 ICCES, vol.11, no.1, pp.19-25

The analysis of the effects of the platform screen door on the fire driven flow in the deeply underground subway station by using parallel computational method

Yong-Jun Jang[1], Hag-Beom Kim[1,2], Woo-Sung Jung[1]

Summary

In this study, fire simulations were performed to analyze the characteristics of the fire driven flow and the effects of the platform screen door on the smoke flow in the station, when the fire occurred in the center of the platform. Soongsil Univ. station (line number 7) was chosen which is the one of the deepest (47m) underground subway stations in the Seoul metro(SMRT). The parallel computational method was employed to compute the heat and mass transfer eqn's with 6 CPUs of the Linux clustering machine. The fire driven flow was simulated using FDS code in which LES method was applied. The heat release rate (HRR) was 10MW and The ultrafast model was applied for the growing model of the fire source. The 10,000,000 structured grids were used.

keywords: DUSS(Deeply Underground Subway Station), PSD(Platform Screen Door), Fire Source, Grid Size, LES(Large Eddy Simulation), Fire Driven Flow

Introduction

The subway in Seoul has a large system comprising as many as 9 lines. #1 through #4 lines are operated by SEOULMETRO, while #5 through #8 lines are by Seoul Metropolitan Rapid Transit Corp. (SMRT). There are lots of subway stations at each line. Some of the stations go down more than 20m deep because some different lines run overlapped and topographical features such as the hills and highland area in Seoul.

Lee [2] defined the subway more than 40m deep underground as the space which is not used for subsidiary facilities of the building (underground parking or shopping mall et al.) by the landowner and the compensation for using underspace is very low. To build more than 40m-deep underground subway, therefore, takes less cost and gives an economic benefit. Though the subway more than 40m depth over the entire line is not yet to be built in Korea, many subway stations built at more than 40m depth are available as shown in Table 1. In this point, the subway built at more than 40m depth is regarded as the Deeply Underground Subway Station (DUSS). DUSS is expected to increase gradually in the future.

In this study, Soongsil Univ. station was chosen for numerical simulation model as a DUSS which is one of the deepest stations in the Seoul [Table. 1].

[1]Railroad Environment Research Department, Korea Railroad Research Institute, Gyeongi-Do, Korea

[2]Correspondence author. Fax: +82 31 460 5279 Email: kimhb31@krri.re.kr

In DUSS, it is difficult to evacuate from the fire disaster because of long stairs to exit and low visibility after fire accident

The platform screen door (PSD) has been being installed on line #5 to #8 to protect the passengers from falling down the platform and also from heating and cooling effect and to isolate them from the noise and dust.

But the analysis of PSD-effect on the fire still remains at the beginning stage [1].

Table 1: The deepest underground stations in the Seoul Metro & SMRT (2007)

Line	**The Deepest Station**	**Depth**	**Company**
1	Jongno 3ga	13m	Seoul METRO
2	Ewa Woman Univ.	36m	
3	Chungmuro	28m	
4	Hoehyeon	23m	
5	Singeumho	44m	SMRT
6	Beotigogae	43m	
7	**Soongsil Univ.**	**47m**	
8	Sanseong	56m	

Thus, in this study numerical 3D simulation for fire driven flow at DUSS are performed and the characteristics of the heat and smoke flow caused by PSD are analyzed.

The features of Soongsil University station

Fig. 1 is a guide map of Soongsil University station. As shown in Fig. 1, the bank type (two platforms on both sides of the track) platform is situated at B6 level. The concourse accessible by the passengers are on B5, B4, B2 and B1 level, and as B4 level is not used for specific purpose, it's not shown on a guide map. B3 level is not accessible because it's occupied by equipment room. Among the features of this station is the directly extended stair from level 2 to level 5 and as shown in Fig. 2, those are the reason why most of passengers move using only passenger escalators. The Geometry of Soongsil University station is 165m long and 23.5m wide and 47m deep.

Mesh generation and boundary conditions

H/W configuration used is as shown in Fig. 3. Fig. 4 shows model and fire location of Soongsil University station for analysis. As shown in Fig. 4, the passengers are not allowed to access to B3 level occupied by equipment room and the heat and smoke also were assumed to be blocked by wall, which was excluded from modeling. The location of fire source was set as 1 m^2 area in electric car corresponding to the platform center.

