

The impact of jet fans layout on the CO concentration distribution inside tunnel for the congestion scenario

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Abstract: Air pollution inside tunnel has attracting more people's attention in China. The occurrence of traffic accident in the rush hours would cause widespread traffic congestion inside tunnel. This may further lead to accumulation of air pollutants near the accident location. To analyze the accumulative effect, the air velocity and CO concentration under different jet fans layout are predicted by use of the multi-segments model. The results show that the occurrence of the accident does influence the spatial-temporal distributions of air velocity and CO concentration. After the accident, air velocity in the congestion region drops significantly and CO concentration jumps downstream the accident location. For a traffic accident-induced congestion scenario, increasing the jet fans in the upstream area is more effective to dilute the air pollutants inside tunnel.

1. Introduction

As one of the modes of transportation, urban road tunnel has been widely used in the construction of cities to relieve the traffic pressure. The occurrence of vehicle traffic accident easily triggers the massive traffic jam in tunnel especially in rush hours. The former researches focus on the thermal environment inside tunnel [1-2], air pollution [2-3], tunnel traffic management [4-5], etc. Researchers have conducted a series of field measurements and found that the air pollution inside tunnel was serious. Due to the limited measuring points, it is impossible to get the detailed air pollutant distribution inside tunnel for a congestion scenario. To solve the problem, the CO concentration before and after the accident is predicted by use of multi-segments model proposed in the former research [6]. The effect of jet fans' layout on CO dilution inside tunnel is analyzed. The results can be used as the supported data for tunnel management.

2. Traffic flow characteristics for the congestion scenario

The Yuhan Road Tunnel is a two-way four-lane road tunnel. It is about 2.79 km long with a cross-section of about 32.8 m². There are 10 sets of jet fans in the southbound tunnel, each set has 2 jet fans. Detailed on-site measurements were conducted in the southbound direction during the evening rush hour on January 9, 2020. And only half of the jet fans were operated during the tests, N1=5, N2=5, as exhibited in Fig.1. Four measuring points (a-d#) are placed along the tunnel to monitor the air velocity and CO concentration. At 18:36, a car broke down at 2000 m from the tunnel entrance, which completely blocked one lane of the tunnel. The combination of the traffic accident and the peak traffic flow caused the widespread congestion in the tunnel. As a consequence, the vehicle speed in the region upstream the accident location decreased rapidly to lower than 10km/h, and the number of vehicles in this region is about 3-5 times higher in comparison with the pre-accident value, as shown in Fig.2.

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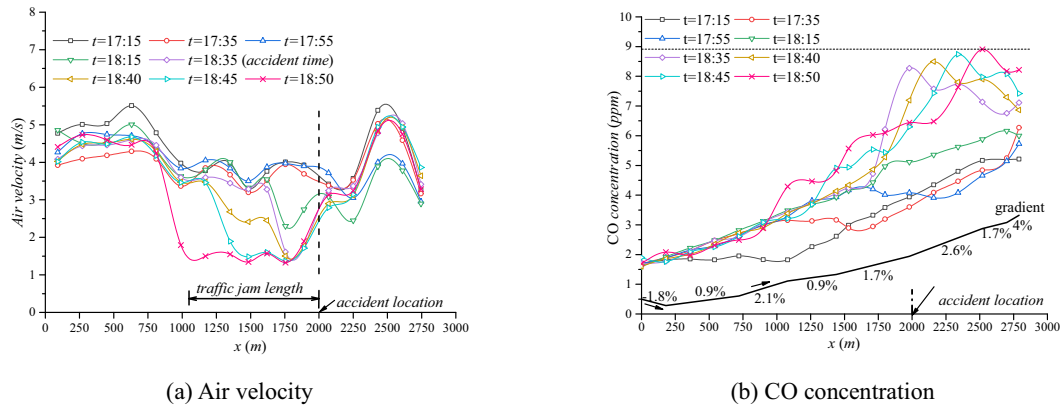


Fig.3 Predicted distribution of air velocity and CO concentration [6]

note: only half of the jet fans are opened before and after the accident (N1=5,N2=5) in the actual situation

3.2 Jet fans' layout on the distribution of CO concentration

According to the theoretical model, jet fans layout may affect the air velocity, and further influence the diffusion of air pollutant inside tunnel. Therefore, different combinations of jet fans in the first and latter half of the tunnel after the accident are taken into consideration in the following analysis. The fans layout for different cases is specified in Table 1.

