Study on Performance Evaluation of Mechanical Ventilation Systems for Occupied Houses

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ABSTRACT

In the first phase of the current project, the ventilation rates of occupied houses in the northern region of Japan were investigated from 2001 to 2005. It was revealed that, despite installing mechanical ventilation system, low ventilation rate was found in many houses. The causes were believed attributing to lack of cleaning of grills, filters and insect protection meshes. The second phase of the project was to investigate the causes and resolve the problems. This project was started in 2005 and 12 houses installed with mechanical ventilation system were investigated. The investigation included measurement of airflow rates at inlet/outlet by using airflow meter, observation of dust conditions in filters and questionnaire survey about the condition of usage and maintenance of the ventilation system. This study found that some of the ventilation systems were not properly operated and airflow rates were insufficient in almost all houses because the dust was accumulated on the filters as airflow rate at inlet/outlet increased after the filter was cleaned. Only very few occupants cleaned the filters regularly as reported in questionnaire survey. The investigation confirmed that airflow meter is a convenient and efficient method to measure airflow rate, particularly for the occupied house. It is thus recommended that periodic measurement using airflow meter should be carried out to monitor the airflow rate.

KEYWORDS

Ventilation rate, Mechanical ventilation, Airflow meter, Maintenance, Filter, Field survey

INTRODUCTION

Newly constructed houses in Japan, especially in the northern region, have become more and more airtight as well as highly insulated. It is because the demand for thermal comfort and necessity of conserving energy. However, such houses caused many issues of residents suffering health problems due to low ventilation rate. To resolve this problem, Japanese Building Standard was revised in 2003. The revised standard prescribes that residential buildings installed with mechanical ventilation system must have minimum of 0.5 air change per hour (ACH).

The purpose of this study is to investigate the actual performance of ventilation and the cause of low ventilation rate in occupied houses in the northern region of Japan. The investigation included measurement of airflow rate at inlet/outlet by using airflow meter, observation of dust conditions in filters and questionnaire survey for occupants about the condition of usage and maintenance of the ventilation system.

OUTLINE OF INVESTIGATION

First Phase of the Investigation

In the first phase of this project, the actual ventilation rates of 27 houses (See Figure 2) were investigated in the Tohoku district, which is situated in the northern region of Japan. Measurements of Houses 2, 4, 5, 7, 8, 9, 11 and 12 were performed more than once. The airflow meter manufactured by Kona Sapporo Co. (Figure 1) was used to measure the airflow rate through inlet/outlet for the investigated houses. The airflow rate at the inlet/outlet was measured for 10 seconds after the conditions became steady. During the measurement, the windows and doors were closed.

Second Phase of the Investigation

In spite of installing mechanical ventilation system, it was found that low ventilation rates were observed in many houses. The causes were believed attributing to unclean grills, filters and insect protection meshes. In order to investigate the causes and resolve the problems, as the second phase of the project, this study was started in 2005, to examine 12 houses installed with mechanical ventilation system. Table 1 summarizes the characteristics of these houses. The measurements were carried out from August to October in 2005. All these houses were detached type. Houses A to G, I and J were constructed after the Japanese Building Standard was revised. Forced supply and exhaust ventilation system with a heat exchanger was installed in 9 houses (A to H and L), while the other 3 houses (I, J and K) equipped with forced exhaust system. The air-tightness was measured, using the depressurization method by an air-tightness-measuring device (Kona Sapporo Co.). All houses achieved the target value of 5.0 cm^2/m^2 prescribed by the Energy Conservation Standard for Next Generation Residence in Japan (Institute for Building Environment and Energy Conservation (1999)). The air-tightness of Houses A to J was lower than 1.0 cm^2/m^2.

