PERFORMANCE STUDY ON HYBRID VENTILATION SYSTEM WITH AIR SUPPLY FROM CRAWL SPACE USING A TEST HOUSE

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ABSTRACT

Ventilation is one of the most important measures to dilute indoor air pollutants. In order to maintain a clean indoor air environment, not only the total ventilation rate of the building but also the distribution of outdoor air to each area must be taken into consideration. A performance evaluation of the combined system of air supply from the crawl space and hybrid exhaust ventilation with a small fan and damper has been investigated. This investigation was undertaken over a heating season using a full-scale test house. The ventilation airflow rate and the distribution to each room of the test house were measured by the constant concentration method. The influence of indoor-outdoor temperature difference on ventilation rate was also analyzed. Additionally, the performance of this system was investigated by numerical analysis. The results revealed the performance of this ventilation system.

KEYWORDS

Hybrid Ventilation System, Performance Evaluation, Airflow Distribution, Tracer Gas Measurement, Numerical Analysis, Full-Scale Test House

INTRODUCTION

Background

Nowadays, indoor air pollution in houses, caused by chemical substances, has become a major social problem. It firstly originates from building materials, furniture and housing facilities that contain polluting chemical substances. Secondly, the problem is made worse because improved building airtightness has resulted in a reduction in adventitious ventilation or natural air infiltration. This stimulates the problem to affect our daily lives. Conceivable measures against the former would be to avoid the use of chemical materials as much as possible and to vent chemical substances before moving into the residence[1)]. On the other hand, airtightness is now considered to be a common trend because of the social needs for energy conservation. The revised energy conservation standard for residential building[2)] stipulates that houses nationwide must be made airtight. Therefore, it is most important to ventilate rooms properly and to dilute pollutants to prevent indoor air pollution. Thus, the development of ventilation systems with good efficiency and their performance evaluation are important research subjects.

Purpose

The purpose of this study is to evaluate of the performance of a hybrid ventilation system with air supply from crawl space for residences. This research is based on the experiments carried out in a full-scale test house, located at Tohoku University, Japan, and the numerical simulation by COMIS model. The performance of a hybrid ventilation system with the air inlet mounted in the wall was investigated in previous studies (Yoshino et al. 2000, Liu et al. 2000).

Methods for Performance Evaluation

A ventilation rate, of 0.5 air changes/hr (ach) is required as prescribed in the energy conservation standard[3)] for Japanese residences. Since the volume of the test house is 163.9m^3, 0.5 ach corresponds to approximately 80m^3/h. The performance of this system was evaluated by using the following two criteria:

- Is the total outdoor air ventilation rate sufficient?
- Is the outdoor air distributed equally to the 1st floor and the 2nd floor rooms?

FULL-SCALE TEST HOUSE AND VENTILATION SYSTEM

Description of the Test House

The outlook of the full-scale test house is shown in Figure 1 and the floor plans are shown in Figure 2. The total floor area is 78.9m^2 and the volume of the house is 163.9m^3. The equivalent leakage area of the building envelope per unit floor area is about 2.65cm^2/m^2 (as determined by the fan pressurization method). An air-conditioning unit is installed in each room except for the hall areas. There are two internal doors between each room and the hall. Each internal door has two ventilation openings of 10cm ×10cm in size.

Figure 1: The full-scale test house

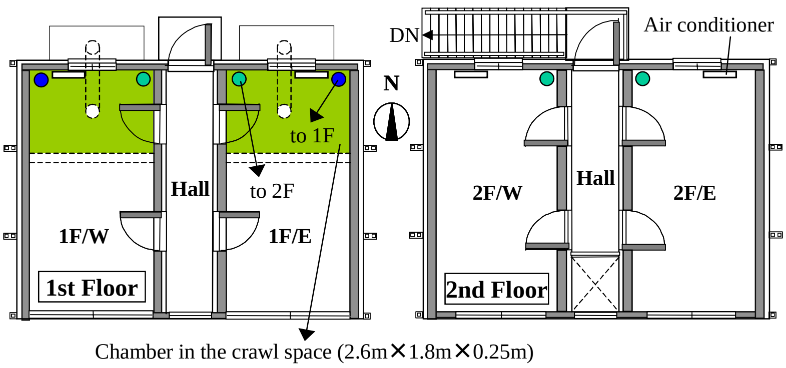

Figure 2: Floor plans of the full-scale test house

Ventilation System

The configuration of the investigated hybrid ventilation system is shown in Figure 3. The outside air comes through the ducts of 20cm diameter, which are embedded under the ground and are connected to a chamber of dimensions 2.6m×1.8m×0.25m located in the crawl space. Additional ducts of similar diameter are connected from this chamber to both the 1st floor and the 2nd floor. An electric heater is

