Study on Ventilation Efficiency in Underground Car Parks; Part 1: Field Measurement of Age of Air

Kondo Y[1], Tadokoro Y[1], Yoshino H[2] and Imai T[2]
[1] Musashi Institute of Technology, Tokyo, Japan
[2] Tonets. Co., Tokyo, Japan

Abstract

This paper presents the field experiments on the ventilation efficiency in an underground car park where high velocity fan-diffuser units were installed as shown in Photo 1. The concentration of SF_6 were measured as tracer gas under the step up condition and the step down condition, and the ventilation efficiency such as the age of air were calculated from the rising curve and the falling curve of the SF_6 concentration in the underground car park. The ventilation efficiencies of two cases were compared, i.e. in Case 1 the fan-diffuser units were operated, and in Case 2 they were not operated.

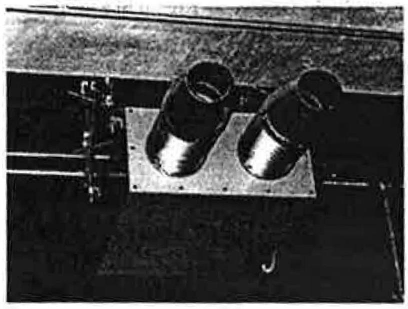


Photo 1. High Velocity Fan-Diffuser Unit

Introduction

A lot of underground car parking has been constructed in Japan because the available land space is limited in urban areas. The underground car parks are usually mechanically ventilated because they are enclosed with walls, etc. and there are few effective openings for natural ventilation. In Japan, the law requires mechanical ventilation equipment in an underground car park that can achieve more than 10 air changes per hour. In a car park, a lot of contaminants are emitted from motorcars e.g.

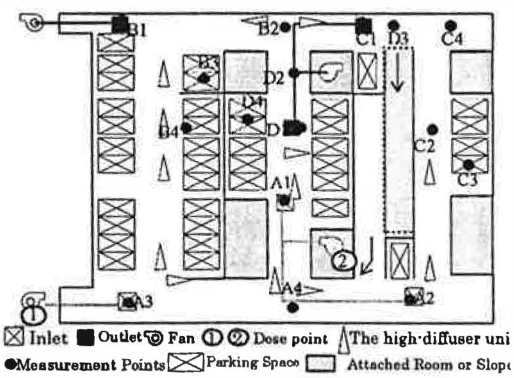


Figure 1. A Floor Plan of Car Park Studied in This Paper

Table 1. Outline of Ventilation System

Ventilation method	Mechanical
Inlet air rate	OA1:22680[m³/h] OA2:40510[m³/h]
Outlet air rate	EA1:26590[m³/h] EA2:36600[m³/h]
Air change rate	10;ACH=
Nominal time constant	6;min=
High velocity fan-diffuser units⊄,a·6	V: 11.1[m/s] Q: 615.6[m³/h]
High velocity fan-diffuser units⊄,b·2	V: 10.3[m/s] Q: 583.2[m³/h]

NOx, SOx, CO and so on. So if the design of the ventilation system is not appropriate, serious indoor air quality problems may occur. It can be supposed that some people stay long time e.g. employees such as the guard or workers for maintenance, the others stay short time e.g. visitors such as shoppers and commuters. From this point of view, it is important to design the ventilation system appropriately. In this paper, the field measurements on the age of air were carried out by tracer gas methods and the distribution of fresh air evaluated.

Thirteen fan-diffuser units were was installed in the underground car park studied in this paper and the effects of these units on the ventilation efficiency were investigated.

Object of Measurement

The measurement was carried out on the third basement floor in an office building that had three basement floors in Tokyo, Japan. The underground car park on the third basement floor was mechanically ventilated and the floor size and the volume were 44.9[m] X 57.6[m] 2097.5[m2] and 8,390[m3] respectively. The plan of the car park and the ventilation system are shown in Figure 1, in which triangle symbols mean the fan-diffuser units and the type of them can be distinguished with character of ⊄,a, ⊄,b and ⊄,c.

