An Evaluation of Energy Performance of Hybrid Ventilation System Using the Balcony Space in Apartment Housing

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ABSTRACT

The purpose of this paper was to evaluate the performance of hybrid ventilation system using the balcony space to solve the problem that mechanical ventilation systems have.

The results of the simulation revealed that hybrid system was better than the constant mechanical system in indoor air quality and energy consumption. Also, Hybrid ventilation method maintained the indoor thermal condition constantly during cooling and heating seasons.

Regard to the energy consumption, the hybrid system could reduce 37% of heating, cooling and ventilation energy compared to constant airflow mechanical system.

Therefore, the hybrid ventilation system using the balcony space in apartment housing would provide better comforts to the occupants and lower the energy consumption compared to the constant airflow ventilation system.

KEYWORDS: Hybrid ventilation, Energy consumption

1. INTRODUCTION

There are ongoing researches around the globe as an attempt to reduce the energy consumption in buildings and to prevent environmental pollution while satisfying the level of comfort to meet the increasing economic standards.

Moreover, having to notify the people of the atmospheric condition of apartments before the moving in under the Indoor Air Quality Control Law has raised people's concern about their living environments in apartments.

Consequently, constant mechanical ventilation systems that aim to remove any indoor pollutants are actively being used as the necessity of ventilation in living environments increases. These systems, however, are expected to increase energy consumption because most of them heavily rely on machineries.

In addition, the thermal-comfort of the residents is jeopardized during the cooling and heating periods considering the nature of ventilations.

Therefore, the performance of the hybrid ventilation system that jointly uses natural ventilation and mechanical ventilation using the balcony space in apartment housings is evaluated as a proposal in this research.

A 85 m² apartment housing was used as the sample of research to accomplish the purpose of this research and TRNSYS simulations were used to evaluate the performance of the hybrid ventilation system.
2. FEATURES OF TWO ALTERNATIVE SYSTEMS

2.1 Hybrid ventilation method using the balcony space

The ventilation method proposed in this research operates by using natural ventilation to maintain indoor thermal status and indoor air atmosphere and the mechanical ventilation helps reduce the ventilation overloading by providing minimal amount of ventilation, removing indoor pollution substances.

As for the balcony area, ventilation is minimized in winters to take advantage of the preheating, maximum ventilation in summers to share the outside atmosphere, and FCU are used for cooling the air flowing in from the balcony to reduce ventilation overloading.

However, the amount of air flowing in from outside will need to be customized according to the season because the FCU energy consumed in cooling the air from the balcony will increase in summers.

Hybrid Ventilation

- **Return header**
- **Header controller**
- **Balcony air**
- **Ventilation system**
- **Supply header**
- **Air conditioner**
- **Chiller**
- **Pump**

a) Mechanical ventilation method of the hybrid ventilation system

Outdoor Ventilation

- **Return header**
- **Header controller**
- **Outdoor air**
- **Ventilation system**
- **Supply header**
- **Air conditioner**
- **Chiller**
- **Pump**

b) Constant Mechanical Ventilation System

Figure 1. The system schematic of the target by ventilation methods

2.2 Constant Mechanical Ventilation Method

Non-stop usage of outside air for 24 hours, namely the constant mechanical ventilation system, is anticipated to bring significant changes to the indoor thermal atmosphere according to the air temperature in the inter-season. Air cooling and heating will become overloaded and their capacities are likely to increase as well as increased energy consumption coming from running the fan. The
layout of the cooling and heating systems and the ventilation systems to be applied to the evaluation is as shown in Figure 1.

3. SIMULATION

3.1 Target Housing Building

A south-facing 33-P type (surface area 85.8 m²) apartment in Seoul with an RC-structure and stairs was selected as the target model house. The ceiling was set to 2.3m above the ground.

3.2 Simulation Configuration

(1) Target Building Requirements
The simulation input configuration is as shown in Table 1.

(2) Amount of required ventilation
In this research, based on the ventilation standards of new local apartment housings, the frequency of ventilation was configured so that it could be controlled by phase - High (1.0 ACH), Medium (0.7 ACH), and Low (0.5 ACH) - in order to satisfy the amount of required ventilation according to the indoor pollutant concentration in the mechanical ventilation mode of the hybrid ventilation method. High ventilation (1.0 ACH) was provided in the initial stages in order to promptly control the detected formaldehyde and then it was made to be toned down to Medium (0.7 ACH) then to Low (0.5 ACH).

(3) Natural ventilation window
The ventilation windows allow controlling the inflow and the amount of inflow of natural ventilation in the balcony area and air is naturally ventilated through the ventilation window in the kitchen.

