Mechanical Supply Only Ventilation System for Single Family House

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ABSTRACT

The Mechanical supply only (MSO) ventilation system has many advantages, such as good air distribution, easy pre-heating of cold fresh air supply and prevention of chemical aerosols intake through wall cavity. However, this system has not been used for dwellings because of the risk of the condensation in the wall. The recent developed extreme house building airtight technology makes it possible to use the MSO system for wooden single family houses. The target of this study is to evaluate the MSO system using the under floor cavity as supply chamber, combined with air filtering and pre heating of flesh air supply.

This paper shows the design outline of the MSO system developed for a Japanese conventional wooden single family house and the measurement results of ventilation characteristics and indoor thermal conditions of the experimental house built in Asahikawa Hokkaido. The indoor air quality is also discussed through the measurement results of 166 houses with the MSO system. As a result, this system has the possibility to realize the well-balanced air distribution and comfortable thermal condition. The concentrations of some chemical aerosols in the house are quite low also.

1. INTRODUCTION

We have been dealing with MSO system using cavity under the 2nd floor. Our previous study on the original MSO system indicates the well balanced air distribution and comfortable indoor thermal condition (Fukushima, 2001). Over 500 houses using this system have been built in 5 years. To extend the system variation, the basement is also used as a supply chamber for the MSO system on this experimental study. As for measurement of ventilation characteristics and indoor thermal condition, the experimental house is the subject of this study. About the indoor air quality, the concentrations of some chemical aerosols were measured in 166 houses with original MSO system built in recent 2 years.

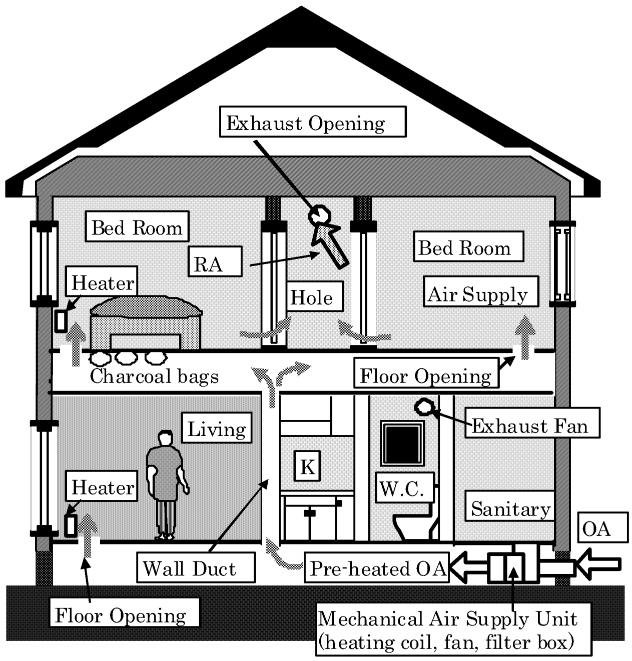


Figure 1 Mechanical Supply Only System (MSO)

2. VENTILATION SYSTEM

Figure 1 shows the outline of the developed MSO system using cavity under the floor as fresh air supply chamber. The developed Mechanical air supply units installed in the basement takes in outdoor air (OA) through filter box with high efficiency particulate air (HEPA) filter, and make it warm up. Then the pre-heated clean OA is supplied to the basement and flows to every rooms through wall duct and floor openings.

The Mechanical Air Supply Units shown in Figure 2 has large filter box with HEPA filter and insects net, the fan unit with high efficiency by using DC motor and heating coil for pre-heating. The heating coil is possible to rise the temperature of 250m^3/h air up to around 20degrees.

The filer box has large opening for cleaning on the upper side for easy maintenance. According to the questionary survey to the house holders of 152 houses using this unit, the only 2 house holders have not clean up the filter box in recent 1 year. The rate of houses without cleaning for over 1 year is extremely low compare to our previous study on the maintenance of the houses adapted conventional mechanical supply and exhaust (MSE) ventilation system. Most of all the mechanical ventilation systems for dwellings are installed as being maintained from the ceiling in Japan. That is one of the key reasons why the ventilation unit usually has not been maintained. The developed ventilation unit is expected to make house holders have a habit of cleaning ventilation unit.

