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# THE EVALUATION OF NATURAL VENTILATION IN UNDERGROUND OFFICE SPACE

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## ABSTRACT

One of the major factors in human comfort is the air quality, which occupies a specific environment and is usually renewed through natural ventilation. However, isolated underground spaces do not benefit from this factor and are often subject to high relative humidity, poor air quality, pollutant emissions and penetration of moisture from the surrounding soil and ground base.

Due to such negative characteristics, underground spaces are generally recognized as undesirable living environments by most of Koreans. Consequently, most underground spaces are commonly planned as parking lots requiring a lower standard of Indoor Air Quality (IAQ) control.

The paper will investigate a scheme using natural ventilation to improve air quality in underground spaces, analyzing subsequent results supported by actual survey data and measuring contaminant concentration.

## INTRODUCTION

The continued development of underground spaces such as market place, parking lots and office environments are due in part to a lack of suitable aboveground spaces and increasing urban congestion in south Korea. As these spaces increase in the use and popularity, the corresponding increase in problems associated with underground spaces (temperature, humidity, ventilation and Indoor Air Quality (IAQ)) have also been the focus of much discussion and debate.

In addition to an inherent difficulty in ventilating underground spaces, they are generally more susceptible to fluctuation in temperature and humidity usually requiring above average control methods. Moreover, air in the underground spaces contain contaminants such as carbon dioxide, carbon monoxide, radon, dust, nitrogen oxides and asbestos to name but a few. Due to these reasons, appropriate ventilation for the provision should be considered as a viable option in as effort to minimize costs in equipment, installation and maintenance.

The following results are based on a comparative analysis of the Indoor Air Quality (IAQ) between artificial and natural ventilation in underground spaces. The survey concentrates on data gathered from the types of ventilation systems used, several indoor measuring points and seasonal differences. Various indoor measuring points were analyzed to ventilation systems. The analysis has focused primarily on information collected from the winter months. Although data has been gathered from both winter and summer months.

## METHODS / METHODOLOGY

Analysis of this study is based on research begun in 1994. Specific data used in the analysis is based on information collected during the summer of 1997 and the winter of 1998.

Weather patterns of the climate in Seoul are characterized by two extremes. The summer months exhibit relatively high humidity and high temperatures while the winter months generally experience low temperatures and a relatively low humidity factor. Measurements for the study taken at the site in Seoul, building "D", averaged temperatures ranging from 25±5°C in during the summer and 5±5°C in the winter. Additional factors such as $CO_2$, CO and TSP(particulates) were regarded as major pollutants.

The measuring points of the building were the entrances of the exterior that are sunken and the interior itself. In Fig.1 the left measuring point is located at the front of the entrance where fresh air is introduced and the right measuring point is from the sunken area where the measured depth is 7.2m.

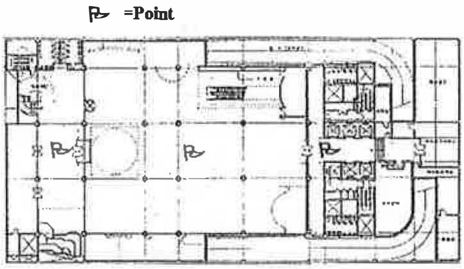


Fig. 1 "B1" Plan of the building

## RESULTS

### Temperature

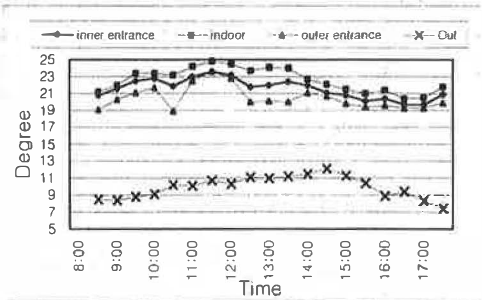


Fig 2. Temperature (Winter)

Fig.2 and Fig.3 shows changes of temperature at three different measuring points. The highest temperature was recorded in the middle of the room, and the next high occurred near interior entrance. The lowest point is shown near the exterior the entrance, about 3°C lower than internal temperatures. The profile of outdoor temperature is similar to that of indoor temperatures. The temperature gap between inside and outside is smaller in summer than in the winter season.

