A STUDY OF OPTIMAL ARRANGE OF VENT IN A SUBWAY STATION

W. Zhong , H.B.Wang, W. Peng

State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230027, Anhui, China

ABSTRACT

The subway station is a special location with very dense crowd. Because subway station situates in underground, people can not evacuate to ground easily. Once a fire occurs in subway station, it is very dangerous for people to stay in it. So, a well designed smoke exhaust system must be installed in subway station to control the smoke's propagation and descending. Usually, the ceiling screens are placed above the platform's ceiling, and produce several smoke reservoirs in the top of platform layer. Because smoke extraction in a subway station is depended on the duct laid above the ceiling, so the position of vents is situated in the same level of platform layer's ceiling. As a result, the height of vents is lower than the smoke reservoir. If subway station catches a fire, smoke will cumulate in smoke reservoirs at the beginning, mechanical fan can not exhaust any smoke in this process. When smoke layer descend below vents' height, mechanical fan can work authentically, due to the thin smoke layer underneath the ceiling, a mass of air is exhausted by mechanical fan instead of fire smoke. This situation will weaken the effect of smoke exhaust greatly. This paper uses a CFD technique FDS4.0 to simulate smoke's movement in a side platform of an actual subway station during a fire, schemes out several smoke exhaust plan, compares the result of simulation under different height of vents, different depth of smoke reservoirs and the same volume flux of mechanical fan.

KEYWORDS

Subway Station, Smoke Extraction, Smoke Reservoir, Vent Height

INTRODUCTION

There are more and more concerns on subway station's smoke management since the arson fire on subway in Daegu, South Korea, causing 192 people dead and 148 injured. The investigation shows that there were 142 people died in subway train and 50 people died in evacuation, and most victims' death was caused by the toxic smoke(Hyung-ju Park 2004, Won-hua Hong 2004). So it is very important to build a credible smoke's management system to ensure the passengers have enough time to evacuate.

F.L.Chen etc.(2003) applied a CFD technique CFX to simulate the smoke's propagation in Gong-Guan subway station in Taipei, examined the Smoke Control Schemes of Gong-Guan subway station, and evaluated the effect of platform edge door in smoke control. Won-hee Park etc.(2006). used FDS to predict the smoke movement under ventilation with the measured velocity data as boundary conditions. Dong-Ho Rie etc.(2006) compared the effect of smoke control under different models of vents' opening in subway station, and suggest an optimal vent model. And there are many researchers studied the ventilation model of subway station when fire situation(Y.L.Na 2003, G.L.Guo 2004, L.Feng 2002). But they didn't notice the importance of vent's height in smoke control system's design.

Usually, the smoke extraction in a subway station depends on the exhaust pipe locate upon the ceiling, and the height of smoke barrier in subway station is always equal to the ceiling, so the vents lies on the underside of the reservoir. So plenty of air will be exhaust instead of fire smoke during fire, this phenomena calls plugholing. Once plugholing occurs, the efficiency of smoke exhaust reduces distinctly, and brings an added air flux into smoke layer than normal situation. These effects will weaken the capability of smoke control in subway station. So to insure the validity of smoke management, the height of exhaust vent should be discussed.

In China's national standard: "Code for design of metro" (GB 50157-2003), the volume flux of smoke exhaust and the velocity of vent are ordained, but how to prevent plugholing is not mentioned. As a result, the exhaust vent is situated in the reservoir's underside in China's most subway stations. The full-scale experiments indicate that the effect of smoke control is deficient in those subway stations with low vent height.

In the present paper, a CFD technical is used to study the smoke propagation in a side platform named exhibition center station in Shenzhen subway. A series of designed fire scenarios are designed to investigate the smoke control effect in different conditions. Based on the simulation result, the proper vent height and barrier height is discussed.

STRUCTURE OF STATION AND CONDITIONS FOR CALCULATION

NIST has developed a computational fluid dynamics fire model using large eddy simulation (LES) techniques. This model, called the NIST Fire Dynamics Simulator (FDS), has been demonstrated to predict the thermal conditions resulting from a compartment fire. A CFD model requires that the room or building of interest be divided into small three-dimensional rectangular control volumes or computational cells. The CFD model computes the density, velocity, temperature, pressure and species concentration of the gas in each cell. Based on the laws of conservation of mass, momentum, species and energy the model tracks the generation and movement of fire gases. FDS utilizes material properties of the furnishings, walls, floors, and ceilings to compute fire growth and spread.

