STUDY ON ENERGY CONSERVATION EFFECT OF HYBRID VENTILATION SYSTEM UTILIZING WIND PRESSURE FOR MULTI-FAMILY BUILDINGS

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ABSTRACT

According to the R&D Project on Low Energy Housing with Validated Efficiency, the CO_2 emissions due to operation of ventilation systems are estimated to be 7 to 12% of total CO_2 emissions of a unit of multi-family buildings in mild climate regions of Japan. Using network model calculations, CO_2 emissions of a hybrid ventilation system using Natural Ventilation Openings and other ventilation systems were estimated. The input power needed by the ventilation system can be reduced by 79 % when it employs the hybrid ventilation system compared with when it employs the balanced ventilation system. The hybrid ventilation system features not only sufficient ventilation performance, which is estimated by using the Overall Supply Rate Fulfilment index, but also reduced power input.

KEYWORDS

Hybrid ventilation, Multi-family buildings, Energy conservation, CO_2 emissions

INTRODUCTION

It is required under the Kyoto Protocols to reduce greenhouse gas emissions by 6% from the 1990 level for Japan between 2008 and 2012. However, in 2002, CO_2 emissions from housing use increased by as much as 28.8% from the 1990 level. In addition, since July 2003, the amended Japanese Building Standard Law has required whole house mechanical ventilation systems for new dwellings to improve indoor air quality. Hence, reducing energy consumption of housing use including whole house ventilation systems has been an important issue in Japan. Therefore, this paper is intended to estimate CO_2 emissions of whole house ventilation systems, especially hybrid ventilation systems utilizing wind pressure, installed in a unit of multi-family buildings with sufficient ventilation performance.

The R&D Project of Low Energy Housing with Validated Efficiency

MLIT (Ministry of Land, Infrastructure and Transport), NILIM (National Institute for Land and Infrastructure Management) and BRI (Building Research Institute) have carried out the R&D Project of Low Energy Housing with Validated Efficiency (LEHVE) to reduce CO_2 emissions from dwellings. In the LEHVE project, two units in a test multi-family building, which were called the Reference unit and Energy Conservation unit respectively, were utilized for estimating CO_2 emissions. The Reference unit employs typical equipments, consumer electronics and thermal insulation material, which is based on the Japanese Energy

Conservation Standard of 1999. At the same time, the Energy conservation unit has better heat insulation properties, the latest energy efficient equipments and consumer electronics. Both of the units employ identical whole house ventilation systems, which are balanced ventilation with heat recovery, to set the same ventilation aspects and same ventilation loads. Experimental results of CO_2 emissions of the two units are shown in Figure 1. The CO_2 emissions of the ventilation system are estimated to be 7 % to 12 % of total CO_2 emissions in mild climate regions of Japan. It is expected that energy conservation methods on whole house ventilation systems have a definite effect for reducing CO_2 emissions of multi-family buildings.

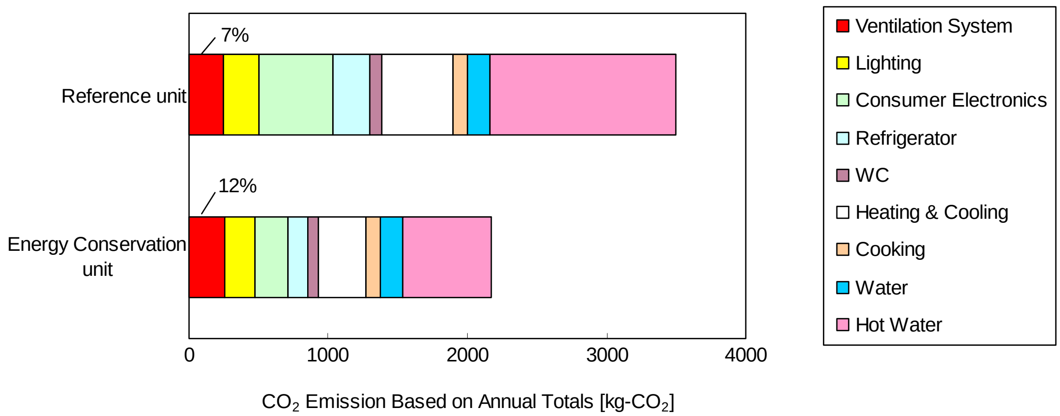


Figure 1: CO_2 emissions based on annual totals in Tsukuba city (mild climate region in Japan)