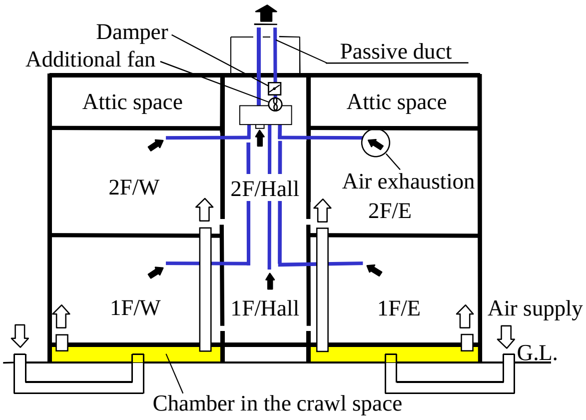

Figure 3: Crawl space supply and hybrid exhaust ventilation system

TABLE 1
Experimental conditions and periods

No.	Period	Heating in the crawl space chamber	Opening area of duct inlet		Indoor temperature (℃)
			1F	2F	
1	01.1.15～17	×	Fully open	Fully open	25
2	01.1.17～19	○			
3	00.12.16～18	×	1/6 open of original area		
4	00.12.29～30	○			

installed in the chamber to preheat the incoming air. Other ventilation features include a supplemental fan and a damper, which are incorporated into the exhaust passive duct of the hybrid ventilation system. These are controlled automatically according to the indoor-outdoor temperature difference. In this case, the fan capacity is 170m^3/h at the pressure of 18.62Pa and the electric power of 5W.

OUTLINE OF EXPERIMENTS

Experimental Conditions and Periods

Experimental conditions and periods are shown in Table 1. In each case, the outside air was supplied to each room via ducting from the crawl space. A mixing chamber in the crawl space was used to heat the incoming air. In Experiments No. 1 and No. 3, there is no heating in the chamber. In Experiments No. 2 and No. 4, the incoming air was heated to room temperature. In Experiments No.1 and No.2, the air inlets of the ducts from the crawl space were kept fully open. In Experiments No. 3and No. 4, the areas of the 1st floor duct inlets were reduced to 1/6 while the 2nd floor duct inlets remained fully open.

Measurement Method of Ventilation Airflow Rate and Air Distribution

The outdoor airflow rate distributed to each space for ventilation (i.e. the ventilation rate and the distribution of ventilation air between floors and rooms) was measured using the constant concentration tracer gas method in which SF_6 gas is used for the tracer. Gas injection was controlled so that the indoor SF_6 gas concentration should be maintained at 10ppm. The test equipment consisted of a B&K 1302 multi gas monitor and two B&K 1303 multipoint sampler and dosers.

RESULTS OF EXPERIMENTS

Relationship between Ventilation Rate and Inside Temperature of Chamber in the Crawl Space

Figure 4 shows the temperature profile at the outlet of the chamber installed on the 1st floor and the airflow distribution to each room for Experiment Nos. 1 and 2. The results for Experiment No 1 are shown to the left of the dotted line and the results for Experiment No 2 are to the right of the line. The air distribution to the 1st floor rooms is high when no heating is applied (i.e. Experiment No.1). When the heater in the chamber was turned on (Experiment No.2), the air distribution to the 1st floor decreased gradually while the air distribution to the 2nd floor rooms increased. When the temperature in the chamber was close to the room temperature of 25°C, the distribution of air to the 1st floor and 2nd floors were almost the reverse of the unheated case. When the temperature in the chamber was at 17°C, the air distribution supplied to each room was almost equal.

Ventilation Rate and Distribution

The results are summarized in Figure 5. The total ventilation rate considerably exceeded 80m^3/h in all cases. The distribution of outdoor air to each room in each case is discussed as follows:

- **Experiment No.1:** The outdoor airflow rate to the 2nd floor was very low. This is because the length of supply duct is long and the airflow resistance of the supply duct is large in comparison with that to the 1st floor.
- **Experiment No.2:** In this experiment, the outdoor air entering the crawl space chamber was heated. The amount of outdoor air supplied to the 2nd floor became large, and that to the 1st floor decreased considerably. This is because the stack effect due to the heated supply air to the 2nd floor became greater.
- **Experiment No.3:** The opening area of the duct inlet on the 1st floor was reduced to 1/6 of the original area. As a result, the outdoor airflow rate to the 2nd floor increased in comparison with

