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An analysis of the ventilation rates in residential buildings

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Abstract. The ultimate goal of environmental buildings is to minimize the use of fossil fuels and resources while providing a comfortable environment for occupants. Through continuous research and development, the physical performance of the buildings has been greatly improved for this purpose. However, focusing only on physical performance, it is seen that there is a big discrepancy between predicted and actual performance of building by treating occupants, who are the most affective object of building and energy consumption, as simple passive elements. These results increase the energy and cost of the building and become an obstacle to the construction of environmentally friendly buildings. Among occupant behavior, window opening is the biggest factor of increasing heating and cooling energy consumption. The purpose of this paper is to analyze the ventilation rate of each window opening for being embedded in an energy simulation program. A method to analyze the ventilation rate was carbon dioxide decay method as shown in Fig. 1. As a result, the ventilation rate was affected by the wind direction and speed, and floor level, but was somewhat constant because of monsoon effect in summer and winter of Korea.

1. Introduction

According to International Energy Agency (IEA), building energy consumption accounts for 40% of the total energy consumption. The energy consumption of buildings is greatly influenced by occupants' behaviors, and among this, window opening greatly affects energy consumption [1-4]. Window opening is an act to make indoor air quality pleasant, but it also causes increase of energy consumption due to changes in indoor temperature because of outside air [5]. Besides, Brager et al. [6] shows that there is 1.5°C difference in the neutral temperature between occupants with high and low degree of window control. However, research on energy conservation has been carried out from various perspectives, but research on energy consumption in buildings according to occupants has received relatively little attention, and depending on how occupants perceive and use energy, the pattern of energy consumption in real buildings can vary greatly[7]. In addition, Turner et al.[8] showed that heating energy consumption varies by 60kWh/m², year depending on the occupants' behavior, despite the fact that they have the same physical performance of building. Therefore, if these occupants' behaviors are embedded in the energy simulation program, it will be very helpful to design environmental buildings by predicting the actual energy consumption at the design phase. Therefore, in this study, the ventilation rate, according to the wind direction, wind speed, and floor levels using carbon dioxide decay method, was analyzed in order to develop the behavior prediction model of the occupants before putting into the energy simulation program.

2. Method

2.1. Samples

Twenty-three occupied housing unit was selected from three complexes from suburban area of Seoul city. The sample was carefully selected based on floor area, number of occupants, location as shown in Table 1. These samples were measured from 2014-12-01 to 2015-09-30.



Table 1. Characteristics of the sample housing unit

Samples	Complex	Built year	Floor Area(m ²)	Floor level	Location	Number of Occupants
A1	A	2007	109	4F	Border	3
A2			109	8F	Border	4
A3			130	14F	Border	4
A4			172	8F	Border	4
A5			109	16F	Border	4
A6			109	5F	Border	3
B1	B	2011	147	4F	Border	4
B2			137	2F	Border	4
B3			147	13F	Border	4
B4			163	12F	Border	4
B5			163	4F	Border	4
B6			163	10F	Border	4
B7			163	6F	Border	4
B8			163	5F	Border	4
B9			163	1F	Border	4
C1	C	1998	72	14F	Border	4
C2			108	9F	Center	4
C3			80	7F	Border	4
C4			80	19F	Center	4
C5			80	6F	Border	4
C6			108	9F	Center	4
C7			80	25F	Center	4
C8			163	15F	Border	4

2.2. Measurements

Indoor and outdoor Parameter, and each device are shown in Table 2. Every parameter is measured at interval of 10 minutes. Wind data is from Korea Meteorological Administration.

Table 2. Measurements parameter and the specification of devices

Parameter		Device	Accuracy	Interval[min]
Outdoor	Dry-bulb temperature	Data Logger (TR-72ui and RS-11)	$\pm 0.3^{\circ}\text{C}$	10
	Relative humidity		$\pm 5\%\text{RH}$	10
Indoor	Dry-bulb temperature	Humidity, Temperature and CO ₂ monitor (MCH-383SD, Lutron)	$\pm 0.8^{\circ}\text{C}$	10
	Relative humidity		$\pm 4\%\text{RH}$	10
	CO ₂ concentration		$\pm 40\text{ppm}$	10
Window opening	Status	State Logger (UX90-001, Onset Computer)	-	10
Wind	direction	Korea Meteorological Administration	-	10
	speed		-	10

2.3. Carbon dioxide decay method

Figure 1 shows typical trends of decrease in CO₂ concentration according to window opening time. When window opening was short, there was one decreasing tendency as shown in (a) of Figure 1, but when window opening time was long, there was more than 2 decreasing tendency as shown in (b) of Figure 1. This is due to the fact that the concentration of carbon dioxide is converged to the outside air concentration, so we selected the slope 1 to derive the ventilation rate.

