Jialei TAN,Yushu XIE, Peiyi WANG, Tong WANG, Bin HU

Beijing Municipal Institute of Labor Protection

Experiments for Verification of the Effectiveness of Smoke Control System in a Typical Subway Station

***Abstract**. In order to verify the effectiveness of smoke control system in subway station, a series of hot smoke tests were done on real platform and station hall. The temperature of smoke layer and roof are measured by thermocouple and Infrared Thermograph, and the results showed the maximum temperature of platform and station hall roof can reach to 61.4°Cand 55.7°C. The wind speed on stairs are large enough to make the smoke don't enter into station hall (on platform test) and platform (on station hall test).There is a blind area on both sides of platform on the process of mechanical exhaust smoke. It is not easy to exhaust when the smoke flow into both side of platform. The smoke can be exhausted when the air vents are set on both side of platform. There is no blind area of smoke exhaust on station hall in test.*

***Streszczenie.** Przedstawiono system kontroli palaenia stacji kolei podziemnej. Temperatura mierzona jest czujnikiem termoelektrycznym i przy pomocy termografii podczerwonej. W systemie przewidziano możliwości badania dymu z uwzględnieniem przepływów powietrza. (**Eksperymentalna weryfikacja skuteczności kontroli palenie w typowej stacji kolei podziemnej**)*

Keywords: smoke control; hot smoke test; temperature; blind area
Słowa kluczowe: kontrola palenia, pomiar temperatury.

Introduction

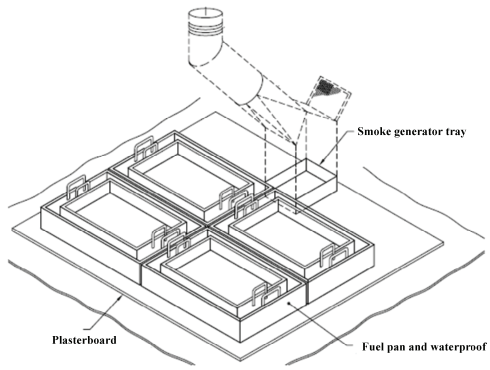
Metro is an important transport tool in cities, which not only provides people with convenient traffic, but also brings a new fire problem. For example, Daegu subway fire caused 192 persons death and 148 persons injured in 2003.High temperature and toxic smoke was inhaled by persons are the main reason of death and injured [1]. So, to protest the safety of persons in fire, the effective smoke control system must be provided in subway stations.

Currently, the subway fire research institutions mostly usually use small-scale subway station model to study in experiments. Model is that real building reduces to a certain percentage based on the similarity theory. The fire that happens in real building is reproduced in model in experiments. D.H.Rie et al built a 1:40 small-scale model of subway station. The mechanical smoke exhaust mode is studied. The best smoke exhaust mode is analyzed based on experiments and numerical simulation [2].Kim et al built a 1:20 subway tunnel model to study the piston wind which appears in car running in tunnel [3].Drysdale et al built a 1:15 small-scale experiment bench to study trench effect because of escalator burning in the King Cross station metro station. The results show that the trench effect caused the spread of flame acceleration phenomenon is the main reason of King Cross subway station fire casualties [4].K. Moodie et al, also used a small-scale model to study the development process of King Cross subway station fire[5,6]. The fire and smoke spread process, fire parameters and smoke exhaust mode is simulated by F.L.Chen, W.H. Park and F.D.Yuan, et al[7-10]. To study subway station fire, a series of small-scale experiments is done by S.Simcox, M.H.Zhong and W.Zhong et al [11-13]. But, there are some differences between the real subway stations and small-scale model of subway stations. Thus, the small-scale experiment results and numerical simulation results don't show the real subway fire and verify the effectiveness of smoke control system of stations. The hot smoke test is done by us in a real subway station, to fill the gap.

Experimental equipment and methods

In order to test the effectiveness of mechanical smoke exhaust system and positive pressure ventilation exhaust smoke test, a series of hot smoke tests are done by us in a station hall and platform. The smoke generate equipment is designed by Australian Standard AS 4391-1999(Smoke Management Systems-Hot Smoke Test). The smoke generate equipment is shown in Fig.1. The fire power is 0.7MW in hot smoke test of platform and station hall. The fuel is industrial alcohol.