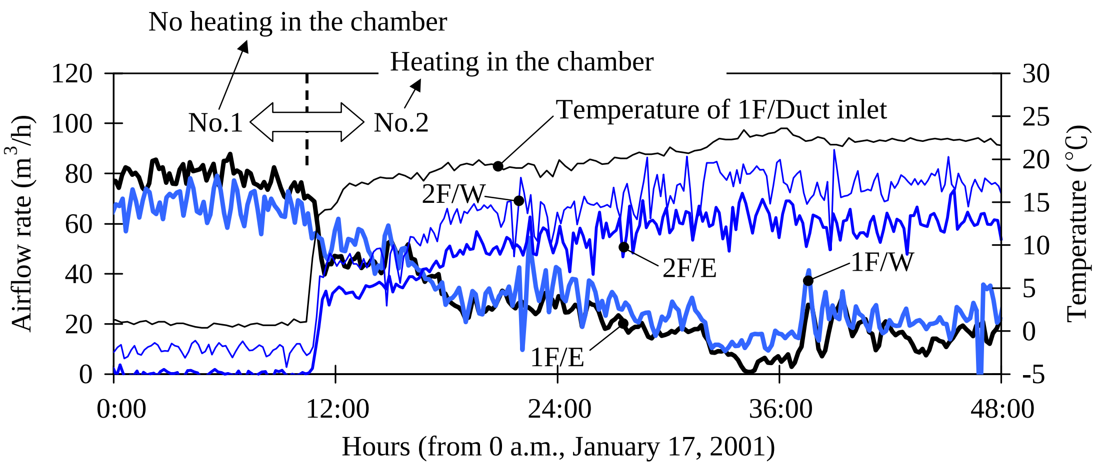

Figure 4: Relationship between airflow rate and inside temperature of the chamber in the crawl space

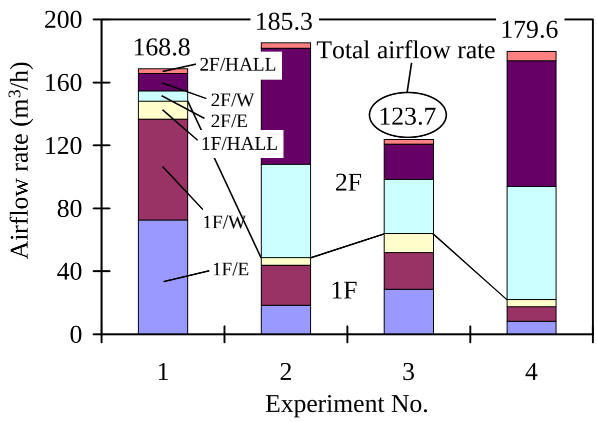

Figure 5: Airflow rate and its distribution

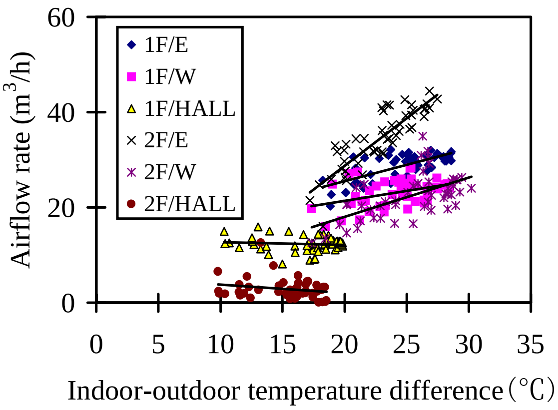

Figure 6: Relationship between airflow rate and temperature difference (No.3)

Experiment No.1 and became equal approximately to the 1st floor.

• **Experiment No.4:** The supply air was heated and the opening area of the duct inlet on the 1st floor was reduced to 1/6 of the original opening area. The outdoor airflow rate to the 2nd floor was very high because of the stack effect. That of the 1st floor became lower than Experiment No.2 because the opening area of the duct inlet was reduced.

Influence of Indoor-Outdoor Temperature Difference

The outdoor airflow rate to each room increased in accordance with the increase of temperature difference, i.e. stack effect. But, the stack effect became smaller when the air resistance of supply duct increased. When the outdoor air entering the crawl space chamber was heated, the ventilation airflow rate to the 2nd floor increased because of the stack effect. In the Experiment No.3, which is shown in Figure 6, the outdoor airflow rate to all of the rooms increased because the supply resistance to all the rooms became almost the same by adjusting the opening area of the duct inlets on the 1st floor.

