

## Influences of Semi-transverse Ventilation on Smoke Spread Rule of Urban Traffic Link Tunnel

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**Abstract.** The fire smoke movement of urban traffic link tunnel (UTLT) under the semi-transverse ventilation was studied by Fire simulation software(FDS). With the method of theoretical analysis and numerical simulation, 3 fire scenarios have been designed to obtain the fire smoke movement. The analytical results show that: Semi-transverse ventilation can effectively control the spread of fire smoke. Exhaust port interval of 20 m and 50 m has little effect on function of smoke control. This result provides references for the design of smoke control measures.

### Introduction

UTLT is an integral part of the development and utilization of urban underground space. It is composed of a main circular tunnel and some connective tunnels [1]. UTLT has the distinguishing feature of multiple points of entry and exit, steep slope and narrow section. The smoke of fire in circular tunnel spreads quickly with high fire risk after the fire [2,3].

The research about longitudinal ventilation and transverse ventilation in UTLT fire draws most attention from researchers at home and abroad [4-6]. Until recently, there is some lack of knowledge about the effect on control the smoke and smoke movement by semi-transverse ventilation. In this paper, UTLT has been taken as a research subject. Three fire scenarios are presented and simulated by FDS. The impacts of exhaust port interval and semi-transverse ventilation on smoke movement are analyzed by means of numerical simulation and theoretical analysis. The results of the research can provide reference for design of fire control in UTLT under semi-transverse ventilation.

### Model of UTLT

#### UTLT Description

This UTLT taken as a research subject runs 2400 m under the municipal road. Each side of UTLT is about 600 m. The tunnel is about 4 m high and 8 m wide. The main tunnel with one-way traffic counterclockwise is two lanes. The exit ramps connected to ground are 560 m long, 4 m high and 4 m wide.

#### Fire Model of UTLT

##### (1) Model of FDS.

According to the design size, the fire model of UTLT is built by the FDS software, as shown in Fig. 1.

##### (2) Heat Release Rate.

In accordance with features and functions of UTLT, one fire can occur at the same time because it allows only sedan car to drive and it is closed for other cars to traffic. The maximum heat release rate is 15MW which is equivalent to the heat release rate of 2-4 cars ignited [7].

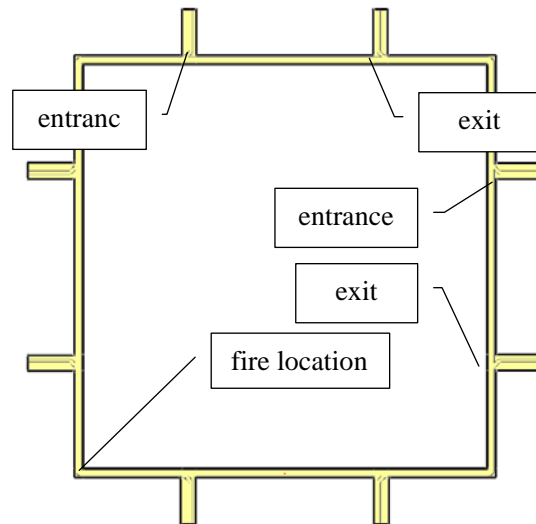


Fig.1 FDS model of UTLT

### (3) Smoke Management System.

The size of fire source is 2.0m x 2.0m x 2.0m situated in the corner of tunnel. The exits and entrances of UTLT are considered as natural ventilation openings. The simulation time is 1200s.

The smoke zone is set up on every 100 m in main circular tunnel. The exhaust port can be set on request under the semi-transverse ventilation. Smoke screen is 0.5 m high. According to the requirement of specifications [8], interval of emergency evacuation path is 250-300 m, therefore, 300 m range is managed as smoke prevention and exhaust area which contains burning smoke zone and its two adjacent site. The smoke management system works properly when there is a fire. According to the < Specifications for Design of Ventilation and Lighting of Highway Tunnel >, exhaust air rate is 12 air changes per hour.

### Scenarios Design

In order to research the influence of exhaust port and semi-transverse ventilation on the fire smoke movement, three fire scenarios are presented and simulated by FDS, as defined in Table 1.

