Thermal Environment Generated by Occupant's Opening Control of Window at Naturally Ventilated Building

K. Kami[1], H. Kotani[1], T. Yamanaka[1], Y. Momoi[1], K. Sagara[1], T. Sakaguchi[2], and K. Tanaka[2]

[1] Division of Global Architecture, Graduate School of Engineering, Osaka University, Osaka, Japan , 565-0871

[2] Takenaka Corporation

Abstract

A field survey in a natural ventilated school building was carried out. The purpose of this study is to figure out the occupant's evaluation of thermal comfort as the result of opening control, which seems to be affected by the outdoor and indoor air condition.

Occupant's active use of natural ventilation system instead of air conditioner is a key to the performance for energy saving of building. The analysis of the data shows that windows were more actively controlled as occupant's knowledge about natural ventilation system increased. The result of this study suggests that understanding about the system leads more active control of window and less use of air conditioner, which play a grate role in saving energy.

Keywords: Natural ventilation, Occupant's utilization, and Thermal comfort

Introduction

Recently the buildings with natural ventilation system are more and more increasing for utilization of natural energy and saving energy. In such buildings, it is expected that comfortable thermal environment will be obtained by using common means of control, e.g.

operable windows. Raja et al [1] has shown that occupants who have grater access to control devices report feel less discomfort than who have less access.

This paper shows the natural ventilation of the school building using staircases as natural ventilation chimneys. Longitudinal surveys in the natural ventilated school building in the west part of Japan were carried out. The building consists of four floors and central corridor, the total floor space is 4098m^2. In this building, controls such as windows are adjusted by occupants. The natural ventilation system uses wind driving force of negative pressure on the rooftop of wind chimneys and buoyancy force caused by the heat generation by occupants in lecture rooms. Komatsu et al [2] calculated ventilation rate brought by natural ventilation through chimneys using wind tunnel test.

The goal of this study is to provide the guidelines for planning and running of naturally ventilated buildings. In this study, the potential of the chimney and the occupant's use of windows had been focused on. Since this building is a school building, the surveys were conducted on exhibit, expecting the educational effect on occupants to raise their awareness. During 2008-2009, field surveys were conducted in spring and fall, when the natural ventilation system may have the biggest effect. Tsumura et al [3] calculated the wind pressure coefficient using wind tunnel test, Fujimoto et al [4] measured air change late in the building, and Wakamatsu et al [5] reported the occupants' use of windows. This paper presents the

result of the analysis on the occupancy evaluation of thermal environment as well as indoor and outdoor temperature.

Method

Figure 1 shows the natural ventilation system of the building. Each room has four kinds of natural ventilation controls, (upper-windows and lower-windows opened to outer side, doors and transoms opened to corridor). Outdoor air flows into rooms through windows first, and then flows to corridor through transoms. Finally, indoor air flows out through rooftop of the chimney. The floor plan of second and third floor is shown in Figure 2.

In 2008, one survey period was set in each of spring and fall. In 2009, three survey periods were set in each of those seasons. Before the survey in fall 2009, an educational activity using posters (see Figure 3) about the natural ventilation system of the building had been taken. The poster has the elucidations about the natural ventilation system, recommended degrees of temperature and simplified thermometer. The posters were posted on the doors of each room and the notice boards. The aim of this activity was to encourage the occupants to use controls. This paper shows the result of the survey in 2009.

As for the understanding of occupants, one questionnaire (hereinafter called understanding questionnaire) was conducted each survey period. And for the thermal evaluation of occupants, one questionnaire (hereinafter called thermal questionnaire) was conducted each

day. Table 1 shows the survey periods and the number of the respondents of questionnaires in 2009.

In 2009, visual evaluations of using controls (opening checks) were conducted every two hours during 9 am to 5 pm, every day in second and third period of each survey season. “Opening-percentage” was identified for upper-windows or transoms on the basis of percentage of opening area of them. And utilization of natural ventilation system is examined using opening-percentages of student’s rooms and teacher’s rooms. Student’s rooms are the north side rooms mainly used by students, and teacher’s rooms are the south side rooms used by teachers. The definition of Opening-percentages used in this paper is shown in Figure 4.