The code used for analysis was FDS(v 5.0) which was developed by National

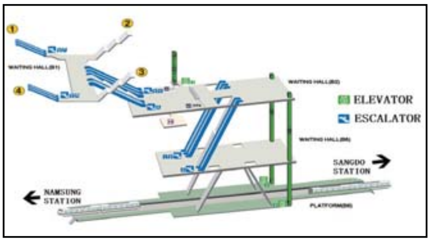


Figure 1: The Guide map of Soongsil Univ. Station

Figure 2: Passengers availing of Soongsil Univ. Stations

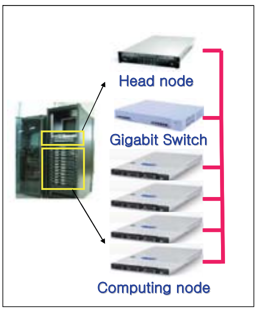


Figure 3: Cluster configuration

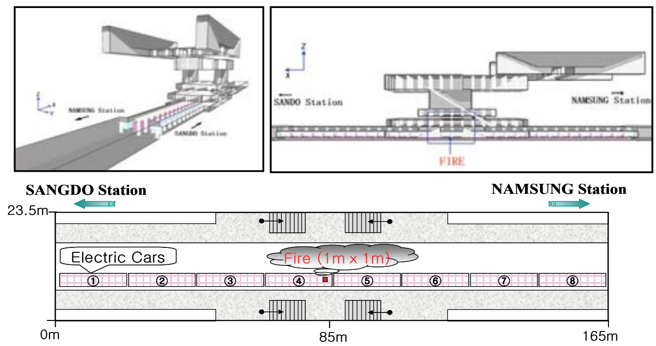


Figure 4: Model and fire location for Soongsil Univ. station

Institute of Standards and Technology(NIST) in USA. H/W resource used for calculation was 6 CPUs (3.0GHz Dual core). 41 multi mesh blocks and about 10,000,000 hexahedron structured grids were generated. Parallel computational method was applied to simulation for fast calculation. The grid size should be appropriate to produce reliable simulation results. One methodology requires that the characteristic fire diameter span at least ten grids within D* [4]. According to Drysdale D.[5], the characteristic fire diameter be defined by Eqn.(1).

$$D^* = \left(\frac{\dot{Q}}{\rho_0 T_0 C_{p0} \sqrt{g}} \right)^{\frac{2}{5}} \tag{1}$$

Atmospheric condition was defined as air pressure at 10 °C. Because Daegu subway fire accident in South Korea was occurred at Feb 18, 2003 which was the period of changing season (winter–> spring). The maximum heat release rate was defined as 10MW, according to the railroad facility safety standard (Korean MLTM Announcement No. 2006-395)

The characteristic diameter of the fire source D* was calculated at 2.415m, and the size of grid at or near the flame should be less than 0.2415 which corresponds

Table 2: Physical properties

Item	Value	unit
Temperature	283.15	K
Density	1.1934	kg/m^3
Specific	1.007	kJ/kg·K
Gravity acceleration	9.81	m/s^2
HRR	10,000	kW

to one tenth. And guard rail, stair and escalator were modeled to sufficiently incorporate the shape of actual platform. In this study, no air supply or exhaust operating system in fire were assumed. Because the numerical simulation is mainly focused on smoke and hot air spread in DUSS other than smoke removal or controlling performance. In the study, the scenario was not assumed to spread the fire over entire electric cars. Heptane which has been commonly used for smoke generation test was used as the fire fuel model. The outcome values of SOOT and CO were set as default condition of FDS [6].

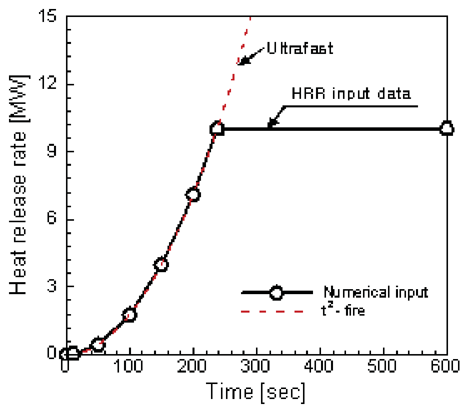


Figure 5: Ultra fast mode for HRR input

The HRR curve was assumed to be Ultra-Fast mode, and thus it reached to 10MW in 237 seconds and then maintained 10MW constantly [Fig. 5]. Total Simulation time was 600 seconds.

