Wind Engineering Joint Usage/Research Center
FY2017 Research Result Report

Research Field: Indoor Environment
Research Year: FY2017
Research Number: 172006
Research Theme: Simulation research on air flow in subway stations

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Budget [FY2017]: 300000Yen

*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage and etc.….

1. Research Aim

With the accelerated process of urban modernization, traditional urban ground traffic can no longer meet the growing passenger traffic. Subway become more and more popular as it has the advantage of high speed, safety, punctuality and large capacity of passengers. Dozens of large and medium-sized cities in the world has widely used subway as the main public transport.

Recently, subway station with platform screen doors (PSDs) is widely used as its safety and economy. PSDs separate the platform and tunnel, so it reduce the heat dissipation into the platform from the train brakes and the air-conditioning condenser, thereby reducing the cooling load of the stations. Also the PSDs also reduce the train noise and minimize the possibility of passengers falling off the platform.

Previous research all think the PSDs is completely sealed and there is no air leakage from the PSDs. However, recent field test found the PSDs still has small gaps in the connection part. Piston wind and mechanical exhaust from the tunnel leak into the station from PSDs, which create large amount of unorganized ventilation at the station entrance as Figure 1. The unorganized ventilation will increase the cooling load of the subway stations as it brings the outdoor air and tunnel air in the platform. This paper put forward a simulation method to determine the air exchange volume between entrance and platform in subway with platform screen door, and also study its main influence factors by simulation, therefore supply suggestions to reduce the air exchange volume.

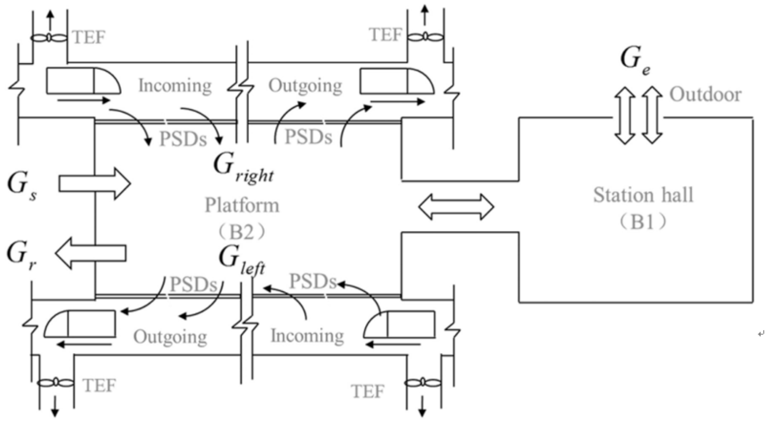

Figure 1 Schematic of the wind network in a subway station.

2. Research Method

In the study, we use subway thermal environment simulation software STESS. It was developed based on the achievements of field tests and theoretical analysis in Subway over the years by Tsinghua University in 1980s, and has been widely used by subway projects in China. STESS use network model to solve the air flow in subway and the simulation model used in the research is as Figure 2. Most of the resistance coefficient used in the simulation was empirical coefficient. In the simulation, the resistance coefficient of the platform screen door is changing as the door switch between open and closed. The resistance coefficient when the door is closed was measured by field test, and the value when the door is open is obtained from CFD simulation(Liang(2006)).