The smoke is generated by smoke cakes. The experiment equipments include anemoscope, thermocouples, video and Infrared Thermograph. The protective shed is used to protect the roof of platform and station hall. The Fig.2 and Fig.3 is the layout of hot smoke test on platform and station hall.Fig.4 shows the position of fire source in platform test.



a. Smoke generate equipment of Australian Standard AS 4391-1999

b. real of smoke generate equipment

Fig. 1.Smoke generate equipment

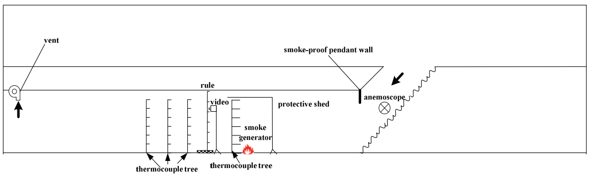


Fig. 2. Hot smoke test on platform

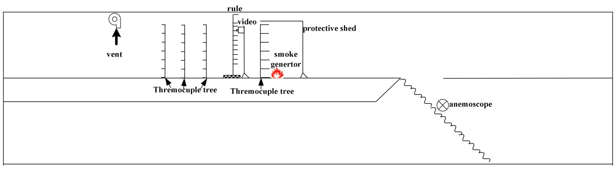


Fig. 3. Hot smoke test on station hall

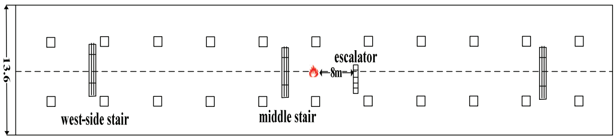


Figure 4.The position of fire source in platform test

Experiment results

Volume of Smoke

The produce rate of smoke in per unit time can be calculated by formula 1.

$$V = \frac{\pi D^2}{4} v \quad (1)$$

D is the chimney diameter of smoke generator, which is 0.18m in experiment;V is smoke speed in generator exit(m/s),which is 2m/s in experiment.So the produce rate of smoke in per unit time is 0.051m3/s. The total volume of smoke can be calculated by formula 2.

$$VT=0.051\times t \quad (2)$$

The decreased rate of smoke layer can be measured by rule and video record in per second. The average value is 0.75m/min in 3m from center of fire source.

Temperature of Smoke Layer and Roof

The temperature of atmosphere is 11°C in experi-ment. The height of platform and station hall each is 4.4m and 4.3m.Fig.5 is the temperature of smoke layer which lies in 0.2m under platform roof and 3m, 4m, 7m from the center of fire source. The maximum temperature can reach to 57.39°C.The smoke exhaust starts at 103s.Fig.6 is temperature of smoke layer on each 0.4m under platform roof.

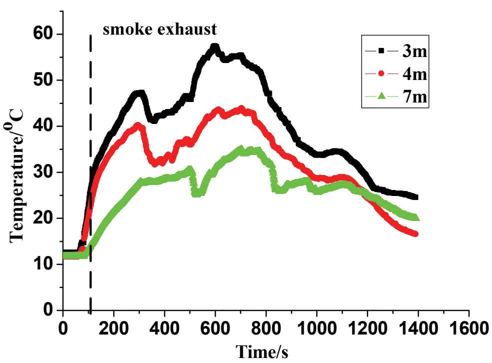


Fig 5. Temperatures in 0.2m under platform roof

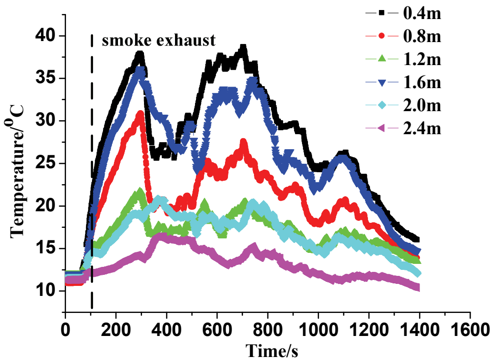


Fig. 6. Temperature in each 0.4m under platform roof

Fig.7 is the temperature of smoke layer which lies in 0.2m under station hall roof and 3m, 4m, 7m from the center of fire source. The maximum temperature can reach to 53.06°C. The smoke exhaust starts at 53s Fig.8 is temperature of smoke layer on each 0.4m under station hall roof. The first thermocouple lies in the 0.3m under the roof not is the 0.4m under the roof in platform hot smoke test, because the height of platform is higher than station hall.