Although the pressure at the both end of underground train-way was expected to be different from atmospheric pressure, but outlet boundary conditions were set as atmospheric pressure, because of lack of sufficient data necessary for Soongsil University station. PSD breaking down due to fire and natural wind from the train-way were assumed not to occur. The numerical fire simulation for DUSS was conducted for two cases. One is DUSS with PSD. The other is without PSD. The Smargorinsky model for LES method was employed, FDS default condition for

Radiation and Combustion model were used. [6]

Results and discussion

Fig. 6 and 7 show transient smoke flow in DUSS after fire (Y=14.04m) and transient temperature distribution into the NAMSUNG-direction train-way of the Soongsil Univ. Station after fire (Y=14.04m). As the results of comparison on both cases which were shown in Fig. 6, 7, the smoke spread to the train-way direction much rapidly in the case of with-PSD.

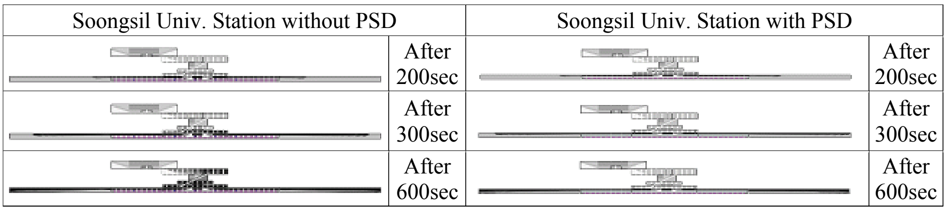


Figure 6: Transient smoke flow in the Soongsil Univ Station after fire (Y=14.04m)

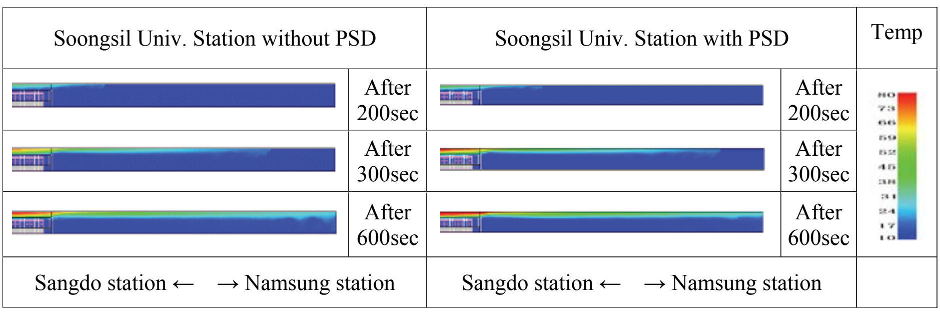


Figure 7: Transient temperature distribution in the Namsung-direction train-way of the Soongsil Univ Station after fire (Y=14.04m)

As one of the causes of such tendency for with-PSD as shown in Fig. 8, CO concentration at the top of train-way section (Z= 6.18m) was relatively higher, and as shown in Fig.9, the high temperature at the top of train-way section (Z=5.8m) was investigated for with-PSD. And as shown in Fig.9, hot air was distributed asymmetrically along the train-way where the fire source existed when PSD was not installed. Then when PSD was installed, hot air was formed at the other side of fire source, causing the temperature to be distributed symmetrically.

For such reasons, smoke spread was developed a little more rapidly to the train-way when PSD was installed than the case of without-PSD. Fig 10 shows the temperature and velocity vector distribution on a vertical section where the fire accident was occurred. When with PSD, hot air movement was investigated to have been blocked to the platform direction by PSD. If the materials of PSD are fire resistant, PSD could give the effect of smoke-control wall as well as change the direction of