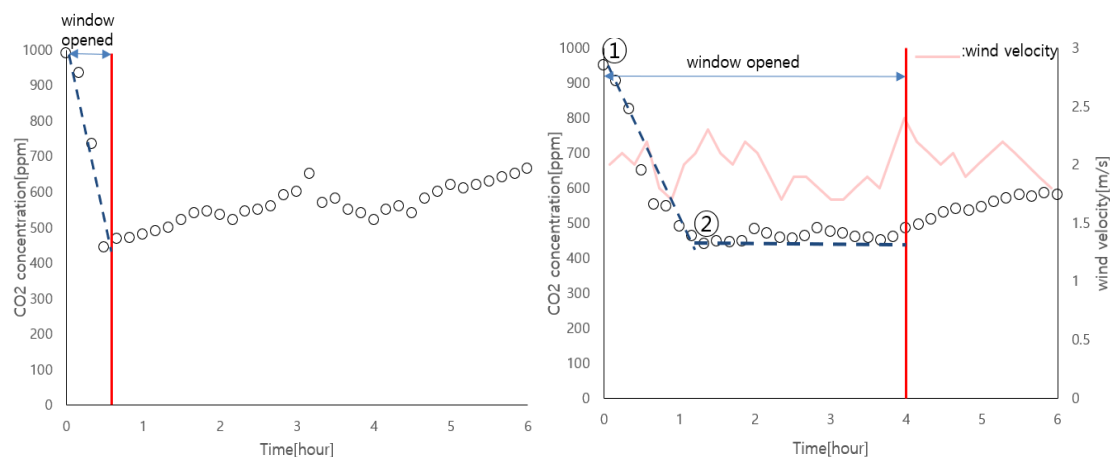


Figure 1. Comparison of CO2 decrease when ventilation time is short(a) and long(b). (a)left, (b) right

3. Results and discussion

3.1. Ventilation rate according to wind speed considering wind direction

The angle of the wind direction was divided into four categories based on the living room window of the sample as shown in Figure 2. The correlation of ventilation rate with wind speed was significant at $0 \sim 22.5^\circ$ and $22.5 \sim 45^\circ$, which are close to cross ventilation. On the other hand, as the direction of the wind became farther away from cross-ventilation, the ventilation rate was not correlated with the wind speed.

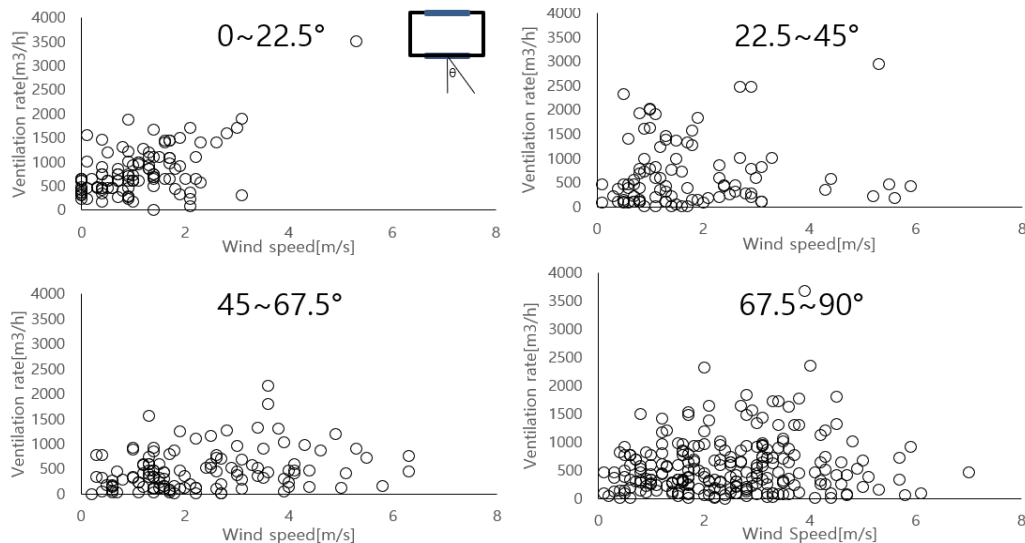


Figure 2. Ventilation rate according to wind speed considering wind direction.

3.2. Monthly ventilation rate considering floor level

Monthly ventilation rate considering floor level is as shown in Figure 3. 1st floor from 5th floor to the bottom floor, 6th from the 10th floor to middle layer and 11th floor or more were selected as the high floor. As a result of the T-test, the ventilation rate showed a significant difference between low and high floor levels in all months except September.