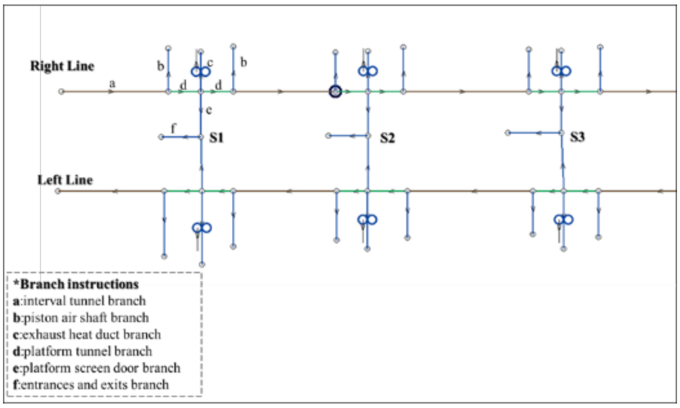

Figure 2 STESS simulation model

3. Research Result

3.1 Experiment verification

To verify the simulation result, the air exchange volume in the entrance was tested and compared with the simulation result. From the result in Figure 3 under the piston action of the train, there will be inlet and outlet in the subway entrance, the peak and trend of simulation and experiment results are in good agreement. According to statistical results, the inlet air volume of simulation and experiment is 11500m³/h and 12500m³/h respectively, the error was less than 10%. So simulation can predict the air exchange volume very well, in the following different examples were simulated to study the influence factors.

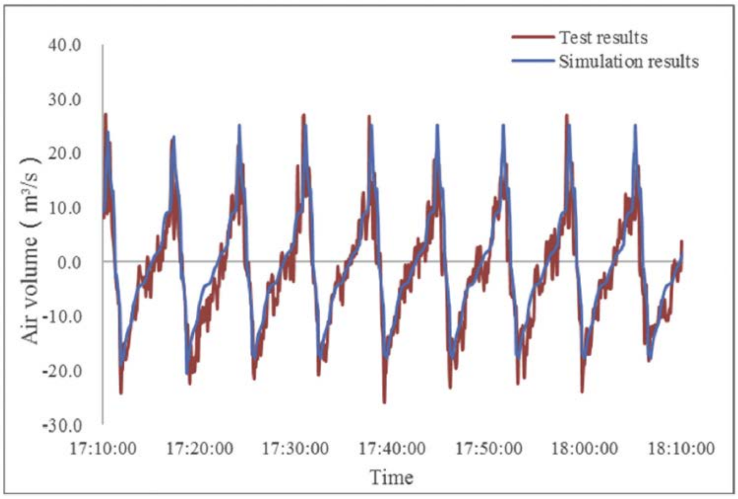

Figure 3 Comparison of test and simulated results for unorganized ventilation at the station entrance; '-' is air inflow and '+' is air outflow.

3.2 Influence factors analysis

3.2.1 Operation of exhaust heat fans

In the subway system with platform screen door, it will install platform screen door between the tunnel and the platform to separate the two parts. Central air conditioning system is set to control the subway thermal environment, while in the tunnel, piston air shaft at both ends of the station and mechanical ventilation is set to exhaust extra heat and moisture as Figure4. In Figure 4, TEF represents exhaust heat fans set in the top and bottom of the track to exhaust the heat emission of the air conditioner and brake of the trains, and it will open when the tunnel's temperature is too high. Usually, every station will have two exhaust heat fans, the air volume of each is 40~50m³/s.

Figure 5 shows simulation results of air exchange volume with outdoor under different exhaust heat frequency. When the exhaust heat fans are closed, inlet air and outlet air all happen under the piston wind action. However when the exhaust heat fans are open, inlet air become the dominant and increase greatly as the fan frequency increase.