3. THE EXPERIMNTAL HOUSE

Figure 3 shows floor plan of the experimental house, which is a 2 story-house with basement. The house is located in the residential area in Asahikawa one of the coldest cities in Japan. Specifications of experimental house are as follows,

- Total floor area: 129 m^2
- Required ventilation rate: 130m^3/h
- Air tight performance:
  Equivalent opening area 0.77cm^2/m^2
  1.56ach/50Pa
- Thermal performance: 1.53W/ m^{2}K

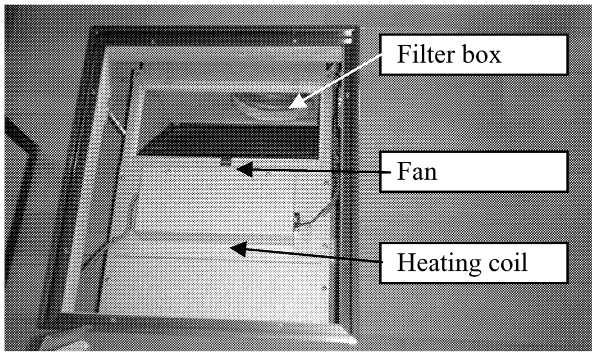


Figure 2 Mechanical Air Supply Units

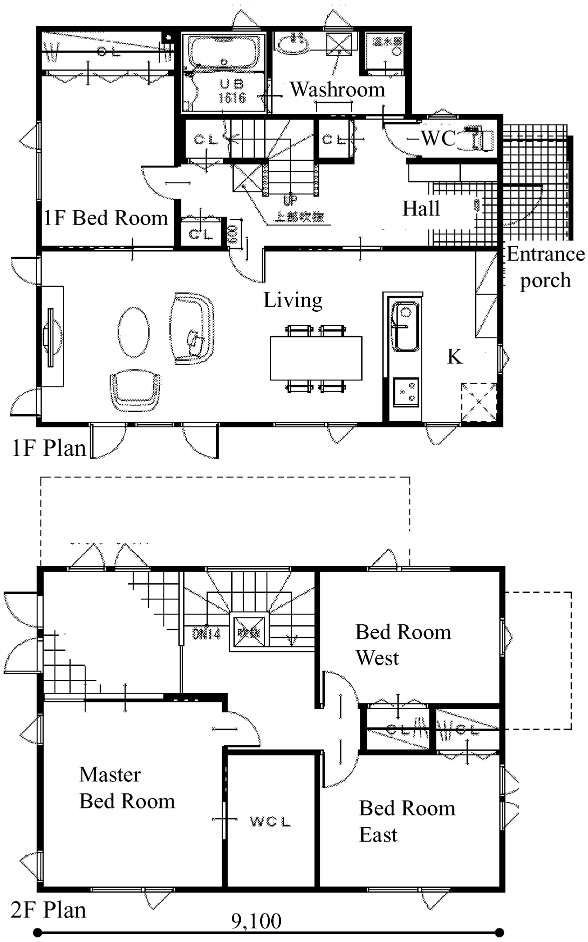


Figure 3 Experimental house

Table1 Air tight test results

Condition: Seal of the natural exhaust opening, the floor openings, the fans,	Equivalent opening area [cm^2]
Seal all[wall performance]	113.9
Open the floor openings	121.1
Open the natural exhaust opening and the floor openings	160.8
Open all	189.1

4. MEASURMENT and DISCUSSION

4.1 Measurement method of air flow rates

The constant concentration method using CO_2 as tracer gas was used for measuring the airflow rates of the rooms. Figure 4 shows the CO_2 variation. There is rather wide difference among rooms. However, fresh air is forced to be supplied to each room and there is no mutual convection between the rooms on MSO system. Since the CO_2 concentrations of each room are stabilized, air flow rate of the room is calculated by the following equation.

$$Q=W/C \quad (1)$$

Where:
Q: Air flow rate (m^3/h)
W: CO_2 injection (m^3/h)
C: CO_2 concentration (m^3/m^3)

The air flow rate of mechanical fan was measured by airflow measuring device using a hot wire probe. The forced supply air volume is $220m^3/h$ on high, $105m^3/h$ on low. In order to simulate the mechanical supply and exhaust system, wall fan was attached to vent opening for natural exhaust of MSO system. The air flow rate of that fan operating is around $110m^3/h$.