METHODS

Natural Ventilation Opening

A Natural Ventilation Opening utilizing wind pressure, which employs a constant air flow damper, is shown in Figure 2. The opening limits inflow with the damper when the pressure difference is larger than 8 Pa. This opening was used as a component of a hybrid ventilation system for simulations. The ΔP-Q characteristic of the opening was measured on a test chamber. Furthermore, by tracer gas measurement, ventilation performance and total ventilation rates were estimated by installing the natural ventilation openings on a full scale unit model, which was built outdoors. Therefore, the performance of this opening was certified in actual conditions.

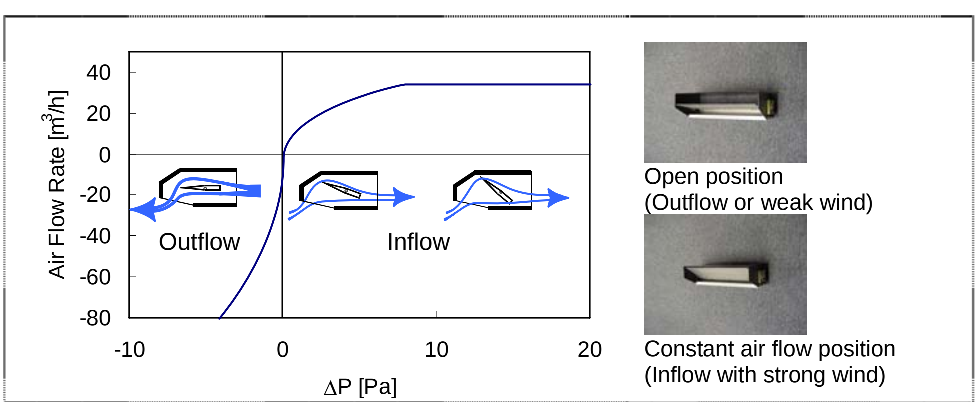
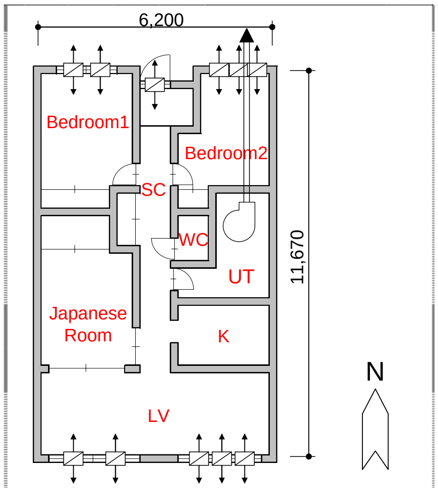
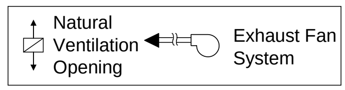


Figure 2: ΔP-Q characteristics of "Natural Ventilation Opening"

Network Model Simulation

Figure 3 shows a model of a typical unit of multi-family buildings, which were simulated by a network model VENTSIM. This unit employs a hybrid ventilation system with a typical exhaust fan system and the Natural Ventilation Openings. The Standard Expanded AMeDAS (Automated Meteorological Data Acquisition System) weather data of Tokyo and Cp distribution data of multi-family buildings (shown in Table 1), which were collected by wind tunnel measurements, were given for simulations. Fresh air supply rate and ventilation performances based on the Supply Rate Fulfilment index were calculated as outputs. Simulation cases are shown in Table 2.