Table 1. List of fire scenarios

fire scenarios No.	maximum heat release rate (MW)	exhaust port interval (m)	semi-transverse ventilation system
A	15	-	failure
B	15	50	normal
C	15	25	normal

### Analysis of Simulation Results

#### Simulation Results of Fire Scenarios A

The size of fire source is 2.0m x 2.0m x 2.0m situated in the corner of tunnel.. The heat release rate is  $t^2$  growth pattern. The maximum can reach 15MW. Semi-transverse ventilation system can't work correctly in fire scenario A. The simulation results show that the fire smoke can spread out of the smoke prevention and exhaust area at 300s. The total distance of fire spread can reach 765 m in the range of main circular tunnel at 1200s, as shown in Fig.2. The poor visibility at right-and-left distance of 150m to fire location can only be 10 meters at 332s. The distribution of visibility field on the height of 2 m at 300s is presented, as shown in Fig.3.

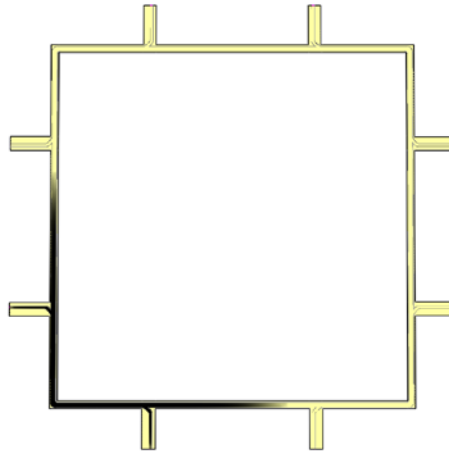


Fig.2 Smoke spread pattern at 1200s

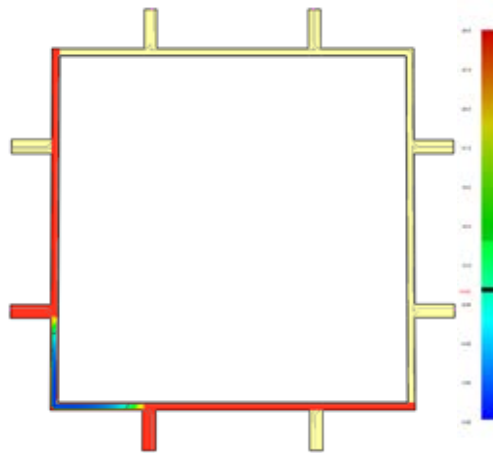


Fig.3 The distribution of visibility field on the height of 2m at 300s

### Simulation Results of Fire Scenarios B

It is two exhaust ports in one smoke zone interval of 50 m in fire scenario B. The simulation results indicate that the fire smoke can spread out of the smoke prevention and exhaust area at 450s. The total distance of fire spread can reach 335 m at 1200s, as shown in Fig.4. The poor visibility at right-and-left distance of 150m to fire location can only be 10 meters at 708s.

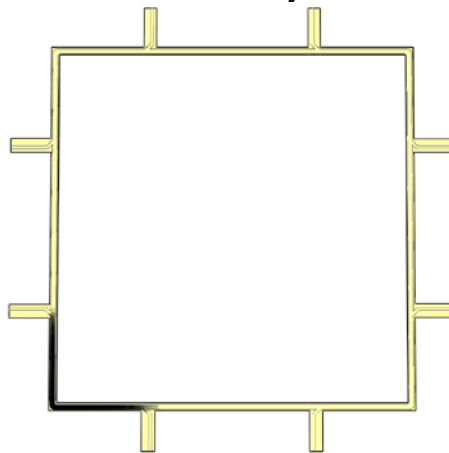


Fig.4 Smoke spread pattern at 1200s

### Simulation Results of Fire Scenarios C.

The exhaust air rate is 12 air changes per hour determined by way of the specification. It is four exhaust ports in one smoke zone interval of 25 m in fire scenario C. From simulation results, the fire smoke can spread out of the smoke prevention and exhaust area at 450s. The total distance of fire spread can reach 360 m at 1200s, as shown in Fig.5.