In the region downstream the accident location, increasing 5 jet fans in the first or latter half of tunnel after the accident, would obviously alleviate the CO accumulation. As exhibited in Fig.4, the peak CO concentration decreases from 9 ppm (actual situation) to

7 ppm (case 1, case 2). As time goes on, the peak CO concentration continues to move towards the tunnel exit. And the maximum value shows a slight increase. However, the reverse is true for CO concentration upstream the accident location. The CO could not be diluted effectively by only opening more fans in the latter half of the tunnel. The environmental situation for case 1 is superior to that of case 2. For case 3, all the jet fans inside the tunnel are turned on after the accident, the CO concentration both in the upstream and downstream area continues to decrease in comparison with other cases. The CO concentration drop downstream the accident location is about 0.25 ppm. Overall, it is more effective to dilute the air pollutants by increasing the jet fans in the upstream area for a traffic accident-induced congestion scenario.

Table 1 Jet fans layout for different cases

Jet fans layout	Case 1		Case 2		Case 3	
	$t < 18:35$	$t \geq 18:35$	$t < 18:35$	$t \geq 18:35$	$t < 18:35$	$t \geq 18:35$
Jet fans in the first half tunnel N1	5	10	5	5	5	10
Jet fans in the latter half tunnel N2	5	5	5	10	5	10

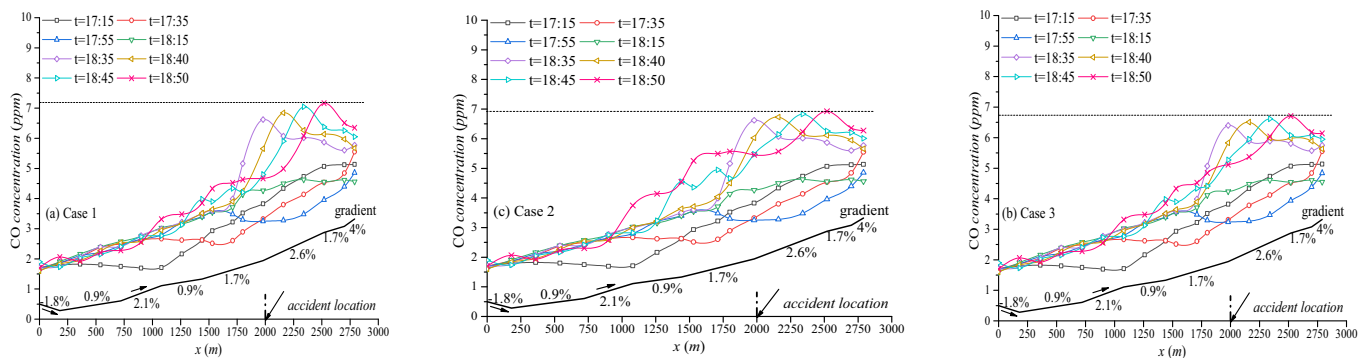


Fig. 4 Predicted distribution of CO concentration for different jet fans layout

4. Conclusions

The occurrence of traffic accident in the rush hours would lead to significant distribution variations of vehicle speed and vehicle number along the tunnel length. By use of the multi-segments model, the CO concentrations under different jet fans layouts are predicted. The following conclusions can be drawn: (1) Under the circumstance of the same jet fans layout, the air velocity in the congestion zone decreases significantly to 1.3-1.4 m/s after the accident. The CO concentration gradient near the accident location increases rapidly to 7.9-14.5 ppm/km. (2) Increasing 5 jet fans in the first or latter half of tunnel would help to dilute CO downstream the accident location. The peak CO concentrations drop by 2 ppm. Opening all the jet fans inside tunnel only leads to the maximum CO concentration further drop by 0.25 ppm. (3) The augments of jet fans in the latter half of tunnel does not help for CO dilution in the upstream area.

5. Acknowledgement

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