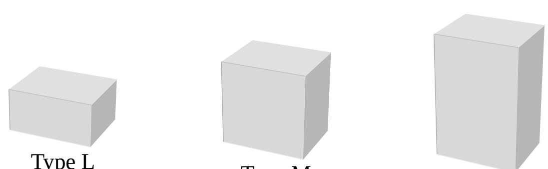
Required fresh air supply rate P_i of each zone

Zone	P_i
LV + Japanese Room + K	50 m^3/h
Bedroom 1	20 m^3/h
Bedroom 2	20 m^3/h

Applying to Japanese Energy Conservation Standards of 1999

Figure 3: Model of unit for simulation

Table1: Scale models of multi-family buildings for wind tunnel testing



Type L	Type M	Type H	
H: 15m (5-Storey)	H: 30m (10-Storey)	H: 45m (15-Storey)	W: 30m D: 15m Terrain: Urban or City (Coefficient = 0.27)

Table 2: Simulation

CASE 01	Exhaust ventilation
CASE 02	Natural ventilation (utilizing only wind pressure)
CASE 03	Hybrid ventilation

Ventilation Performance Terminology

The SRF index was used to evaluate ventilation performance. This terminology is based on the theory of conservation law of fresh air rate. The index is given by Eqn.1 and defined as the ratio of the effective supply rate S_i (Eqn.3) to the substantial required fresh air supply rate P_i'. The SRF value ranges from 0 to 1 and SRF=1 means the referenced room has sufficient effective fresh supply air rate compared to P_i'. S_i and P_i' are calculated by using α_i (surplus fresh air supply rate of the zone i, which is obtained by solving Eqn.2 or Eqn.2'). α_i can be calculated when all airflow rates among zones in a building are known. The maximum value of α_i, 1.0 represents purely fresh air like outside air, and a negative value means there is no fresh air. The Overall Supply Rate Fulfilment (OSRF) is defined as the geometric mean of SRF values of rooms as shown in Eqn.4.

$$SRF_i = \frac{S_i}{P_i - \sum_{j=1}^{n} \min(0\,,\,\alpha_j Q_{ij})} = \frac{S_i}{P_i'} \quad (1)$$

Steady condition

$$0 = A_i + \sum_{j=1}^{n} \alpha_j \cdot Q_{ij} - \alpha_i \left(\sum_{j=1}^{n} Q_{ji} + B \right)_i - P_i \quad (2)$$

Transient condition

$$\frac{d\alpha_i}{dt} V_i = A_i + \sum_{j=1}^{n} \alpha_j \cdot Q_{ij} \alpha_i \left(\sum_{j=1}^{n} Q_{ji} + B \right) - P_i \quad (2)'$$

$$S_i = A_i + \sum_{j=1}^{n} \max(0, \alpha_j \cdot Q_{ij}) - \sum_{j=1}^{n} \max(0, \alpha_i \cdot Q_{ji}) - \max(0, \alpha_i \cdot B_i) \quad (3)$$

$$OSRF \equiv (SRF_1 \times SRF_2 \times \cdots \times SRF_M)^{1/M} \quad (4)$$

where

- A_i direct fresh air supply rate, the rate of air that is supplied directly from outside to room i [m^3/h]
- B_i rate of air exhausted directly to the outside from room i [m^3/h]
- M number of rooms for which the required fresh air supply rate is specified
- P_i required fresh air supply rate for room i [m^3/h]
- P_i' substantial required fresh air supply rate of room i [m^3/h]
- Q_{ij} transferred airflow rate, rate of air flowing from room j to room i [m^3/h]
- S_i effective fresh air supply rate of room i [m^3/h]
- V_i air volume of room i [m^3]
- n number of rooms
- α_i surplus fresh air supply rate contained in the air exhausted from room i

RESULTS AND DISCUSSION

Ventilation performance

Relationships between OSRF and pressure differences between the north external wall and the south external wall are shown in Figure 4. Hybrid ventilation operation (CASE 03) uses an exhaust fan when wind pressure is less than 2 Pa and larger than -2 Pa, and gives better OSRF values than other ventilation operations. Annual OSRF of each case is shown in Figure 5. These OSRF values indicate this hybrid ventilation system provides sufficient ventilation performance.