Outline of Measurement

Method

The measurements of concentration of tracer gas were carried out under the step up condition (SU) and the step down condition (SD).

The SF6 gas was dosed constantly in two supply ducts, namely 0.76[L/min] and 1.35[L/min] of about 2.0[ppm] SF6 were emitted at point ⊄,1 and point ⊄,2respectively, and the concentration was observed by the gas monitor (B&K) at each point. Then the local age of air and the local air change effectiveness εp(the ratio of the nominal time constant □n and local age of air) were calculated from the rising curve during the step up condition and the falling curve during the step down condition.

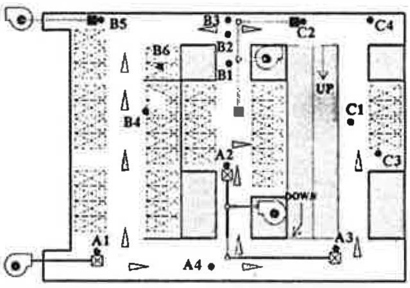


Figure 3. Plan of Second Basement Floor

The total numbers of measurement point were sixteen that consisted from three points at the inlet (point A1, A2, A3), three points at the outlet (point B1, C1, D1), ten points at the various the car parking area at FL+1,600 [mm]. In this paper, the measurement points of A1, A2, A3 and A4 were called Group A, points of B1, B2, B3 and B4 were Group B, points C1, C2, C3 and C4 were Group C and points D1, D2, D3 and D4 were Group D for the sake of convenience. The time interval of the gas monitor was about 6 [min](1.5 [min] per point).

Measurement Cases

The cases of measurement are shown in Table 2, in Case 1 fan- diffuser units were operated, and they were not operated in Case 2. The measurement was conducted on December 13, 1998.

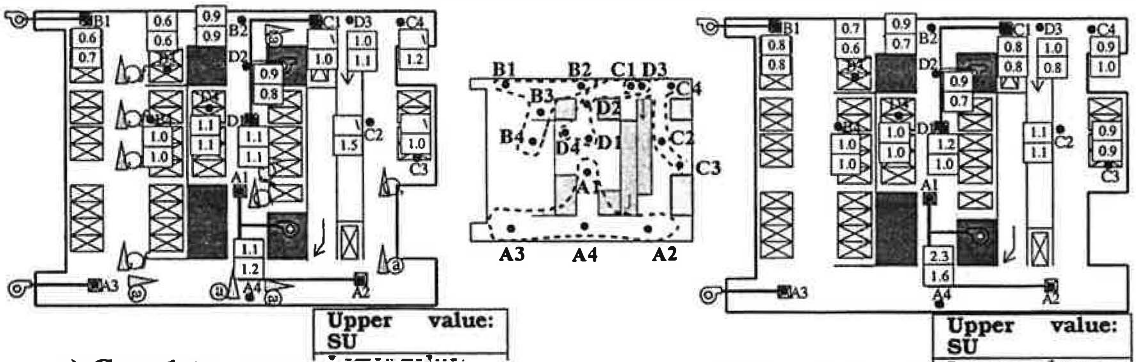
Table 2. Measurement Cases

Case number	Fan-diffuser units
Case1	ON
Case2	OFF

Results And Discussions

Comparison of Two Cases

Figure 2 shows the Local air change effectiveness ε_p evaluated from the concentration. In Case 1, the car park was ventilated efficiently because the value of ε_p at almost points were larger than 1.0 except for the region in Group B. In Case 2, however, there were some points where the local air change effectiveness was a little smaller than 1.0, there was no remarkable difference between Case 1 and Case 2 except for point A4. In other words, the effect of the fan-diffuser units on the local air change effectiveness was not remarkable in Case1.



a) Case 1 (fan-diffuser units ON) **b)Case 2** (fan-diffuser units OFF)

Figure2. Distribution of The Local Air Change Effectiveness

From the observation at each region, it was found that the drive through space (the space through which cars pass) was ventilated efficiently $\varepsilon_p > 1$, however the parking space (the space where cars park) was not ventilated efficiently, $\varepsilon_p < 1$ because such spaces were partly enclosed with walls, and therefore the pollutant air may stagnate in such regions.