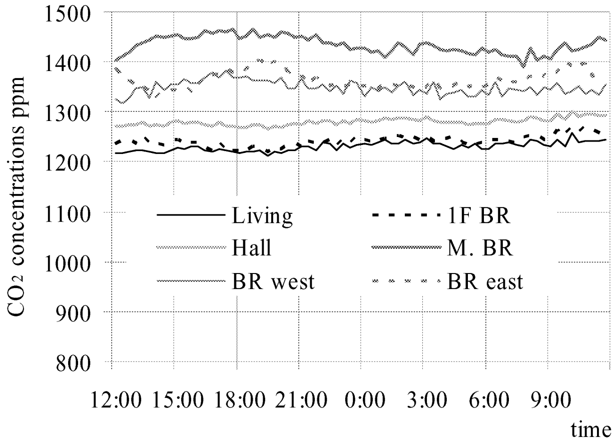


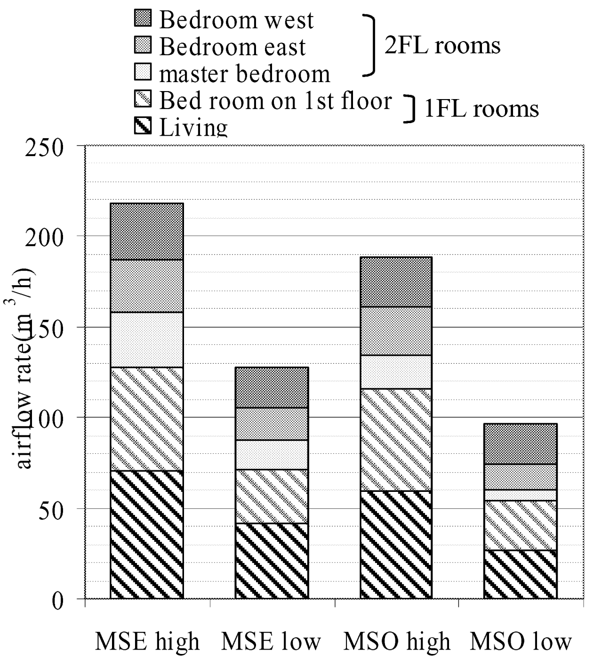
Figure 4 Measurment result of CO_2 concentrations

The air flow rate was measured at following 4 patterns; MSE high and low, MSO high and low. On MSE high pattern, only the supply fan was on high.

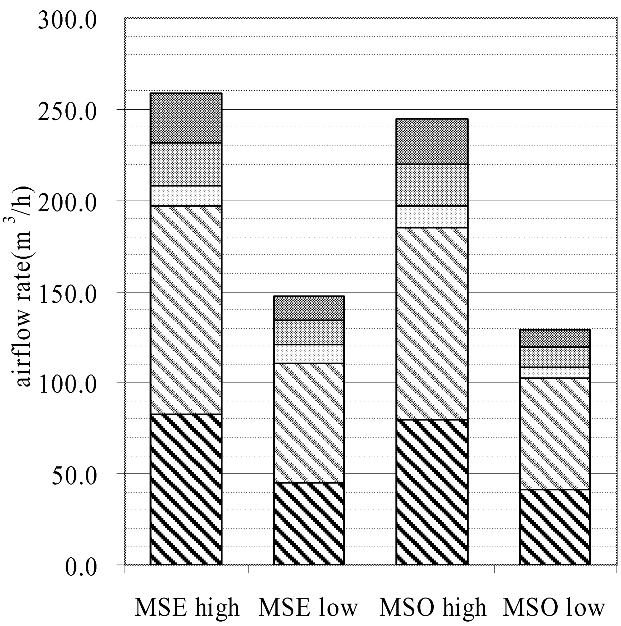
4.2 Ventilation characteristics

4.2.1 Airflow rate on summer condition

Figure 5-a shows the measurement results of the airflow rate on summer condition. The total airflow rate is different but the airflow balance is well and almost same on MES and MSO. The



a. Airflow rate on summer condition



b. Airflow rate on winter condition

Fig.5 Measured air flow rate

total air flow rate on MSO pattern is same as the air flow rate of mechanical air supply unit on both of on high and on low. It suggests that there is no infiltration on MSO system. The certain amount of indoor chemical aerosol is supplied from the inside of the wall with an air infiltration (Hayashi, 2004). So the MSO system is expected to avoid air infiltration through wall cavity and is efficient to lower the indoor chemical aerosol concentration.

