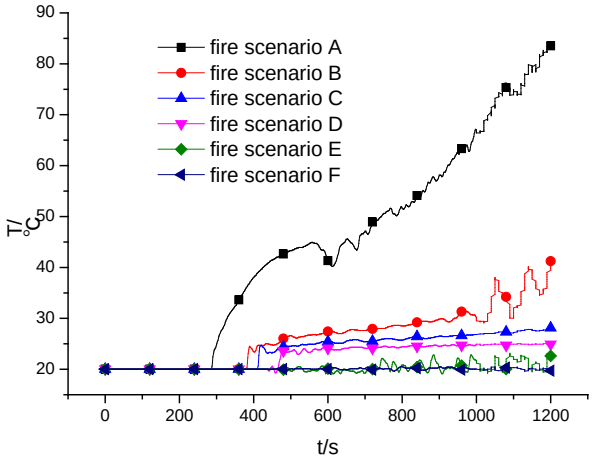

Figure 6. Temperature variety curve at 150m

4. Conclusions

In this paper, the UTLT is taken as the research object, and the fire simulation software FDS is used to calculate 6 fire scenarios respectively. Through the comparative analysis of smoke spread range, temperature and visibility, the following conclusions can be drawn:

(1) Within 300m of the exhaust area, the semi-transverse ventilation is effective in controlling the spread of fire smoke, reduce the temperature of smoke in the tunnel and improve the visibility in the tunnel.

(2) When the fire source is located at the corner of the tunnel, the air change rate is set 12 times per hour, and the smoke management system in the exhaust area can be started to control the smoke spread range within 300m, ensuring the safety of other areas. The fire smoke temperature can be decreased slightly with the increase of ventilation frequency, but the effect is not obvious. The smoke management system should be regularly checked and maintained to ensure the normal operation, so as to effectively control of fire smoke diffusion and ensure the safe evacuation of personnel under fire conditions.

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