NUMERICAL ANALYSIS

Conditions of Calculations

The conditions of calculations are shown in Table 2. The test house was also used for the simulations. The opening area of the duct inlet on the 1st floor and the temperature in the crawl space chamber were

TABLE 2
Conditions of Calculations

Opening area of duct inlet		Temperature in the crawl space chamber(℃)	Indoor tempera-ture(℃)	Outdoor tempera-ture(℃)	Wind velocity (m/s)
1F	2F				
Fully open	Fully open	5,10,15,20,25	20	0	0
1/2 open of original area					
1/4 open of original area					
1/6 open of original area					

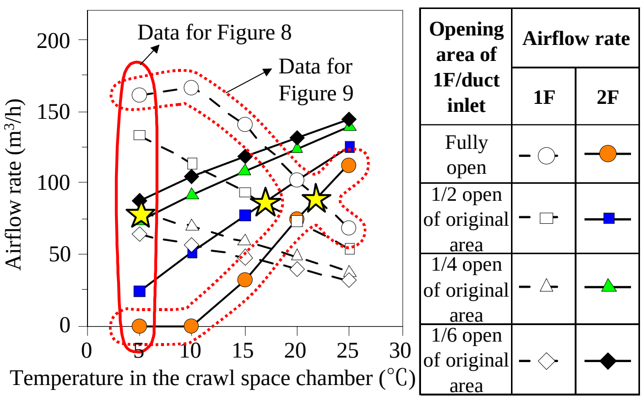

Figure 7: Results of simulations

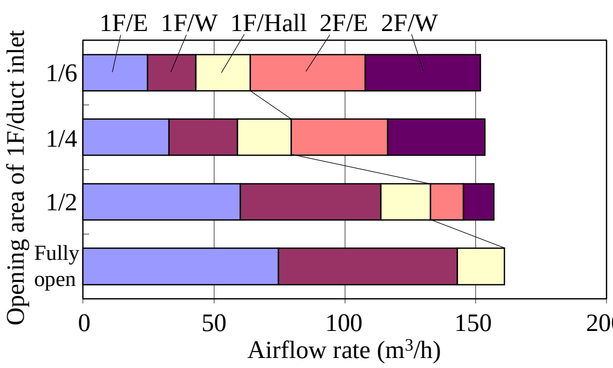

Figure 8: Influence of the opening area of the duct inlet on the 1st floor (temperature in the chamber: 5℃)

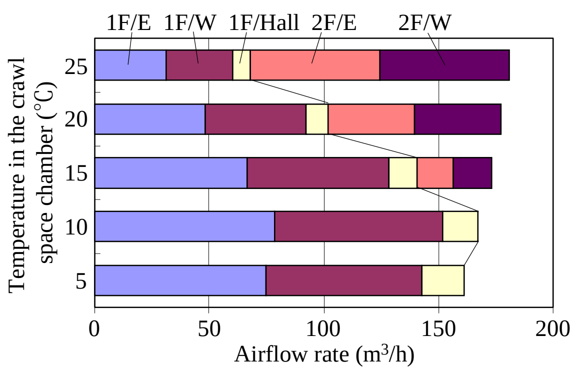

Figure 9: Influence of the temperature in the crawl space chamber (1F/duct inlet: fully open)

changed as calculation parameters. Their influences on the ventilation rate and distribution to each room were investigated.

Results of Simulations

The results of simulations are shown in Figures 7, 8 and 9. Figure 7 shows the whole results of simulation. Figure 8 shows the influence of the opening area of the duct inlet on the 1st floor. Figure 9 shows the influence of the temperature in the crawl space chamber. The star marks in Figure 7 mean the conditions in which the air distribution to each floor was almost equal between each room. In Figures 7 and 8, the air distribution to the 1st floor decreased in accordance with the decrease of the opening area of the duct inlet, and that to the 2nd floor increased. In Figures 7 and 9, when the temperature in the chamber became higher, the air distribution to the 1st floor decreased and that to the 2nd floor increased. In all the cases, the total ventilation rate considerably exceeded $80m^3/h$.

CONCLUSION

In this system, outdoor air could be supplied almost equally to all rooms by both adjusting the opening area of the supply air inlets and controlling the temperature to which the supply air is heated. This system could achieve sufficient ventilation without using the exhaust fan in the exhaust passive duct.

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FOOTNOTE

1) The method of heating indoors to expedite emission is called “Bake Out,” and its effects have begun to be studied in various fields. Nonetheless, it has not established itself as a technique. Air pollution of newly built houses disappears after the summer has passed. That is, it is believed that pollutants are emitted during summer like the Bake Out effect.
2) Judgment Standards for Builders Regarding the Rationalization of Energy Use for Houses; Notification No. 2 of the Ministry of International Trade and Industry and the Ministry of Construction, March 30, 1999
3) Institute for Building Environment and Energy Conservation, Energy Conservation Standard for Next Generation Residence, September 1, 2000

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