Table 1. Caracteristics of 12 houses investigated (2nd phase)

ID	House Type	Ventilation System	Total Floor Area [m^2]	Date of completion (year. month)	Air tightness [cm^2/m^2]*4	Date of measurement (year. month)	Temperature difference [℃] (indoor-outdoor)*5	Outdoor wind velocity [m/s]*6
A	detached	S&E *1	154.7	'04.11	0.6	'05.10	0.8	1.05
B	detached	S&E	124.6	'05.03	0.5	'05.10	0	2.16
C	detached	S&E	147.7	'05.03	0.6	'05.10	-0.1	0.73
D	detached	S&E	151.4	'04.12	0.6	'05.10	-0.3	1.37
E	detached	S&E	128.7	'05.03	0.5	'05.10	-0.7	2.27
F	detached	S&E	205.9	'04.11	0.6	'05.10	0.2	1.34
G	detached	S&E	151.4	'04.10	0.6	'05.10	0.2	1.26
H	detached	S&E	194.6	'01.11	0.7	'05.10	5	1.24
I	detached	E *2	121.8	'03.12	0.8	'05.10	5.1	5.23
J	detached	E	157.9	'04.03	0.6	'05.10	3.2	4.57
K	detached	E	134.2	'98.03	1.91	'05.08	3.7	1.96
L	detached	S&E *3	173.3	'95.06	2.03	'05.10	2.6	3.92

Figure 1. Measurement by airflow meter placed at inlet/outlet

*1: “S&E” represents forced supply and exhaust ventilation system with a heat exchanger.
*2: “E” represents forced exhaust ventilation system.
*3: The ventilation system of House L was installed in September 2003 to increase ventilation rate.
*4: The air-tightness of Houses A to H was measured before occupants moved in.
*5: “Temperature difference” is the average of outdoor temperatures from indoor temperatures during measurement period.
*6: “Outdoor wind velocity” means the average outdoor wind velocity of weather data during measurement period. The outdoor wind velocity of weather data were altered to height of 6m from ground.

The order of investigation is as follows:

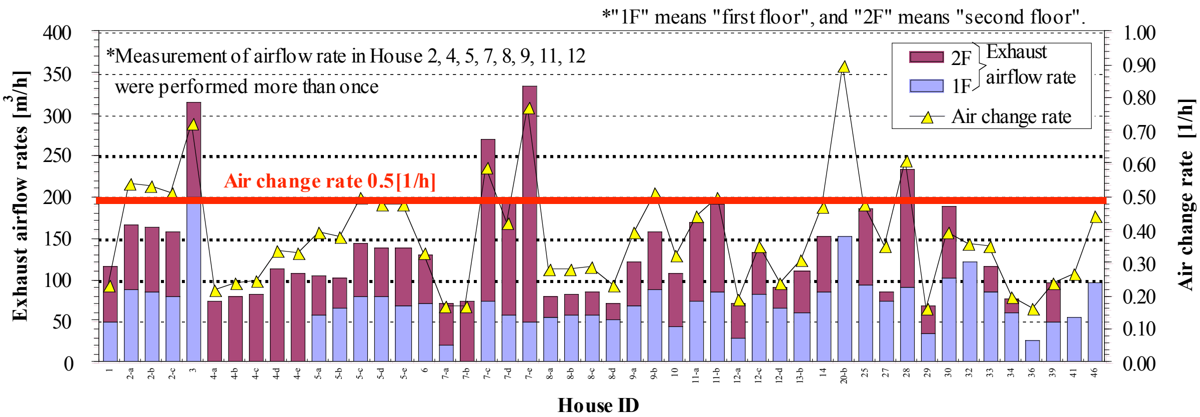
1) Measuring airflow rate at inlet/outlet by using airflow meter
2) Distributing questionnaire to occupants about condition of the usage and maintenance of the ventilation system
3) Assessing dust condition in the filters of the ventilation system using observation method
4) Cleaning filters and meshes that used for protecting against insects
5) Measuring airflow rate at inlet/outlet after cleaning

RESULTS AND DISCUSSION

First Phase of Investigation

Figure 2 shows the exhaust airflow rates through the outlets reported in the first stage of investigation. Airflow rates at outlets shown in Figure 2 are the values of the running mode in which the occupants usually set up. Exhaust airflow rates of first and second floors were summed up to represent the overall airflow rates.