On the MSE pattern, the total air flow rate is 10-20% higher than the air flow rate of the mechanical air supply unit on both of on high and on low. The difference of air flow rate is expected to be an air infiltration.

4.2.2 Airflow rate on winter condition

Figure 5-b shows the air flow rate measured on winter condition. The total air flow rate increases 30% comparing to the measurement result on summer condition. The balance of air flow rate of each room changes widely also. The ratio of fresh air intake to the total airflow rate increase 30% on 1FL room and decrease 30% on 2FL room. This is supposed to be caused by stack effect. It is important to determine the size of floor opening correctly for well-balanced fresh air supply.

The total air flow rate is 130m^3/h, which is 30m^3/h greater than on summer condition. This almost fulfilled the required air flow rate. And the air flow rates of the rooms also cover 0.5ach except master bed room. As the result, MSO system should be controlled on high in summer and on low in winter.

The reason why air flow rate of the master bed room is not sufficient is that the beams constructing the 2nd floor are larger than the planed those. It is important to construct the house according to the original construction plan.

Figure 6 shows the airflow rate when the size of floor opening of the 1FL rooms was half. The air flow balance became same as that on summer condition. In order to realize well balanced air distribution on MSO system using basement as fresh air supply chamber, the floor vent opening have to be determined according to the different criteria from the system using only under floor cavity of 2nd floor.

4.3 Thermal condition in winter

Figure 7 shows the temperature variation in the living room on very cold days. The vertical indoor temperature difference is 3-4deg. It is wider than that of houses with original MSO system. The better thermal performance of the house is, the lower the heating water temperature is controlled. The heating coil cannot supply enough heat when the heating water temperature is lower than the design value. To avoid low temperature in the basement, heating water temperature has to be kept higher.

Figure 6 Air flow rate when floor opening of 1FL is half

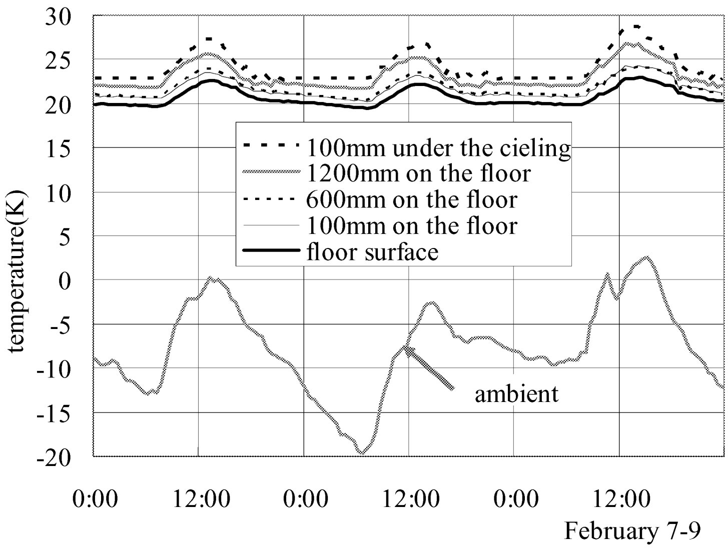


Figure 7 Temperature variations in the living room

4.4 Pressure difference at the top ceiling

To evaluate the influence of the MSO system to the air ex-filtration, the pressure difference between 2nd floor ceiling and attic was measured on the winter condition; indoor and outdoor temperature difference was around 24deg. It was 6 o'clock in the morning 23/03/2008. Table 2 shows the measurement results. The pressure difference calculated by the following equation is around 3Pa on the balanced condition.

$$\triangle P=(ro-ri)\times h\times 9.8 \quad (2)$$

where:

$\triangle P$: Pressure difference at the top ceiling (Pa)
ro: Outdoor air density (kg/m^3)
ri: Indoor air density (kg/m^3)
h : Distance from balanced height (2.6m)

It is same as the pressure difference on MSE on low. So the MSE system on low is shown to be a balanced system. The MSO system has natural exhaust opening near the top ceiling for reducing the pressure difference. As a result, the increase of pressure difference between the top ceiling and the attic on the MSO system compare to that on the MSE system is only 2Pa. Since the most of all houses with this system have high air tight performance, the effect of indoor air ex-filtration is limited.

