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Influence of smoke damper configuration on point extraction ventilation system of an urban tunnel

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Abstract

Smoke poses a great risk to people in a tunnel fire if not controlled effectively, so how to extract smoke out of tunnel is an important issue of tunnel fire protection. In this study, numerical simulation has been carried out to study the influence of smoke damper configuration on point extraction ventilation system of an urban tunnel using FDS 5.5. Six fire scenarios have been simulated with different damper configurations, and simulation results of damper flow rate, visibility and temperature distribution in the tunnel have been analyzed to evaluate the different fire cases. It can be concluded that the damper area has little influence on the fire smoke control when it is large than $3m^2$, but the damper number and damper spacing have much more influence on smoke control of the point extraction ventilation system of this tunnel.

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Keywords: smoke damper；tunnel fire；point extraction ventilation; simulation;

1. Introduction

More and more road tunnels have been or are being built to provide access routes through mountainous areas, to cross waterways, or to avoid environmental difficulties. As a consequence of the significant tunnel fires that have occurred in the past years [1], global interest in road tunnel fire safety has intensified.

In tunnel fires, if the fire smoke is not controlled effectively, it may cause a large number of casualties, such as the Mont Blanc tunnel fire. Basically there are two kinds of fire smoke control system—longitudinal and transverse. Longitudinal ventilation for smoke control is ideal in a non-congested road tunnel with unidirectional operation. The ventilation flow would be in the direction of traffic, and so traffic ahead of a fire will exit the tunnel, and traffic behind the fire will be in fresh air. For the longitudinal smoke control, the `critical velocity' is used to represent the value of the ventilation velocity which is just able to eliminate the backlayering, and force the smoke to move in the downstream direction. This value has become one of the prime criteria for the design of longitudinal ventilation systems, and many research have been carried out on it [2-6].

Transverse smoke control system has the characteristic of extracting smoke in a distributed fashion over the length of the tunnel. Typically, the extraction flow rate is constant along the length of the tunnel, which is not efficient for smoke control. Recent developments in transverse smoke control system apply remotely controlled dampers enabling point extraction of smoke. In this case, only the dampers near the fire are opened, and the remaining ones are closed, as shown in figure 1. This kind of extraction system can be categorized as a single-point extraction system, two-point extraction system, three-point extraction system, etc., by the number of smoke dampers operating during a fire [7].

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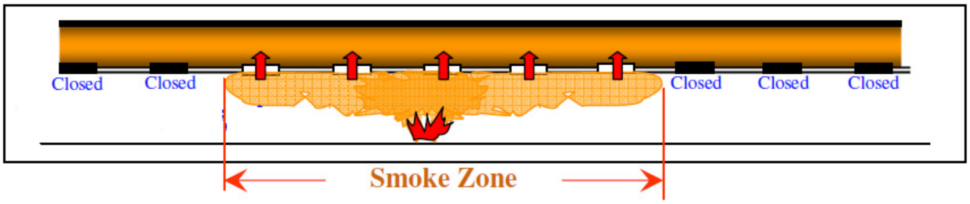

Fig.1 point extraction ventilation system for tunnel smoke control

Ingason and Li [7] conducted experiments to study the smoke flow control with point extraction ventilation system to confirm whether a large tunnel fire involving a HGV fire or several HGVs can be controlled or confined in an acceptable zone. Vauquelin et al [8,9] carried out a series of model scale experiments with a helium/nitrogen gas mixture in an isothermal test-rig to investigate the extraction capability and efficiency of a two-point extraction system. A symmetrical two-point extraction system was used in their experiments, ignoring the probable longitudinal ventilation velocity across the fire site。

Based on the heat and mass flow theory and combustion reaction kinetics, study on fire smoke control of tunnels with point exhaust ventilation system will be carried out using numerical simulation. The CFD software of FDS5.5 [10] is used to study the influence of smoke damper configuration on the point extraction ventilation system of an urban tunnel. FDS is a fluid dynamics program developed by NIST (National Institute of Standards and Technology), which can be used to analyze fire related problems, such as temperature, velocity and concentration distribution. FDS has been validated to be very effective to study the smoke control of tunnel fires by other researchers [11,12].

2. Tunnel model and simulation parameters

The tunnel under studied is an urban tunnel in Wuhan with a length of 2700 m underwater. It is an urban twin-tube road tunnel with heavy traffic, so a point extraction ventilation system is adopted for fire smoke control. The cross sectional area of the tunnel traffic space is 13.5 m (W) x 5.5m (H), and the exhaust duct with a cross sectional area of 3 m (W) x 2.5m (H) is located above the evacuation passageway between the two tunnel tubes, as shown in Figure 2. Smoke dampers are located in the wall between traffic space and exhaust duct. As it would be too time consuming to simulate the whole length of the tunnel, a tunnel model with 800m has been built by FDS, as shown in Figure 3.

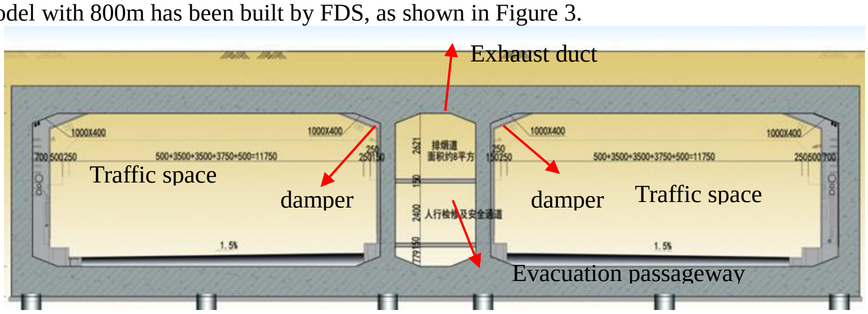

Fig.2 cross section of the tunnel

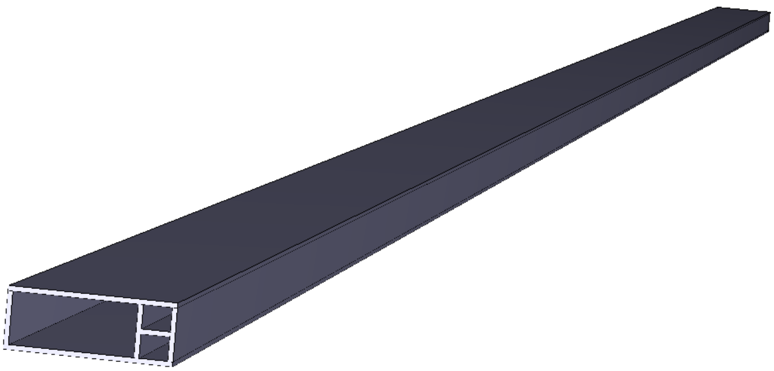

Fig.3 FDS tunnel model with 800m long