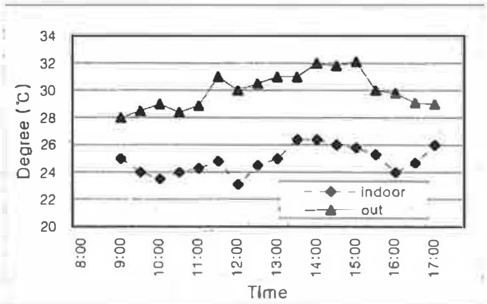


Fig 3. Temperature (summer)

### Relative Humidity

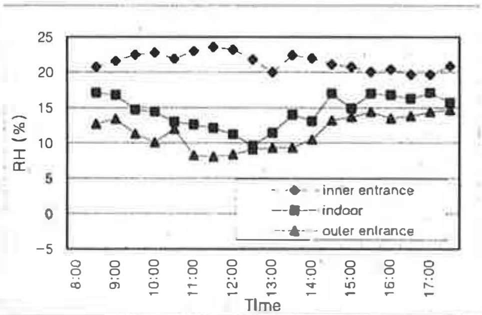


Fig 4. Relative Humidity (winter)

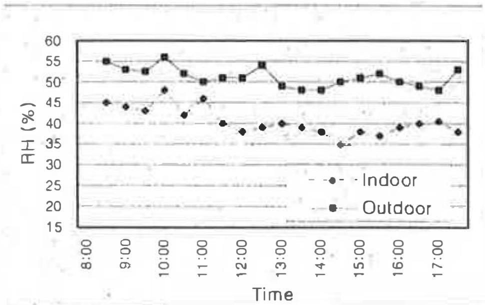


Fig 5. Relative Humidity (summer)

In Fig.4 and Fig.5, humidity at the entrance is much higher than other measuring points. In the middle of the room and in the outside entry area humidity data show similar tendencies. However, the level of indoor humidity is the lowest at noon (lunchtime) and generally higher in the afternoon. Fig.4 shows that the humidity level is inversely proportional to the temperature levels.

## $CO_2$ Concentration

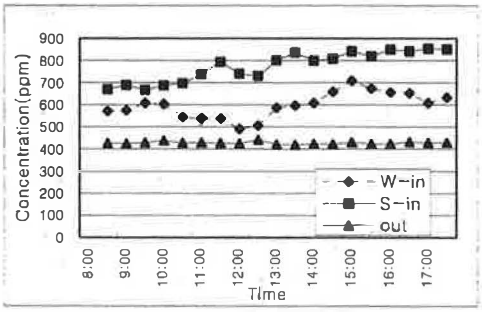


Fig 6. Concentration of carbondioxide

* W-in=winter indoor, S-in=summer indoor, Out= outdoor

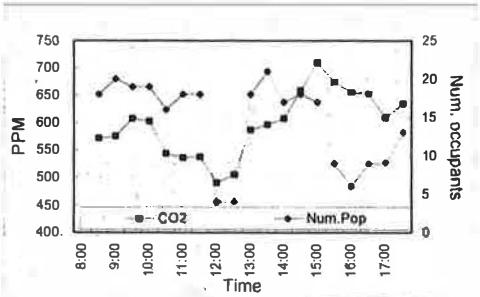


Fig 7. $CO_2$ concentration & Population

The concentration levels of carbon dioxide is constant throughout the day at approximately 410~430ppm. During the summer months, however, the concentration of indoor carbondioxide level increases to 700 PPM in the morning hours and 850 PPM in the afternoon. In the winter, variations are wider and the concentrations are 170 PPM lower than in the summer.

Fig.7 shows the relation between number of occupants and concentration of carbon dioxide. The indoor concentration of carbon dioxide changes by the number of occupants.

## CO concentration

The following chart represents a seasonal difference concentration of carbonmonoxide. The concentration of carbonmonoxide ranged from 6 to 7 PPM in the summer, and around 4 PPM in winter. These results increased that there was a considerable difference between indoor temperature and outdoor temperatures due to natural ventilation.

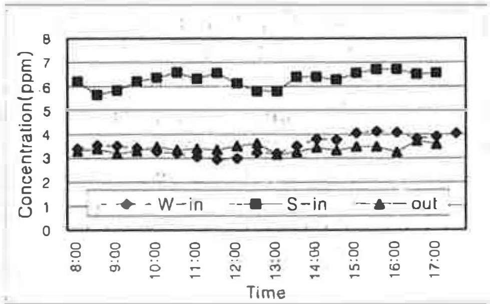


Fig 8. Concentration of CO

* W-in=winter indoor, S-in=summer indoor, out=outdoor

Carbon monoxide concentration is 10 PPM by environmental standards. Data during the winter is the same as outdoor air.