Comparison with Results on The Second Basement Floor

On August 9, 1998 the measurement was carried out on the second basement floor in the same building with the same method as on the third basement floor. The outline of measurement is shown in Table 3 and results of the local air change effectiveness ε_p calculated are shown in Figure 4. In the result on the second basement floor, the difference between Case 1 and Case 2 was more remarkable than in the result on the third basement floor because the interactive airflow between the upper or lower floor was generated on the second basement. In fact, descending/ascending air flow through the slope was observed. It means that the fan-diffuser units were more effective if interactive airflow exists and the uniform one direction airflow in the drive through space could not be made efficiently such as the second basement. On the other hand, if

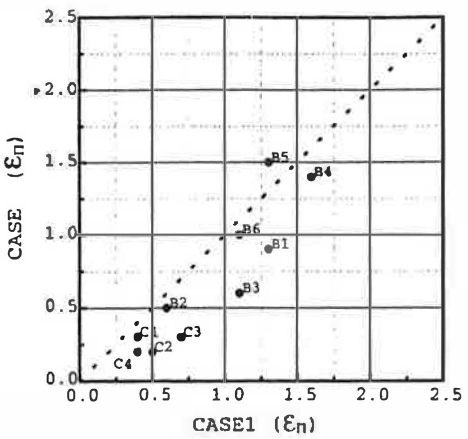


Figure 4. Correlation of The Local Air Change Effectiveness Case1 and Case2 on Second Basement Floor

Table 3. Outline of Measurement on Second Basement Floor

Layout	Almost same as third basement floor (Figure 3)
Ventilation system	Almost same as third basement floor Total supply air rate:85200[m^3/h] High velocity fan-diffuser units X13
Method	Almost same as third basement floor
Equipment	Same as third basement floor
Points of measurement	Reference of Figure 3

Note: the difference between experiments on second and third basement was following;

1 The internal airflow between the upper or lower floor was shut out completely in the experiment on third basement floor. On the other hand, it was not done in the experiment on second basement floor.

2 From the visualization test by smoke, descending/ascending air flow through the slope was observed because the air balance of upper and lower floor was not satisfied enough.

the fresh air was distributed to the drive through space efficiently without the interactive air flow from upper and lower floors such as third basement, the fan-diffuser units were not necessary to promote ventilation. For example, the push-pull ventilation system, which has a uniform one direction flow as shown in Figure 5, can distribute fresh air to the main route. Then the fresh air of the drive through space can be shared with the parking space. In this process, the fan-diffuser units may be useful.

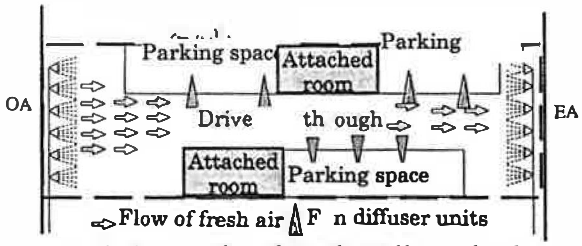


Figure 5. Example of Push-pull Method using High Velocity Fan-diffuser Units (image figure)

Conclusions

1. In Case 1 (the high velocity fan-diffuser units ON), it was found that the car park was ventilated efficiently because the value of εp at most points were larger than 1.0.
2. In Case 2 (the fan-diffuser units OFF), however, there were some points where the local air change effectiveness was a little smaller than 1.0, no remarkable difference between Case 1 and Case 2 was observed.
3. From the observation at each region, it can be found that the parking space was not ventilated efficiently, because such spaces were partly enclosed with walls, therefore the pollutant air may stagnate in such regions.