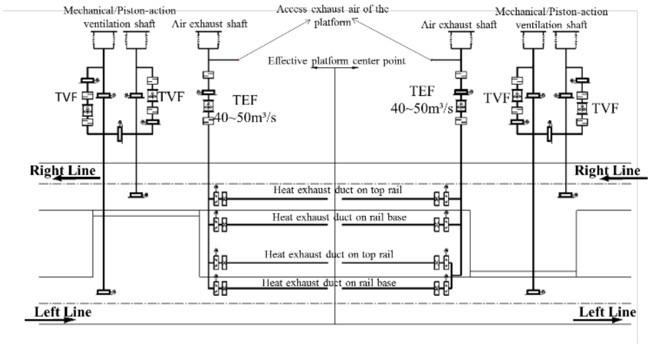

Figure 4 Principle diagram of station tunnel ventilation system

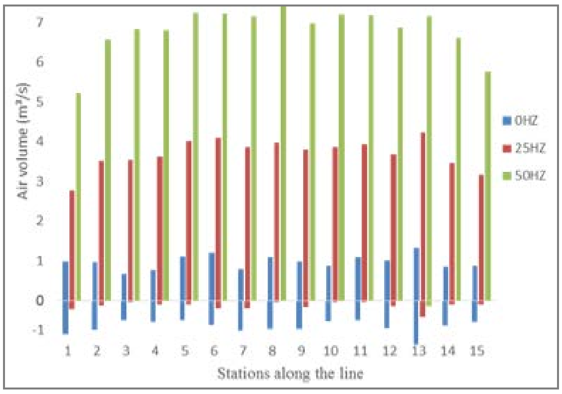

Figure 5 Simulation results of air exchange volume with outdoor under different

Table 1 statistical results of air exchange volume with outdoor

Exhaust heat fans frequency	Inlet air volume from outdoor (ten thousand m³/h)		
	Average	Minimum	Maximum
0	0.97	0.67	1.32
25HZ	3.7	2.77	4.23
50HZ	6.82	5.23	7.45

3.2.2 Length of the tunnel and time interval of trains' arrival

However, from the statistical results from Table 1, even with the same fan frequency, the inlet air volume from outdoors is significant differences among the stations. This is mainly resulted from two reasons. First is the upstream and downstream length of the station, it will effect the action of the piston wind. Another important reason is the time interval of up and down trains. For example, for the third station (as Figure 6), the train on both side arrived one after one, the piston wind through platform screen door resulted from trains cancel each other out, therefore decrease the air exchange with outdoors. For the thirteen station (as Figure 7), trains on both sides arrived almost at the same time, the piston wind mutually reinforce each other, therefore increase the air exchange with outdoors.

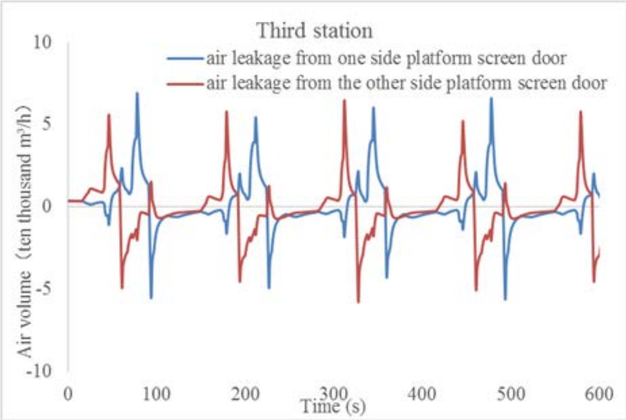

Figure 6 Air leakage of platform screen door in S3 station

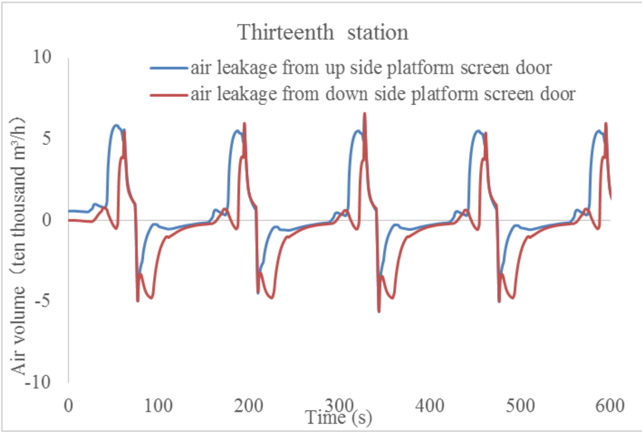

Figure 7 Air leakage of platform screen door in S13 station

3.2.3 Train departure pairs

For the train departure pairs, as the train departure number increase, the piston wind frequency and the opening time of the platform screen door all increase. According to the simulation results in Figure 8, with the increase of the train departure number, the inlet air volume basically showed a growth trend. However, the change of train departure number will affect trains arrival time interval of the stations, so the inlet will not always increase. Here is an example, when the departure pairs changed from 12 to 15, the trains changed from arriving at the same time to arriving on after one, therefore the inlet decreases instead of increasing.