From the figure, 37 out of 48 measurements indicated low air change rates of less than 0.5 ACH. The investigation found that changes in ventilation systems have strong influences on the exhaust airflow rates. For Houses 7 and 12, the third measurements (7-c, 12-c) were higher than 2nd measurements (7-b, 12-b) because new ventilation systems were installed before it. For Houses 4, 5, 9, 11 and 12, the airflow rates were significantly increased after the ventilation systems were set to



House ID	1	2-a	2-b	2-c	3	4-a	4-b	4-c	4-d	4-e	5-a	5-b	5-c	5-d	5-e	6
Measurement month (month / year)	6/'01	7/'01	10/'01	9/'02	7/'01	8/'01	1/'02	9/'03	8/'04	8/'05	8/'01	1/'02	8/'03	2/'04	8/'04	8/'01
Ventilation system	S&E		E		E			E					E			E
Air tightness	2.74	0.40	0.35	0.50	4.64	1.32	1.36	1.86	1.85	1.91	0.53	0.59	0.41	0.94	1.10	0.83

House ID	7-a	7-b	7-c	7-d	7-e	8-a	8-b	8-c	8-d	9-a	9-b	10	11-a	11-b	12-a	12-c
Measurement month (month / year)	9/'01	1/'02	9/'03	9/'04	10/'05	10/'01	12/'01	8/'03	3/'04	11/'01	9/'03	11/'01	12/'01	7/'03	1/'02	8/'03
Ventilation system			S&E				S&E			E		S&E	E		S&E	
Air tightness	1.10	1.71	1.92	1.88		0.83	0.84	0.90	0.94	0.93	1.14	2.66	0.71	0.71	1.22	1.41

House ID	12-d	13-b	14	20-a	25	27	28	29	30	32	33	34	36	39	41	46
Measurement month (month / year)	8/'04	8/'02	2/'02	2/'03	12/'03	2/'04	2/'04	2/'04	2/'04	3/'04	3/'04	4/'04	8/'04	9/'04	8/'05	9/'05
Ventilation system	S&E	E	S&E	S&E	E	E	E	S&E	E	E	E	E	E	E	E	S&E
Air tightness	1.45	0.53	2.30	0.88	1.56	-	2.18	0.28	1.23	2.27	1.12	0.65	1.13	0.77	0.28	2.62

*"S&E" means forced Supply and Exhaust, "E" means forced Exhaust.

Figure 2. Exhaust airflow rates at outlets (1st phase, 27 houses, 48 Measurements)

stronger running mode (4-d, 5-c, 9-b, 12-c, 11-b). Maintenance of ventilation system also plays an important role in ensuring high airflow rate. In House 2, 4, 5, 7, 8 and 12, the ventilation systems were not cleaned, so the results of measurements nos. 2-c, 4-e, 5-e, 7-d, 8-d and 12-d were lower. On the other hand, measurement no.7-e of House 7 was higher after the ventilation filter was cleaned.

Questionnaire Survey to Occupants and Observation of the Dust Conditions in the Filters

Running mode of ventilation system (Figure 3 (a))
The ventilation system was operated for 24 hours in all houses. Figure 3 shows the typical running mode set by the occupants. Out of the total investigated houses, 7 houses (58%) set at ‘minimum mode’, 4 houses (33%) set at ‘maximum mode’, and only 1 house (9%) set at ‘65% of maximum mode’.

Necessity of maintenance of ventilation system (Figure 3 (b))
Half of the respondents knew the necessity of the maintenance of the ventilation system. In these respondents, half worked related to houses. Therefore, it is obvious that they knew the proper maintenance of the ventilation system.

Reading manual (Figure 3 (c))
Although 67% of all respondents read the manuals of ventilation systems, it is expected that only a very few of them read, particularly about the maintenance, carefully.