This paper uses FDS4.0 to model a side platform in Shenzhen subway. The platform discussed in this paper is 140m long, 10m wide and 4.5m high; there is a smoke barrier in the middle of platform and divide it into two smoke bays, marked by smoke bay Ⅰ and smoke bay Ⅱ, and forms two reservoirs on the top of platform, the depth of each reservoir is 1.5m. A smoke exhaust pipe is placed in the top of platform, 17 exhaust vents are arrayed underneath it, and the area of each vent is 0.5m2, see Fig1. According to the China national standard, the volume flux of subway station is 60m3/m2.h, so the exhaust flux in this platform is 84000m3/h.

There are two stairs in the south platform and an escalator in the middle, a set of platform edge doors located in the east and separate the tunnel from platform. The fire is assumed situated in the end of the north platform, to simulate the scenario that retail store catch a fire in subway station, the heat release rate is 1.5MW.

The model is divided into four parts to calculate, which are fire area, platform, escalator and the joint area between platform and escalator. The grid in platform is 0.2m×0.2m×0.2m, grid in escalator and joint area is 0.3m×0.3m×0.3m.

RESULT AND DISCUSSION

Vent height is 3m

When vent's height is 3m high, all vents lies underneath the reservoir. When a fire occurs in a retail store, smoke accumulates in the reservoir. Because the vent is below the smoke layer initially, so the smoke exhaust system can not extract any smoke. Along with the development of fire, the height of smoke layer reduces gradually, when the smoke layer's height descends below exhaust vent, the smoke extraction system works factually, so the smoke control effect is not satisfactory. This process is shown in Fig.2; the CO concentration is used to indicate the propagation in platform. the smoke under the vent is very thin at 100s, mechanical fan can hardly exhaust smoke at the beginning, and smoke enters smoke bay Ⅰ; When time is 200s, smoke in both smoke bay is descend to below vents, but the concentration of CO below vents is relatively low, so only a small part of the fire smoke is exhausted; and the platform is full of smoke in 400s.

Because the low efficiency of mechanical fan, the great mass of smoke is cumulated in the reservoir, and the temperature in platform will be high. Fig.3 displays the temperature in the central plane of platform at 400s, The smoke's temperature in most area of platform is beyond 25℃, and the smoke layer height is about 2m.

Increase the vent height

To increase the vent height is an effectual way to improve the effect of smoke control system. So the vent height is set as 3.5m, 4m and 4.5m, and the volume flux of fan is maintained the same. The simulation results are illustrated in Fig.4 to Fig.6.

When the vent's height increase to 3.5m, the mechanical fan can work factually earlier, and the smoke control effect is better than which vent's height is 3m. From fig.4 we can find that the temperature in smoke bay Ⅰ is reduced obviously. So, the capacity of smoke exhaust system is improved after the vent's height changes to 3.5m.

If the vent height keeps on increasing, the efficiency of smoke exhaust will be improved continually. Fig4 displays the temperature's distribution when vent's height increase to 4m. The temperature in smoke bay Ⅰ reduces to less than 30℃, and the smoke lay height in smoke bay Ⅱ is higher than 2m. The efficiency of smoke control system is enhanced further.

When the vent height is 4.5m, i.e. the vent is arrayed under the top. In this situation, mechanical fan can exhaust fire smoke in time, so the smoke that exhausted by mechanical fan is the maximum in the four situations, and the smoke's propagation is restrained preferably. The simulation result shows that there is only a few area which temperature reach 25℃, the temperature in smoke bayⅡ is also reduced, and the smoke layer height is about 2.5m high.

With the increase of vent height, mechanical fan can exhaust fire smoke earlier, and smoke accumulate under vents will be thicker, so the smoke control system can exhaust more fire smoke in higher vent height situation. The temperature reduces obviously and smoke layer height rises from 2m to 2.5m. To compare the simulation result of four vent height, we can draw this conclusion that with the increase of the vent height, the capacity of the smoke exhaust system is improved obviously. So the height of exhaust vent is a key parameter to be decided seriously.

Reduce the smoke barrier's height

Considering the character of subway station, the vent height can not be placed underneath the top. So to extend the height of smoke barrier properly is a feasible way to ensure the efficiency of smoke exhaust system. Based on the national code "Code for design metro", the smoke barrier height near stairs which connect subway hall and platform can be reduced to 2.3m. So this paper calculates the situation that smoke barrier height is 2.3m.