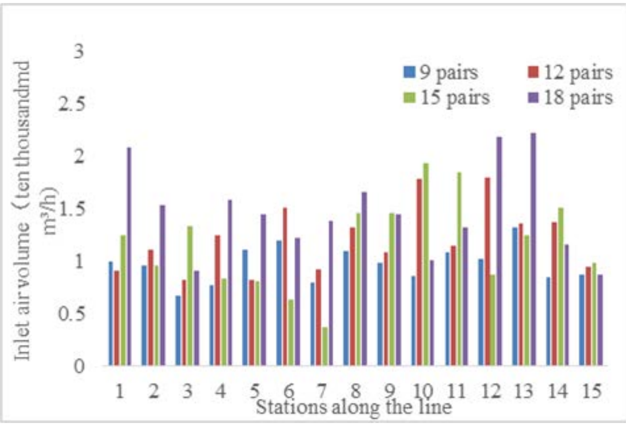

Figure 8 Air leakage of platform screen door under different train departure pairs

Table 2 Statistical results of air exchange volume with outdoor under different train departure pairs

Train Departure pair	Inlet air volume from outdoor (ten thousand m^3/h)		
	Average	Minimum	Maximum
9	0.97	0.67	1.32
12	1.21	0.82	1.8
15	1.17	0.37	1.93
18	1.47	0.87	2.22

3.2.3 Air tight performance of the platform screen door

In the research, the resistance coefficient of the platform screen door was measured in some stations. Based on the resistance coefficient, we can get the equivalent gap width to represent the air tight performance of the platform screen door. According measurement results, we find the platform screen door has significant difference in the air tight performance due to the difference of the installation quality.

Air exchange volume between platform and outdoors was also simulated under different air tight performance of platform screen door, the results are shown in Figure 9. According to the results, improve the air tight performance of the platform screen door can greatly decrease the air exchange volume.

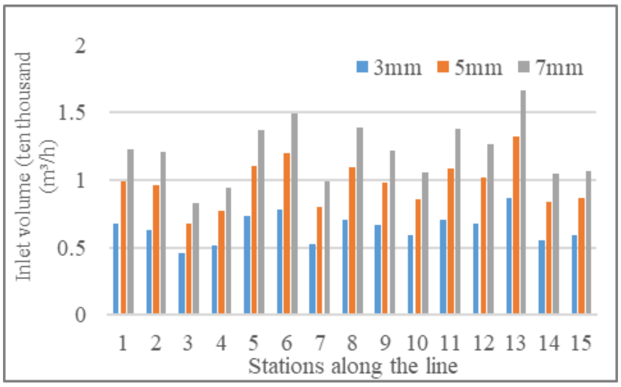

Figure 9 Air leakage of platform screen door under different air tight performance of platform screen door

4. Published Paper etc.

[Underline the representative researcher and collaborate researchers]

[Published papers]

1. Wang Y, Li X. Unorganized ventilation in subway stations with Platform Screen Doors[J]. Building & Environment, 2017.

[Presentations at academic societies]

1.

2.

[Published books]

1.

2.

[Other]

Intellectual property rights, Homepage etc.

5. Research Group
1. Representative Researcher
   Xiaofeng Li
2. Collaborate Researchers
1. Xiaofeng Li
2. Weirong Zhang
3.Ying Wang
4. Yue Zhang
5. Yan Li
6. Liang Li

6. Abstract (half page)

Research Theme:
Representative Researcher (Affiliation)
Summary(less than 300 words)・Figures

Subway station with platform screen doors (PSDs) is widely used as its safety and economy. However, PSDs is not completely sealed, there are still gaps among the structure connection parts. So piston wind and mechanical exhaust from the tunnel leak into station from PSDs, which create large amount of unorganized ventilation. The unorganized ventilation will increase the cooling load of the subway stations as it brings the outdoor air and tunnel air in the platform. This research put forward a simulation method to predict the air exchange between outdoor and platform. The simulation method is verified by field test. Then influence factors, such as operation condition of exhaust heat fans in the tunnel, length of the tunnel, trains' arrival time interval, train departure pairs and air tight performance of platform screen door are studied. To reduce the air exchange, the air tight performance of platform screen doors need to be improved and the air tightness performance of PSDs need to be checked after the construction of stations. And as there is air infiltrated from outdoor, the mechanical fresh air can be decreased or even cancelled.