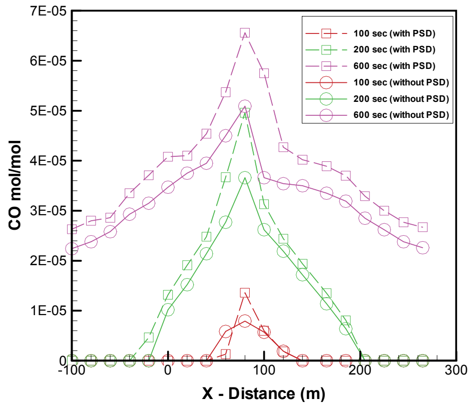
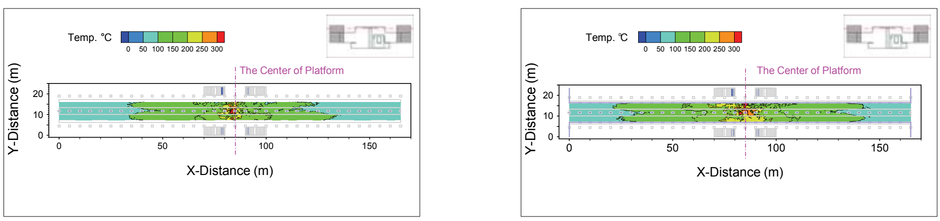


Figure 8: Transient CO concentration along trainway (Z=6.18m)



(a) Temp. contour in case of without-PSD (b) Temp. contour in case of with-PSD

Figure 9: The Temp. Contours of the Longitudinal Section for Platform (Z=5.8m, 600 sec)

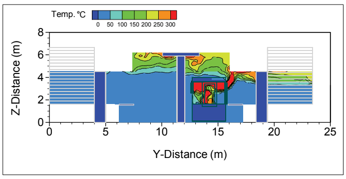
hot air current. At DUSS, evacuation through walk-way is not easy because of long stairs to exit. The evacuation through the train-way in DUSS without any smoke remove and control system was also unsuitable for safety after fire.

Conclusion

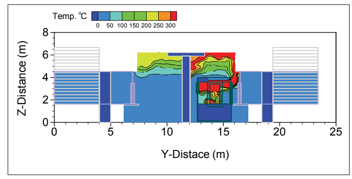
The numerical simulations of fire-driven flow at DUSS(Soongsil Univ. station) with parallel computational method as a full scale model were performed. In both cases, a fire was occurred inside the train corresponding to the center of platform, irrespective of PSD, heat and smoke flow move to train-way direction, and smoke movement was a little faster in case of with-PSD. PSD gives the effect of blocking the heat and smoke spreading to platform and waiting hall. The evacuation to train-way in DUSS without any fire prevention system was unsuitable for safety after fire.

Acknowledgement

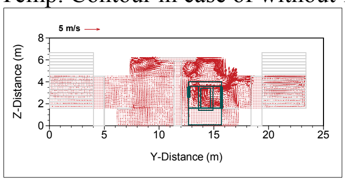
We appreciate the financial supports from the "Development of Technology for Fire-Safety-Performance Evaluation and Accident Prevention" project



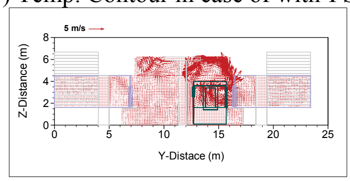
(a) Temp. Contour in case of without-PSD



(b) Temp. Contour in case of with-PSD



(c) Velocity vector distribution in case of without-PSD



(d) Velocity vector distribution in case of with-PSD

Figure 10: The Temp. Contour and velocity vector distribution of the Platform Vertical Section (X: 85m, 600 sec)

References

1. Young-Jun Jang, Hag-Beom Kim, Woo-Sung Jung, Won-Hee Park (2007), "Effect of Platform Screen Door on fire in the subway station", Autumn Conference & Annual Meeting of The Korean Society for Railway, p 234

2. Jae-Lim Lee, Myung-Hyun Lee, Sun-Im Park (1990), “The study on compensation for using the land and underground rights - Final Report, The Korea Transport Institute

3. Ho-Seung Lee, (June 7^{th}, 2008), “Dongtan ∼ Gangnam express train would be the key to the success of Dongtan New Town” article in Maeil Buisiness Newspaper

4. McGrattan K. (1998), “Large eddy simulations of smoke movement”, Fire Safety Journal 30(2) pp 161-178

5. Drysdale, D. (1998), “An Introduction to Fire Dynamics", 2nd edition, John Wiley & Sons

6. Kevin McGrattan, Bryan Klein, Simo Hostikka, Jason Floyd, (2008) “Fire Dynamics Simulator(Version 5) User’s Guide”, NIST Special Publication 1019-5