When the smoke barrier height reduces to 2.3m and keeps the vent height to be 3m, there is a 0.7m deep region for smoke to cumulate. Because the layer height below the vent is increased, so the efficiency of exhaust fan is improved. It can be seen in Fig.7 that the temperature in platform is obviously lower than Fig.3, but the smoke layer height in smoke bay Ⅱ also reduces to about 1.8m due to the decline of smoke barrier height.

CONCLUSION

Vent height plays a key role in smoke exhaust of subway station. The higher of vent height, the sooner mechanical fan works factually, and the efficiency of smoke exhaust system will be enhanced. The simulation result also indicates that the effect of smoke exhaust at high vent height exceed lower situations distinctly, so to insure the capacity of smoke exhaust system, a proper vent height should be decided.

To extend the height of smoke barrier is another way to improve the efficiency of exhaust fan. But the smoke layer height in platform is also reduced in the mean time. So the combination of two methods is a good choice in smoke management system's design.

ACKNOWLEDGEMENT

The author appreciates the support of the National Natural Science Foundation of China under Grant No. 50536030.

REFERENCE

1. Hyung-ju Park. An investigation into mysterious questions arising from the Dargue underground railway arson case through fire simulation and small-scale fire test. Proceedings of the 6th asia-oceania symposium on fire science and technology.p16-27.2004
2. Won-hua Hong. The progress and controlling situation of Daegu subway fire disaster. Proceedings of the 6th asia-oceania symposium on fire science and technology.p28-46.2004
3. Falin Chen etc., Stack effects on smoke propagation in subway stations， Continuum Mechanics and Thermodynamics. 2003, Vol.15: 425－440.
4. Falin Chen etc., Smoke Control of Fires in Subway Stations，Theoretical and Computational Fluid Dynamics. 2003,Vol.16, No.5: 349－368.
5. W.H.Park, D.H.Kim, H.C.Chang, Numerical predictions of smoke movement in a subway station under ventilation, Tunnelling and Underground Space Technology, Volume 21, Issues 3-4, 2006.
6. Dong-Ho Rie etc., A study of optimal vent mode for the smoke control of subway station fire, Tunnelling and Underground Space Technology, Volume 21, Issues 3-4, 2006.
7. Y.L.Na, The experimental and CFD simulation study of the subway fire and ventilation in subway station, Doctor thesis, TianJin University, TianJin (2003).
8. G.L.Guo, Study on the ventilation system in subway station and subway fire, master thesis, Beijing University of Technology, BeiJing(2004).
9. L.Feng, The numerical simulation of smoke management in subway fire, Underground space, Vol.22, No.1, 2002.
10. Hinckley, P.L.1995. Smoke and heat venting. *In SFPE Hand-book of Fire Protection Engineering*, pp.3-219 to 3-241. Quincy, Mass.: National Fire Protection Association.
11. G.D. Lougheed and G.V. Hadjisophocleous, Investigation of Atrium Exhaust Effectiveness, ASHRAE Transactions, 103, 2 (1997).
12. GB 50157－2003. "Code for design of metro"[S].
13. The report of hot smoke test of smoke management system in Shenzhen subway station.
14. W.Zhong, R.Huo, H.B.Wang, Study on the fire scenario's design of subway fire, Journal of Safety and Environment, Vol.6, No.3, 2006.