Cleaning filters (Figure 3 (d))
Almost all the respondents (11 out of 12) did clean the filters. Although the respondents on Houses A, D, E and G answered “I don’t know the necessity of

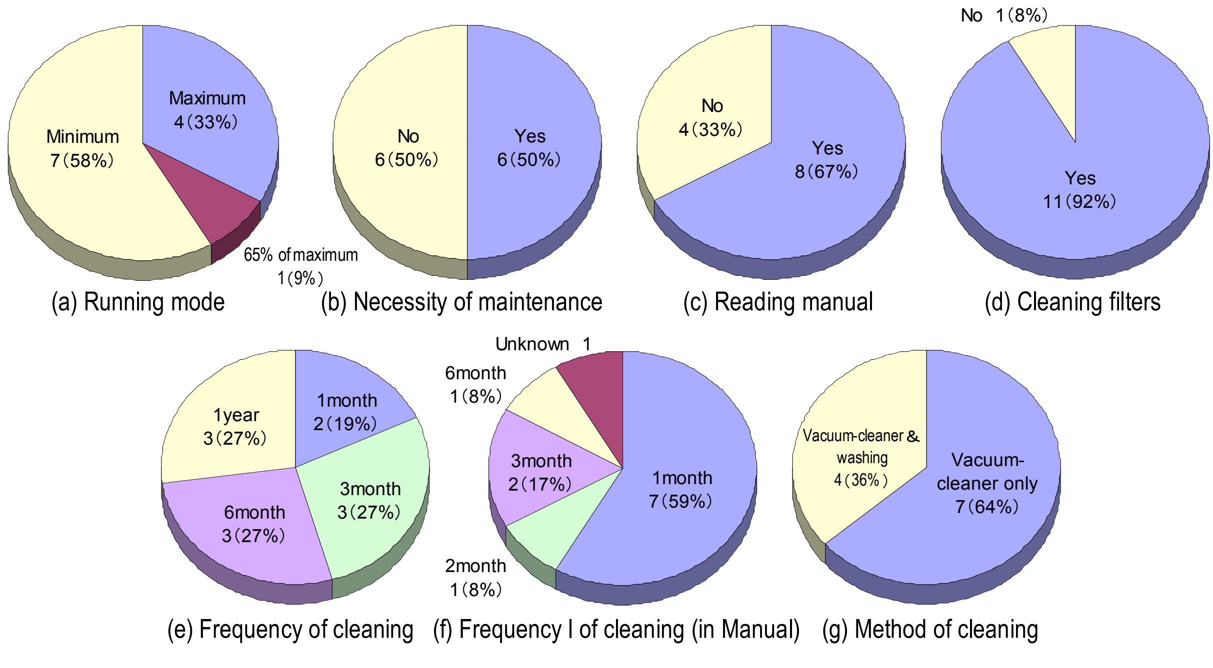


Figure 3. Questionnaire survey of the occupants about condition of the use and maintenance of the ventilation system

ventilation system maintenance" or "I have never read the manual of ventilation system", they did clean the filter installed at the entrance of exhaust side of heat exchanger (Figure 4). The tendency of cleaning these filters is basically due to the fact that the sizes of these filters were quite big and they were installed at the external side of the ventilation system. While, the inner filters such as the insect protection filter (Figure 5) and the filter behind outlet grill (Figure 7), and small external filter (Outside diameter: 5cm, Inside diameter: 3.5cm, Figure 6), which are difficult to be cleaned were covered thick dust.

Frequency of cleaning (Figure 3 (e) and (f))

It was found that the actual frequency of filter cleanings in 9 out of 11 houses (Figure 3 (e)) were lower than that recommended in the manual (Figure 3 (f)).

Method of cleaning (Figure 3 (g))

Manual recommended that the filters should be washed after cleaned by vacuum-cleaner. The result showed that only 4 houses used both methods while 7 houses used only vacuum-cleaner.

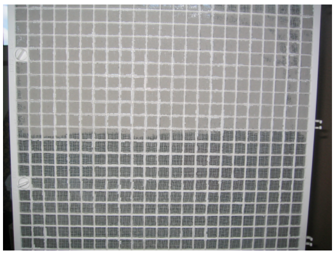


Figure 4. Filter installed at the entrance of exhaust side of heat exchanger (House A)

Figure 5.Insect protection meshes installed inside the heat exchange unit (House E)

Figure 6. Small filter (House A)

Figure 7. Filter installed behind the grill of outlet (House I)