(4) Door Louver
Door louvers that protect the privacy of the resident and induce ventilation during the natural ventilation were used. The surface area of the door louvers was set to 0.18 m² (0.3m × 0.6m), a size that allows enough ventilation even with closed doors.

(5) Cooling and heating devices
The cooling and heating system of the target of evaluation was configured to handle the amount of overloading obtained from the TRNSYS simulation result. A 15-pyeong PAC (Package Air Condition) and a 6-pyeong RAC (Room Air Conditioner) commonly used in local apartment housings were used and their features are listed in Table 2. A typical boiler was applied for the heating system.

(6) Cooling Coil
Cooling coil was designed to reduce the indoor ventilation overloading in summers (TAC2.5%). The coil capacity was obtained by considering the safety and the latent heat and the current heat to satisfy the optimum room temperature during ventilation (26℃).

According to the calculation based on the cooling coil capacity with changing ventilation rate, 265.1kcal/h of coil capacity is required for minimal ventilation 0.5ACH to reduce outside air overloading in summers, 397.7kcal/h for 0.75 ACH, and 530.3kcal/h for 1.0ACH.

(7) Balancing Point Temperature
Ventilation in winter significantly affects room temperatures hence Balancing Point Temperature, which is defined as the outside temperature that could possibly enter the room, was calculated. Based on the simulation results, outside temperatures of 8.0℃ and 12.3℃ prevented from cooling overloading and heating overloading, respectively.

(8) System Control
The first priority of the control for this research is to control the indoor ventilation amount in order to reduce the indoor pollutant concentration, and then to control the indoor thermal atmosphere using cooling and heating systems. The performance of the hybrid ventilation system was evaluated by examining the amount of energy consumed to satisfy the indoor thermal atmosphere and the indoor ventilation atmosphere.
4. ANALYSIS OF EVALUATION RESULTS

Figure 2 shows the energy consumption rate by different system parts and by different ventilation methods during heating and cooling.

Due to the preheating in the balcony area, the hybrid ventilation system used approximately 40% less energy than that of the constant mechanical ventilation system and their cooling energy consumptions were almost identical.

The constant mechanical system used 7 times the ventilation fan energy of the hybrid ventilation system.

Figure 3 and 4 shows the amount of energy consumed in cooling and heating. During the heating period, the hybrid ventilation system and the constant mechanical system each showed heating energies of 4,801 kWh and 8,072 kWh respectively and the hybrid ventilation system was able to reduce the energy consumption of constant mechanical ventilation system by 60%.

In July and August, the hybrid ventilation marked 484 kWh and 593 kWh cooling energy respectively whereas the constant mechanical showed 488 kWh and 660 kWh. Although the additional fan coils are used in the hybrid ventilation system for cooling, the effect of natural ventilation compensates for the coils thereby having lower cooling energy consumption than that of the constant ventilation system.
Figure 2. Energy consumption by ventilation methods

Figure 3. Monthly energy consumption by ventilation methods

Figure 4. Total cooling and heating energy consumption by ventilation methods
However, the hybrid ventilation consumed more cooling energy than the constant mechanical method, 71 kWh in June and 39 kWh in September. Such result can be attributed to the simultaneous operation of the cooler and the fan coil, causing cooling overloading in June and September.

During the cooling period, the hybrid ventilation method consumed 1,370 kWh of cooling energy and the constant mechanical method used 1,328 kWh of cooling energy, thereby the latter method showing 3% energy conservation compared to the prior.

As for the ventilation in apartment housings, the hybrid ventilation method can potentially save up to 86% of the energy consumed by the constant ventilation system.

Comparing the overall cooling and heating ventilation energies of two ventilation methods, the hybrid ventilation method used 6,253 kWh and the constant mechanical ventilation method used 10,004 kWh, so the hybrid ventilation method was able to conserve about 37% of the energy consumption.

5. CONCLUSIONS

In this research, the performance of the hybrid ventilation system was evaluated considering energy consumption of 33-P type apartment housing.

The results of the research are as follows.

In terms of energy consumption, the hybrid ventilation method conserved about 60% of the heating energy used by the constant mechanical ventilation method and the constant mechanical ventilation method conserved about 3% of the cooling energy used by the hybrid ventilation method.

As for ventilation, the hybrid ventilation method was able to reduce about 86% of the energy consumed by the constant mechanical ventilation method.

The cooling and heating energy of the hybrid ventilation method was 6,253 kWh whereas it was 10,004 kWh for the constant mechanical ventilation system. Thus, the hybrid ventilation method using balcony space can conserve about 37% of the energy used by the constant mechanical ventilation.

Therefore applying the hybrid ventilation method using balcony space in apartment housings will not only create a comforting atmosphere but also reduce the cooling and heating energy consumption compared to the constant mechanical ventilation.

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