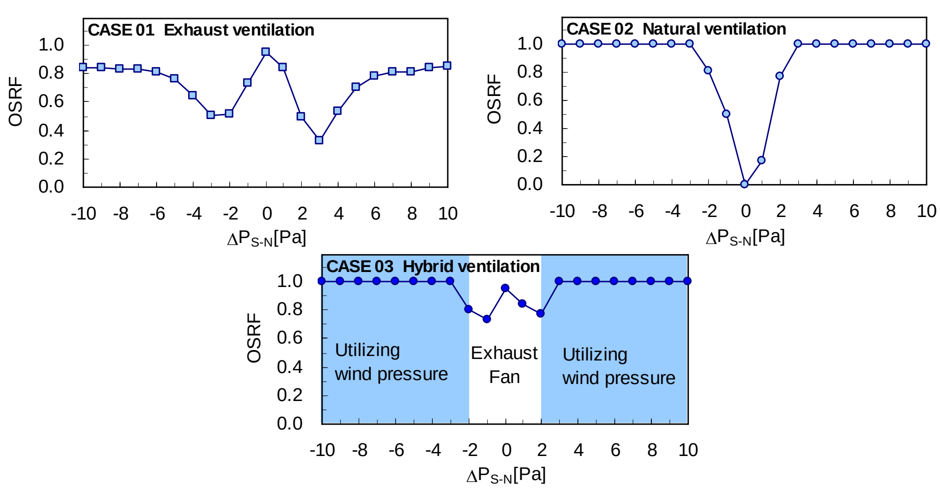


Figure 4: Relations between OSRF and wind pressure, which is based on the north external wall pressures

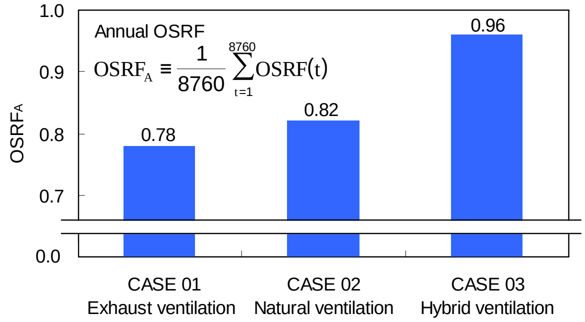


Figure 5: Calculated annual OSRF (Central Unit of 8th floor in TYPE-H)

Estimation of CO_2 emissions of Hybrid ventilation system

Annual percentages of multi-family buildings in Tokyo utilizing only wind pressure, which are based on results of CASE 03 in Figure 4, are shown in Figure 6. In Figure 6, the average percentages of available times are larger than 50%. Specifically, wind pressure can be utilized 70% of the time on many of the units in Type H. These results indicate the hybrid ventilation system features not only sufficiently ventilates but also reduces power input.