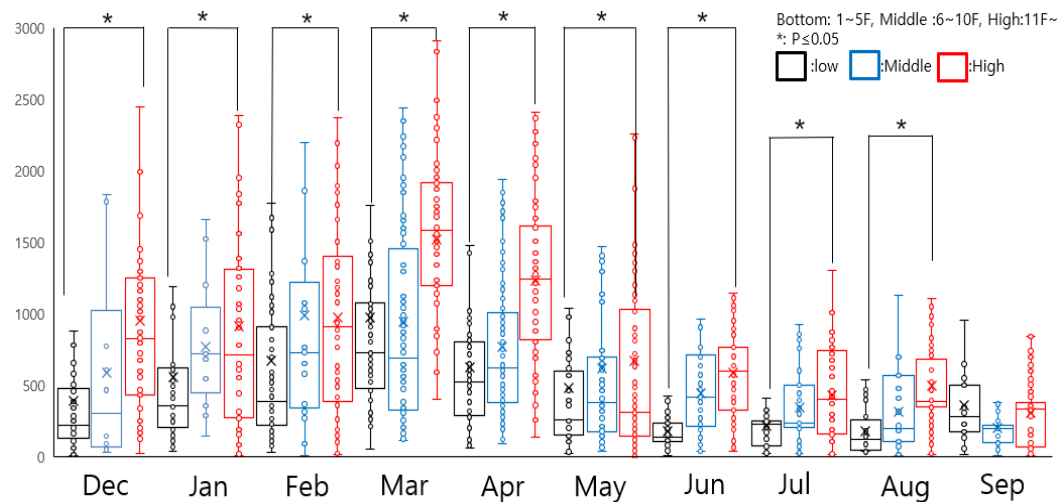


Figure 3. Monthly ventilation rate considering floor level

3.3. Ventilation rate of all samples

Ventilation rates of all samples in measurement period is as shown in Figure 4. The range of pink represents 25% to 75% tile of ventilation rate each day from all samples, and blue line represents the average of ventilation rate. As shown in the figure, the ventilation rates of heating and cooling period were almost constant. This is thought to be the effect of the monsoon in Korea.

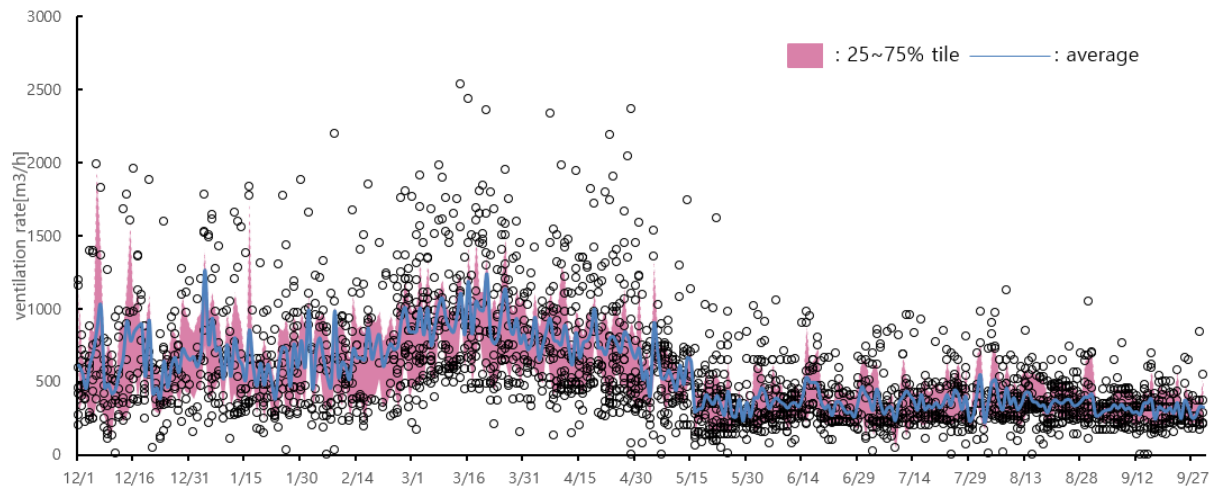


Figure 4. Ventilation rates of all samples

4. Conclusion

In this study, the ventilation rate according to wind direction, floor level, and season was analyzed and the following conclusions were drawn. The ventilation rate was correlated with wind speed considering wind direction. It is considered that the ventilation rate is higher because the amount of outdoor air is increasing because of effect of cross-ventilation. The correlation of the ventilation rate between the lower and upper floors was correlated with all months except for September. It is estimated that wind pressure, according to floor level, affects the ventilation rate. it of floor. In addition, ventilation rates of heating and cooling period showed a certain pattern, which is considered to be a distinctive monsoon in Korea. In future studies, we will derive a more precise energy consumption value by putting this ventilation rate value to the energy simulation program when the window is opened.

Acknowledgements

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