## Particulates

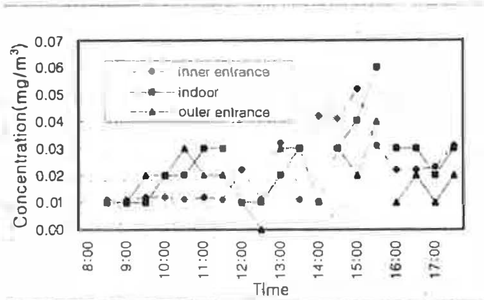


Fig 9. Concentration of particulates (winter)

We observed she changes of particulates' density by several measuring points. As a whole, the concentration of particulates were the lowest during the middle of the day. The tendency of the effects from the inner entrance was similar to that from the outer entrance. If the density at or near the entrances was high, the indoor density increased shortly there after.

Results show that the particulates near the entrance transferred inside along with the cool air from the entrance to the middle of the room. In particular, the particulates generated by people passing into the room migrated inside as the air was gradually mixed.

Fig.9 represents measurements near the entrances and indoors and show a similar pattern at an interval of 30 minutes.

**Air Velocity**

Air velocity does not show a wide variation. At the center of the room, air velocity is about 0.01 m/s, but it is common that the velocities of air flow outside the entrance, indoor space and inside the entrance generally increased at 11:30 A.M. Variations of the air velocity at the outer entrance are a regular pattern. But variation of air velocity inside the entrance is changed according to the air outside the entrance, because the size of the interior door is smaller than that of exterior door.

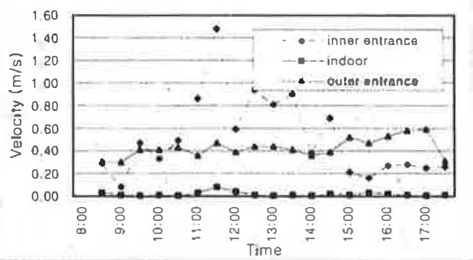


Fig 10. Air Velocity (winter)

**Inlet and Outlet**

In this test the differences between natural ventilation and HVAC in indoor spaces are examined. The concentrations of $CO_2$ outdoor that are supplied to indoor are lower than that of indoor spaces. But in the case of CO, it is not always the case (see Fig.11,12), In the case of $CO_2$, the concentration of outdoor is always lower than that of an indoor or supply duct. But in the case of CO, it is possible that the density of supplied air is higher than that of an outdoor area. Because the concentration of CO at the inlet varies by the density of CO at center of the room, it seems unlikely that there is no place of origin (CO) as most of it flows into supply duct. The number of occupants contributed to the concentration of $CO_2$.

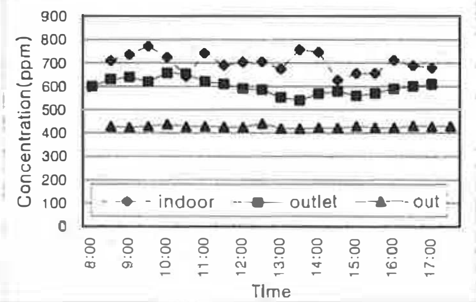


Fig 11. $CO_2$ concentration (winter)

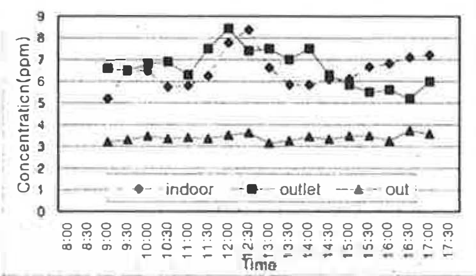


Fig 12. CO concentration (winter)

**Contaminant Concentration Comparison**

Fig.13 and 14 show the differences between ventilation systems used in each analysis. Only underground buildings "A" and "B" are considered multi ventilation systems, indicating a combination of natural and mechanical ventilation systems.

Underground spaces "A" and "B" selected for the study are both office spaces accessible only through the 1st floor lobby and having no direct access from the outside, whereas the underground office space "D" is below grade with an outside entrance.

The underground spaces "A" and "B" are analyzed as having a high concentration of air contaminants, The following Figures 13 and 14 chart the differences among these buildings.