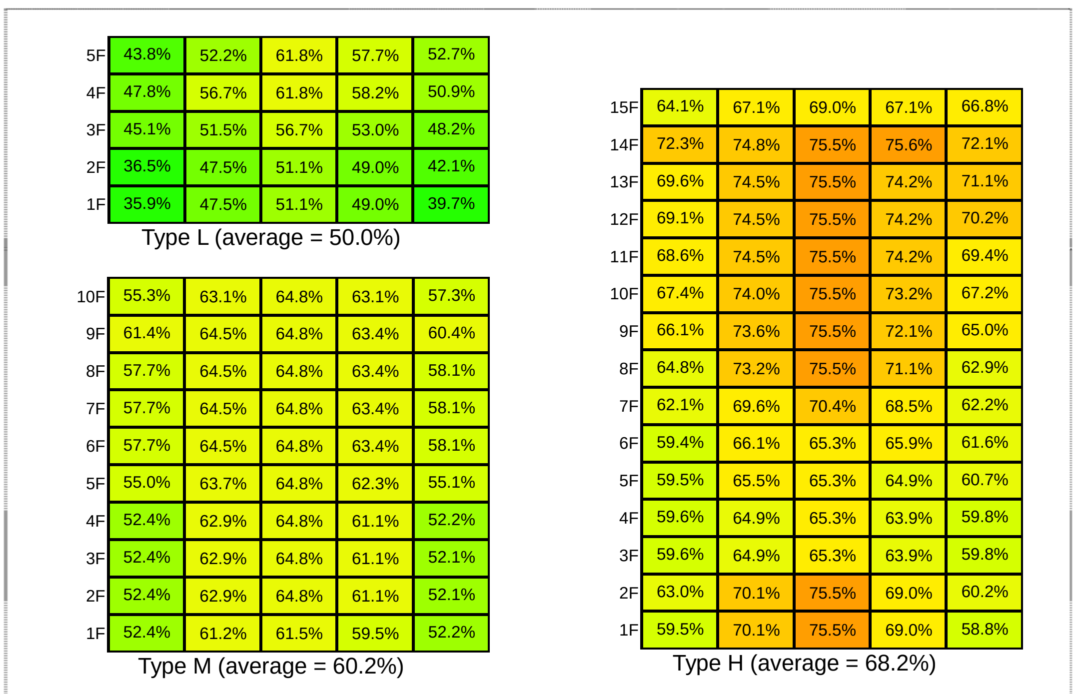
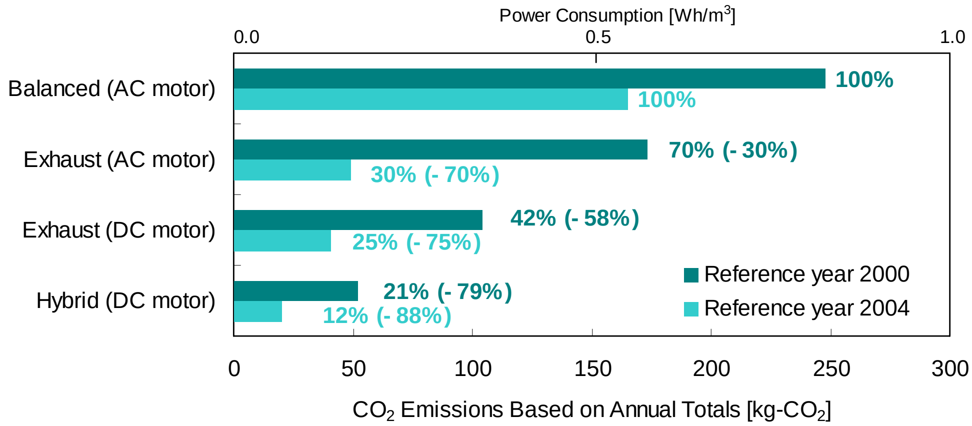


Figure 6: Annual available percentages of utilizing only wind pressure in multi-family buildings at Tokyo (SECTION)

Estimated CO_2 emissions and power consumption of ventilation systems are shown in Figure 7. These results are based on survey results of performance data of ventilation systems available in Japan. These data indicate that input power due to operation of a ventilation system can be reduced by 79 % when the hybrid ventilation system is employed compared with when the balanced ventilation system is employed, according to survey result in 2000. This means that the total CO_2 emissions on the Reference unit of LEHVE project will be reduced by 6%. Furthermore, on the Energy conservation unit, it will be reduced by 10%. In addition, input power reduction will be more efficient when the most up-to-date ventilation systems are employed, which were surveyed in 2004.



- Balanced ventilation: with heat recovery system
- Hybrid ventilation: installed in 5-storey building
- The number of samples were different between 2000 and 2004

Figure 7: Estimated CO_2 emissions of ventilation system

CONCLUSIONS

In the present study, CO_2 emissions of a hybrid ventilation system using Natural Ventilation Openings and other ventilation systems were estimated by network model simulations. From the result of R&D project of Low Energy Housing with Validated Efficiency, the CO_2 emissions due to operation of ventilation systems are estimated to be 7% to 12% of the total CO_2 emissions of a unit of multi-family buildings in mild climate regions of Japan. The input power of ventilation systems can be reduced by 79% when the hybrid ventilation system is employed compared with when the balanced ventilation system is employed. The hybrid ventilation system using the Natural Ventilation Openings features not only sufficient ventilation performance but also reduces power input. The hybrid ventilation system under conditions in an actual installation will be validated by measurements in future work.

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