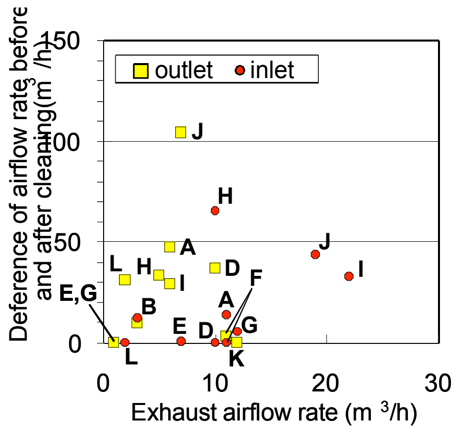


Figure 10. Difference of airflow rate before and after cleaning and time of passage from last cleaning

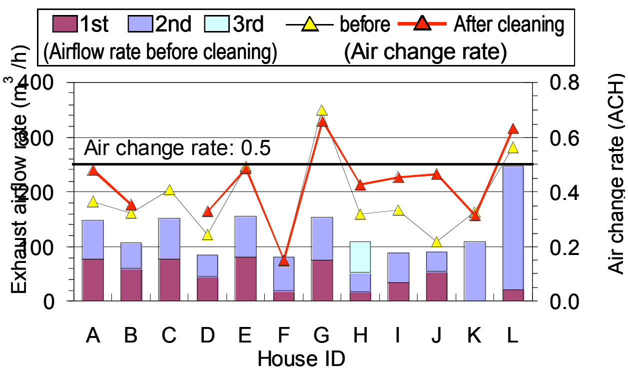


Figure 8. Exhaust airflow rates at outlets and air change rate

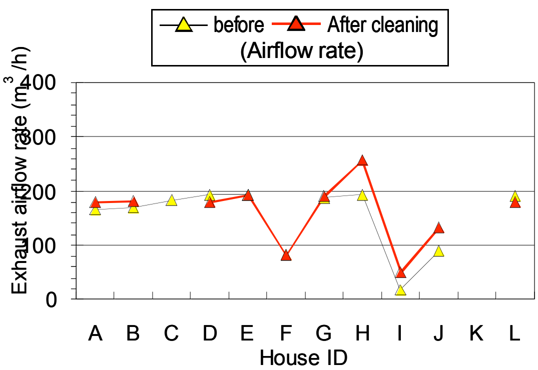


Figure 9. Supply airflow rates at inlets

Measurement of airflow rate at inlet/outlet before and after cleaning

Exhaust airflow rate at outlets and air change rate (Figure 8)

In house C, the filters were very clean because periodical cleaning was performed 4 days before the measurement. It can be seen that 10 out of 12 houses had low air change rates of lower than 0.5 ACH. Air change rate of 7 houses were increased after cleaning the filters. In this respect, it was observed that the exhaust airflow rate of house J was increased by about twice. On the other hand, in Houses E and G, the filters were not so dusty, so the airflow rate did not change much before and after the cleaning. It must be highlighted here that air change rates of Houses F and K were very low both before and after the cleaning, so it is expected that some other problem may exist.

Supply airflow rate at inlets (Figure 9)

The filters at Houses H, I and J had not been cleaned for long time before this investigation. Hence, the airflow rates were significantly increased after the cleaning prior to the measurements.

Difference of airflow rate before and after cleaning and time of passage from last cleaning (Figure 10)

The investigation generally found that the longer time gap of filter cleaning, the bigger airflow rate improvement after cleaning (with exceptional case for Houses F and K). It was found that the type of filter influences the decrease of airflow rate. For example, Houses A and G were using large meshes inlet filters, so the difference of airflow rates before and after cleaning was not big. On the other hand, House H was using small meshes inlet filter, the difference of airflow rate was as high as 65 m^3/h.

CONCLUSIONS

1) In first stage of our investigation, the air change rates of 37 out of 48 measurements were lower than 0.5 ACH. In second stage, the air change of 10 out of 12 houses was lower than 0.5 ACH. In spite of installing mechanical ventilation system, there were many houses still had low ventilation rates.
2) The maintenance of ventilation system was insufficient in the investigated houses. It is thus necessary to assess the performance of the mechanical ventilation system for residential buildings in each stage of the construction from planning to installation and operational stages.
3) It was confirmed that airflow meter is a convenient and efficient method to measure ventilation rate.
4) It was found that the type of filter influences the degree of the airflow rate drop.

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