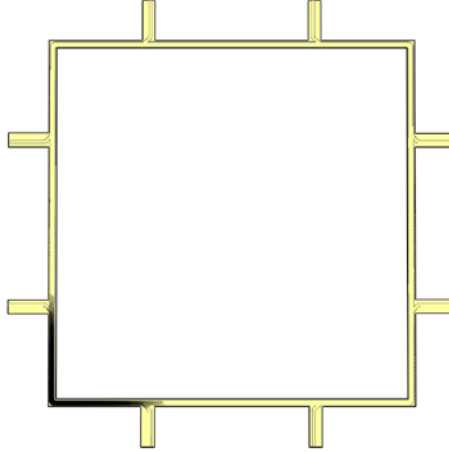


Fig.5 Smoke spread pattern at 1200s

### Influence of Semi-transverse Ventilation System on Simulation Results

Table 2 describes the distance of smoke spread in scenario A and B. Comparison of the results, when semi-transverse ventilation system works properly, distance of smoke spread can be as short as about 335 m. The temperature variety curve at 90m is presented as shown in Fig.6. When semi-transverse ventilation system fails, temperatures in the same place are higher than in normal conditions. Because the hot smoke with large amount of heat is being taken out by semi-transverse ventilation system. Semi-transverse ventilation system has a significant effect on smoke control, improvement of visibility and reduction of temperature.

Table 2. distance of smoke spread in scenario A and B

fire scenarios No.	distance of fire spread in left side(m)	distance of fire spread in right side(m)	Total distance of fire spread(m)
A	380	385	765
B	160	175	335

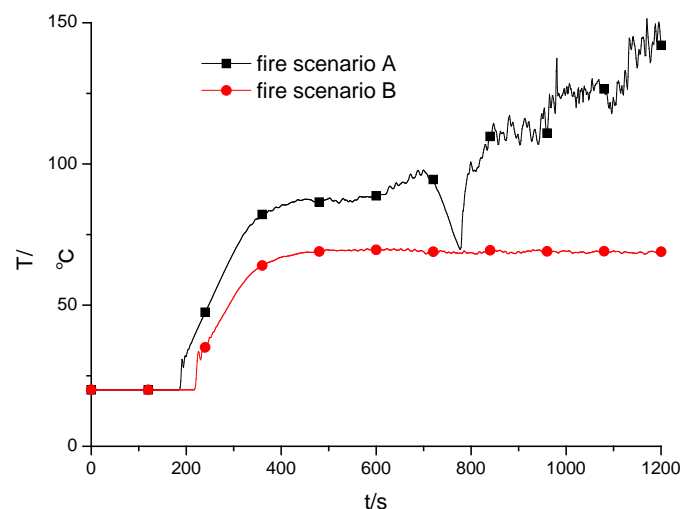


Fig.6 Temperature variety curve at 90m from fire source

## Influence of Exhaust Port Interval on Simulation Results

Table 3 lists the distance of smoke spread in scenario B and C under the semi-transverse ventilation. The temperature variety curve at 90m is presented as shown in Fig.7. The exhaust port interval has a less influence on smoke control.

Table 3. distance of smoke spread in scenario B and C

fire scenarios No.	distance of fire spread in left side(m)	distance of fire spread in right side(m)	Total distance of fire spread(m)
B	160	175	335
C	175	185	360

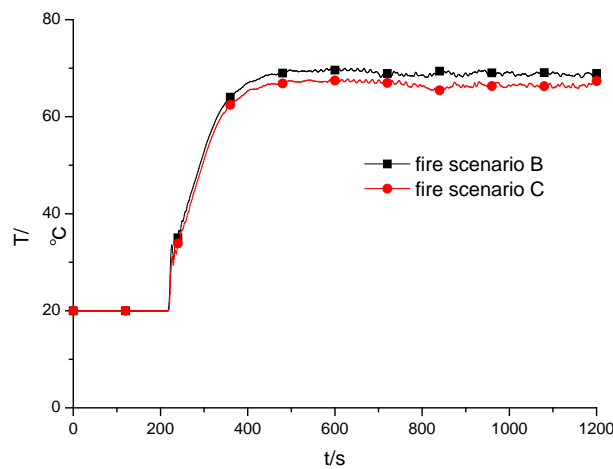


Fig.7 Temperature variety curve at 90m from fire source

## Conclusions

In this paper, UTLT has been taken as a research subject. The fire source is situated in the corner of tunnel. Three fire scenarios are presented and simulated by FDS. Through the analysis of distance of smoke spread and temperature, this paper can reach the following conclusions:

(1) When semi-transverse ventilation system operates properly, distance of smoke spread can be as short as about 430 m. Semi-transverse ventilation system has a significant effect on smoke control, improvement of visibility and reduction of temperature.

(2) When the exhaust air rate is certain, the exhaust port interval under the semi-transverse ventilation has a less influence on smoke control.

The semi-transverse ventilation system have a big effect on smoke control, it must function properly. The settings for exhaust port have been less affected which should be made as economy as possible.

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