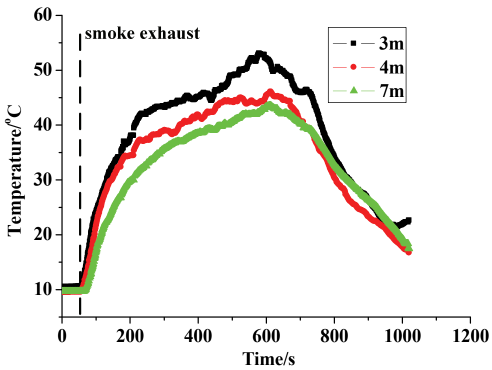


Fig. 7. Temperatures in 0.2m under station hall roof

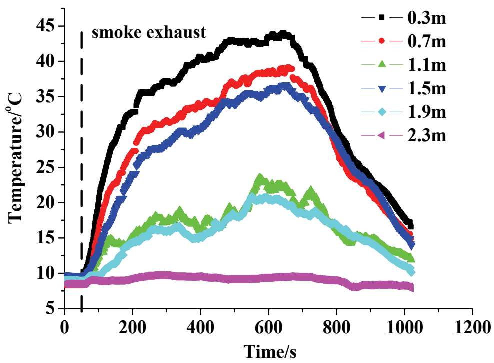
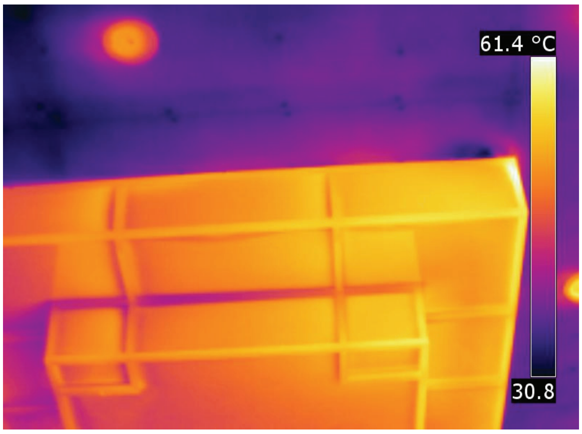
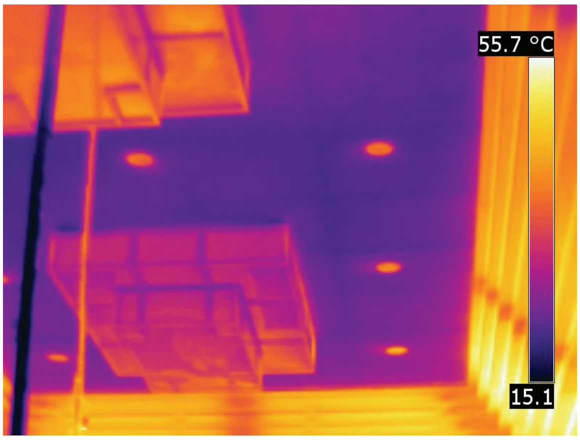


Fig. 8. Temperature in each 0.4m under station hall roof

The temperature of roof is measured by Infrared Thermograph, and the maximum temperature of platform and station hall roof is 61.4°C and 55.7°C (as shown in Fig.9).The high temperature zone focus on fancy lamp.



a. Platform test



b. Station hall test

Fig. 9. Roof temperature of platform and station hall

Wind Speed on Important Points

Figure 10 is the wind speed on middle and western stair, and wind speed on escalator nearby fire source on platform test. Figure11 is the wind speed on intersection of exits and station hall and stair nearby fire source on station hall test.