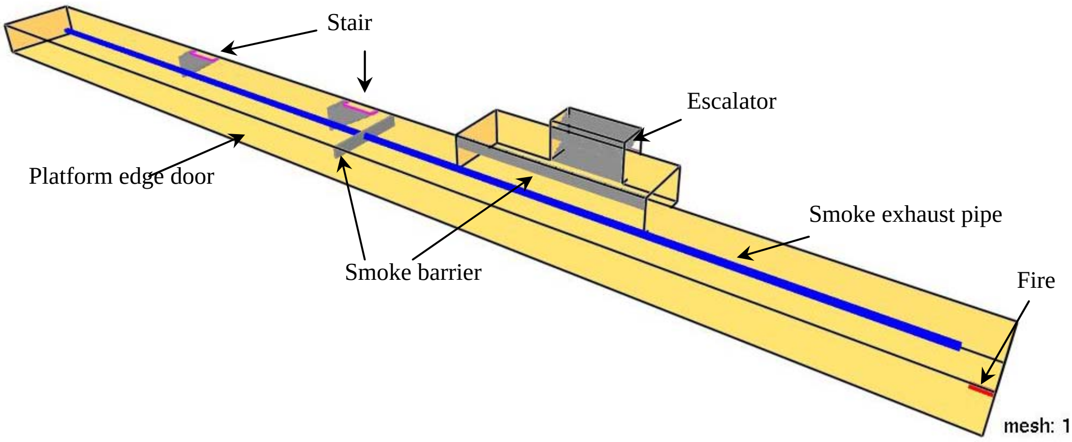


Fig.1 the side platform’s model established by FDS

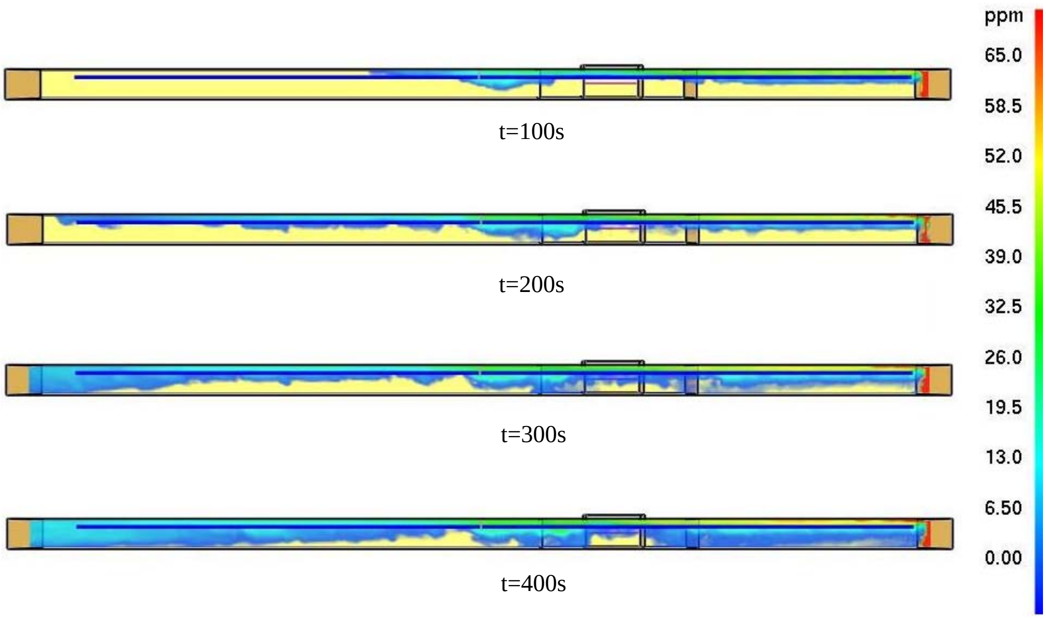
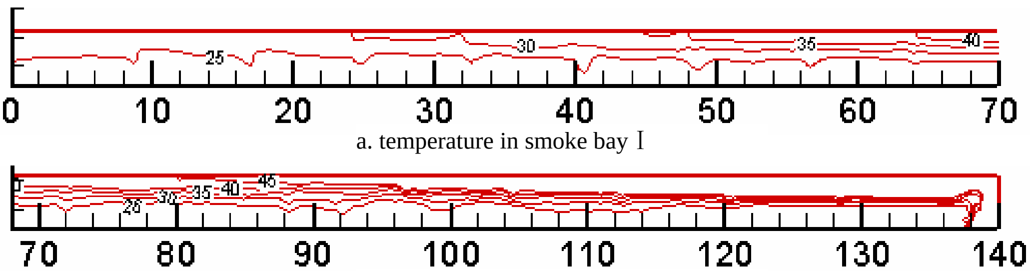


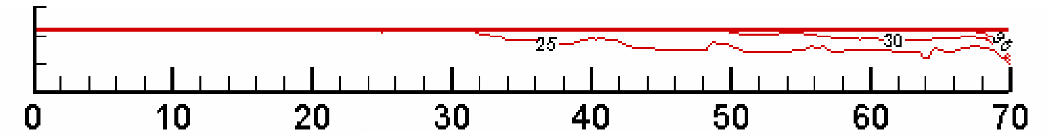
Fig.2 the regions which it’s CO concentration exceed 5ppm under the vent