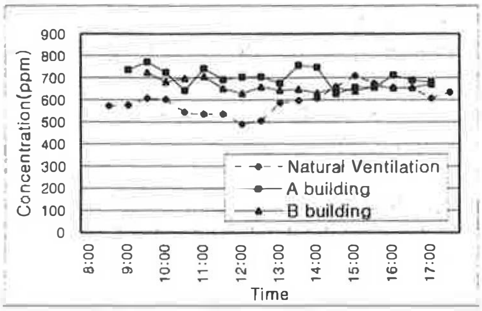


Fig 13. $CO_2$ concentration each buildings (winter)

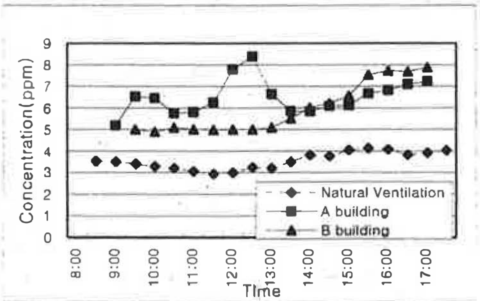


Fig 14. CO concentration each buildings (winter)

**Radon**

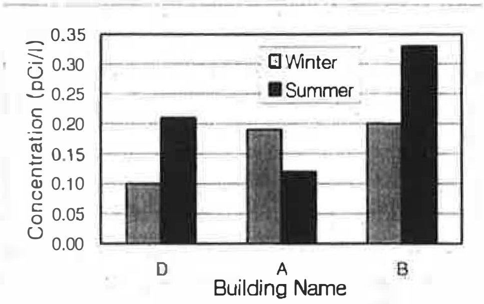


Fig 15. Radon concentration

Generally, radon concentration in winter is higher than that in summer. But in this study, building 'D' shows reverse result, which might be caused by natural ventilation system of building. However, detailed simulation should be needed to finding out the relationship between radon concentration & ventilation system.

**DISCUSSION**

Building "D" is an underground space having a direct outer entrance used by occupant. This entrance provides natural ventilation, allowing indoor contaminants to escape and relatively clean outer air to enter during the winter months.

However, during the summer, the distribution of air temperature is generally predictable: cool air-conditioned air was located in the lower portion of the underground space, and warmer outside air was located in the upper portion

At this point, in winter, lower contaminant concentration of "D"; "D" has HVAC and natural ventilation system, underground building than that of "A" or "B" building: HVAC only in natural.

Figure 2,3 and 10 show a relationship between airflow and temperature. The figures indicate a faster airflow occurs when the temperature differences between inside and outside air increase higher air temperatures in these spaces. Concentrations of particulates were also slightly higher than other times.

**CONCLUSIONS**

1. If a given building's ventilation system relies on a standard mechanical HVAC system, the IAQ has a higher concentration of indoor air pollutants if the system's performance is less than efficient, A natural ventilation system would prove to have a higher quality of air and less air pollutants.

2. Fig.7 shows that if the air contaminant is carbon dioxide, there is some merit in installing a natural ventilation system in addition to an HVAC system, because indoor carbon dioxide concentrations are affected mostly occupant who emit $CO_2$, and HVAC systems do not produce $CO_2$.

3. But the contaminant is carbon dioxide, indoor $CO_2$ concentration is affected by outside air. At this point, we can see that the underground building which has HVAC system only effected outlet contamination concentration so much, but there has natural ventilation and

HAVC system, the underground space contaminant concentration does not effected sensitively.

4. Two types of buildings were compared, i.e., one with HVAC system and natural ventilation capability and the other with only mechanical ventilation system. As the sources of indoor air contamination increase and the operation of the mechanical ventilation system slows down, it is observed, the density of air contaminate stays stable at the building with natural ventilation capability. However, the density of air contaminate is closely related with the operation rate of mechanical ventilation system in the building without natural ventilation capability.

## FURTHER STUDIES

The study has concentrated on an analysis of the IAQ in naturally ventilated underground and mechanically ventilated underground spaces. Results illustrate the need to continue the study and analysis of utilizing energy saving natural ventilation systems in underground spaces.

On the other hand, we study CFD simulation of particulates concentration trace I the underground space.

## ACKNOWLEDGMENTS

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## REFERENCES

Lee, Kyung-Hoi. (1989) *The architectural environmental design*, Seoul Korea.

Lee, Kyung-Hoi, (1996) *Indoor air quality and sick building syndrome in office buildings. The 7th International conference on indoor air quality and climate.*, Vol.3.

ASRAE. (1989) *ASHRAE standard 62-1989, Ventilation for Acceptable Indoor Air Quality, Atlanta.* American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc.

Bright, D et al. (1992) *AL-TR-1992-0016, Guide for Indoor Air Quality Surveys*, Armstrong Lab.