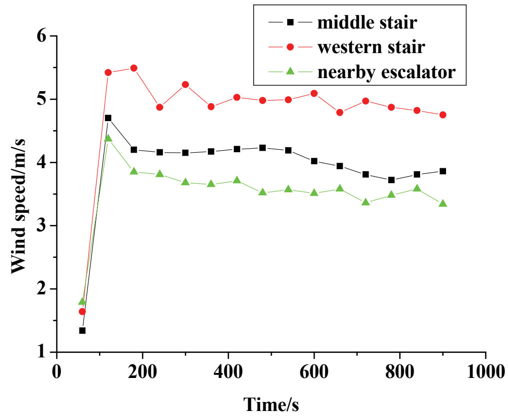


Fig.10. Wind speed on stair and escalator (platform)

The wind speed is large enough to make the smoke don't enter station hall on platform test. It can be found that the effective of smoke exhaust is poor on both sides of platform, and the smoke is not able to exhaust even at end of experiment. It sure there is a blind area of smoke exhaust on both side of platform. The smoke spread process on platform can be seen in Fig.12.Fig.13 shows the smoke accumulation on both side of platform. The first reason is that those are far away from air vents, and the second reason is smoke flow into this area and accumulation. There is not enough smoke exhaust exits on both side of platform, so the wind flow is not a loop. Therefore, the blind area can be reduced or eliminated through adding air vents.

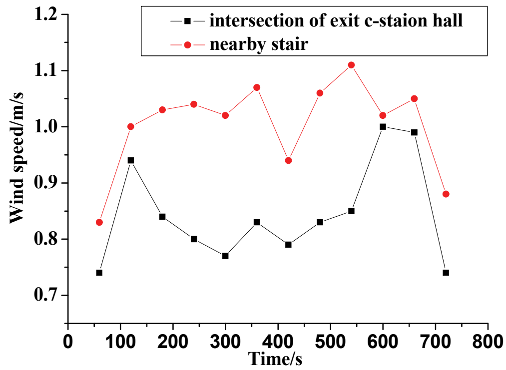


Fig. 11. Wind speed on intersection and stair

Fig. 12. Smoke spread on platform

Fig. 13. Smoke accumulation on both sides of platform

CO2 Concentration on Important Points

The Fig.14 shows the CO2 concentration on middle stair, western stair and escalator nearby fire source. The point value of escalator is higher than middle stair and western stair. When the exhaust starts, the CO2 concentration will rapidly decrease. The Fig.15 shows the CO2 concentration on stair nearby fire source. It can be seen that the CO2 concentration of platform is higher than CO2 concentration of station hall.

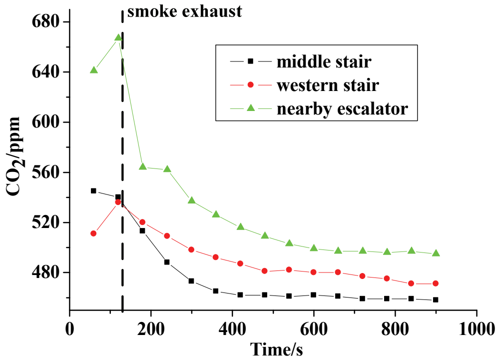


Fig. 14. CO2 concentration on stair and escalator (platform)

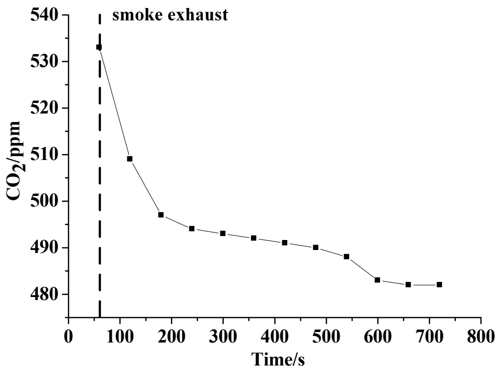


Fig. 15. CO2 concentration on stair nearby fire source (station hall)

Conclusions

The temperature of smoke layer and roof are measured by thermocouple and Infrared Thermograph, and the maximum temperature of roof can reach to 61.4°Cand 55.7°C. The wind speed is large enough to make the smoke don't enter into station hall (on platform test) and platform (on station hall test).There is a blind area on both sides of platform on the process of mechanical exhaust smoke. There is a circuit from stair to air vents. It is hard to exhaust when the smoke flow into both side of platform. The smoke can be exhausted when the air vents are set on both side of platform. There is no blind area of smoke exhaust on station hall test.

Acknowledgment

This research was supported by the Beijing Natural Science Foundation (9102007).

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***Authors**: prof. dr Jialei Tan, Beijing Municipal Institute of Labor Protection, Beijing, China, E-mail: tjlzlb@mail.ustc.edu.cn.*