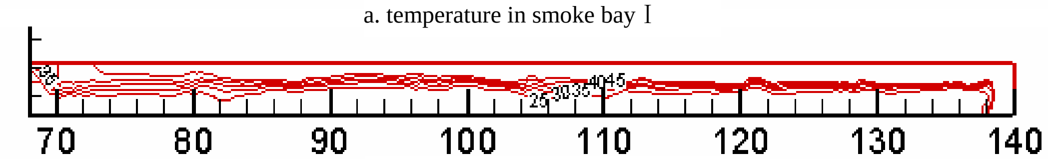
a. temperature in smoke bay Ⅰ

b. temperature in smoke bay Ⅱ

Fig3. Temperature’s distribution in platform at 400s during vent’s height is 3m

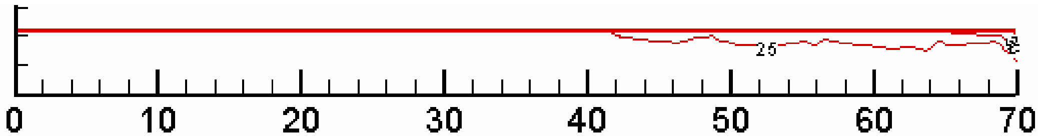


a. temperature in smoke bay Ⅰ

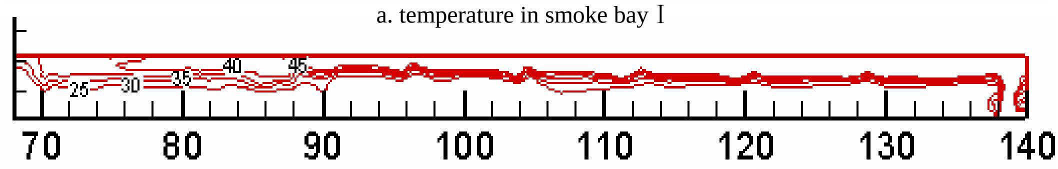


b. temperature in smoke bay Ⅱ

Fig4. Temperature's distribution in platform at 400s during vent's height is 3.5m

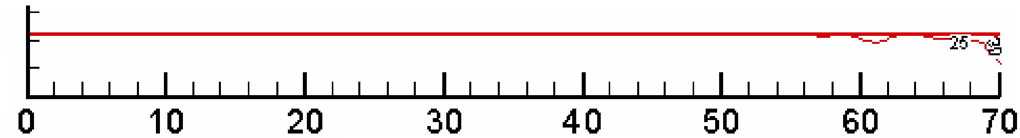


a. temperature in smoke bay Ⅰ

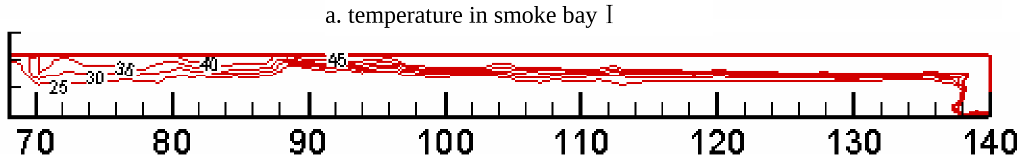


b. temperature in smoke bay Ⅱ

Fig5. Temperature's distribution in platform at 400s during vent's height is 4m

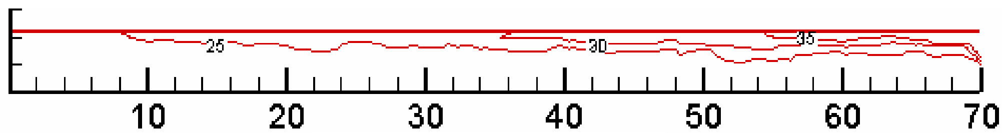


a. temperature in smoke bay Ⅰ

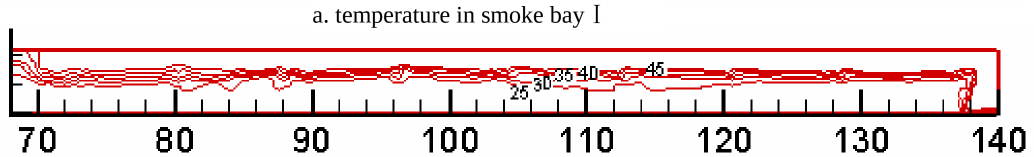


b. temperature in smoke bay Ⅱ

Fig6. Temperature's distribution in platform at 400s during vent's height is 4.5m



a. temperature in smoke bay Ⅰ



b. temperature in smoke bay Ⅱ

Fig7. Temperature's distribution in platform at 400s during smoke barrier height is 2.3m