Table 2 Pressure difference at top ceiling

condition		Pressure difference(Pa)
MSO	On low	5
	On high	9
MSE	On low	3
	On high	7

indoor 22K, ambient -2K

5. Indoor air quality

The indoor chemical aerosol concentration was measured in 166 houses with the MSO system shortly after completion by the active sampling method. Figure 8 shows the measurement results of formaldehyde concentration. The average value is 0.008ppm, and it is around 1/10 of the official guideline value. Formaldehyde

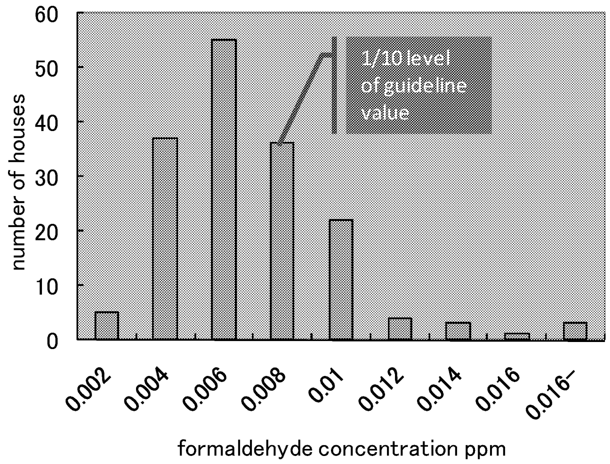


Fig. 8 formaldehyde concentration of 166 houses
0.06ppm is the maximum

Table 3 average concentrations of 5 chemicals

Chemical	Formaldehyde	Toluene	xylen	ethyl benzene	styrene
Measured(M)	0.0069	0.005	0.003	0.0024	0.001
Guideline(G)	0.08	0.07	0.2	0.88	0.05
M/G	0.086	0.071	0.015	0.0027	0.02

concentrations of 163 houses are under 0.016ppm which is 1/5 of official guideline value. The maximum value is 0.06ppm.

The table 3 shows the average values of measured 5 chemical aerosols concentration. The average values were 1/10-1/400 of official guideline value. Neither concentration exceeds official guideline value in all houses.

The measurement results of 166 houses show that the quit low comical indoor air is realized in those houses.

6. CONCLUSIONS

The airflow rates and thermal condition were measured in the experimental house with MSO system using basement and under floor cavity of 2nd floor as fresh air supply chamber in Asahikawa by the constant concentration method using CO_2 as tracer gas. And the indoor chemical aerosol concentration was measured in 166 houses with the original MSO system.

As results,

– The balance of fresh air supply is sufficient on summer condition, but not on winter condition because of stack effect. The fresh air supply to the 1FL rooms increased and it was decreased to the 2FL rooms on winter condition.

- The airflow balance was improved by making floor vent opening of the 1FL rooms half on winter condition.
- The temperature near the floor was 3-4 degrees lower than that on the central position of the living room. When the heating water temperature is lower than the design value, heating unit cannot raise the supply air to the design temperature in mid winter.
- The measurement results of indoor air quality show that the concentrations of all chemical aerosols are extremely low compare to the official guideline value.

According to this study, we are making building and system design manual for constructing the single family house with MSO ventilation system. The subjects to be considered for planning MSO system of a single family house are as follows.

- The place and the size of outlet opening should be designed for preventing increase of air ex-filtration to the wall insulation layer causing condensation problem. High airtight house building technology is indispensable at the same time.
- The volume of under floor cavity has to be included to the indoor total volume for the ventilation system design according to the Japanese building standard law. Because the fresh air is supplied to rooms through the under floor cavity.
- The preheating performance of the fresh air supply has to be decided considering not only outdoor climate but also the thermal performance of the house and heating system. The preheating performance is sometime insufficient in the well insulated house, because the higher the thermal performance of the house is, the lower the heating water temperature tends to be controlled.

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