In Figure 2, the rooms in which indoor temperatures were measured are shown. Outdoor temperatures were measured in the north and south side on the first floor of the building and the average of the measurements is used as outdoor temperature in this paper. Temperatures were averaged per one hour for the value of every two hour (the time of opening checks), and averaged per eight hours for the value of each day.

Results and Discussions

The consciousness of inhabitants

Figure 5 shows the result of understanding questionnaire to present the occupants' level of understanding about natural ventilation system. The result in 2008 is also shown in the figure as the reference. However, the result in the spring and fall in 2009 is compared here because the students are changed in every spring. Students' understanding level was improved between the spring and the fall, 2009. This may be partly because of educational effect, which is arisen from exhibited surveys and educational activity. Given that teachers had been in the building for years and already received explanations about natural ventilation, it's not surprising that the teachers' understanding level is high in spring as well as in fall.

Relation between outdoor air temperature and Opening-percentage

Figure 6 shows the relation between outdoor air temperature and opening-percentage in 2009 of upper-window and transom. Outdoor air temperatures here are the values averaged per one hour. Opening-percentages here are the values of "Opening-percentage for outdoor air temperature" (see Figure 4).

Opening-percentages had increased from spring to fall, especially about upper-window in student's rooms and transom in teacher's rooms. Their changes from spring to fall in student's rooms may be caused by the improvement of understanding. As for teacher's rooms, educational activity seems to have motivated teachers to open transoms. Upper-windows in teacher's rooms may have been frequently opened in spring as well as in fall.

Indoor air temperature as the results of opening control

To figure out the effect of natural ventilation, the data is analyzed based on the result in each room. Figure 7 shows the relation between outdoor or indoor temperature and “Opening-percentage of each room” (see Figure 4) in 2009. Both of air temperatures here are the values averaged per one hour, and indoor temperatures are the values in each room. The height in these graphs shows the total number of the rooms for each control and for every time of opening checks. The number of the rooms where the windows or transoms were closed is not shown in the graphs. These graphs show the result of teacher’s rooms in fall, where controls were actively used and it expected that larger effect could be obtained.

Indoor air temperatures appear to be kept at 22 deg C or higher. Focusing on relation of the temperature and the number of the rooms where opening-percentage of transom is 100%, the number of the rooms is highest when outdoor air temperature was 21 deg C, although the highest values are seen when indoor air temperature was 27 deg C. It follows that the low outdoor temperature has small effect in many of the rooms where transoms are largely opened. The point is that inhabitants may use transoms for ventilation when it is too cold to largely open the windows opened to outdoor, and they prevent indoor environment from getting too cold.

Occupant's evaluation of indoor environment

To make analysis on occupant's thermal sensation, Figure 8 shows the relation between indoor temperatures and the occupant's evaluation using the result of thermal questionnaire. Indoor temperatures here are the values averaged per eight hours from 9 am to 5 pm. The result is averaged over every responses collected in rooms where indoor air was measured as same temperature. For the comparison of two seasons, it must be noticed that the way of asking in questionnaires is different from each season. In spring, occupants were asked about the thermal sensation under the situation of using natural ventilation, although they were asked about before and after opening the windows in fall.

About the evaluations in fall, it is clearly shown in the graph that opening windows is related with thermal sensation. Despite the indoor air had been measured as almost same temperatures, evaluations in fall take the cooler value than in spring when using the natural ventilation; however the difference in way of asking might be involved with the difference in the result. As one of possible reason, the ventilation rate may have increased because of the increasing use of controls, and occupants could feel wind velocity. As the other possible reason, occupants could imagine rooms as ventilated by understanding the natural ventilation system and that impression let them to feel cooler. However, as the advantages of opening control, occupants may expect not only to feel cooler but also to enjoy fresh air.

Conclusions

The results presented show that occupants controlled the opening area of devices (windows and transoms here) so as to achieve indoor thermal comfort. The use of them was more active in fall than in spring. It is therefore suggested that understanding how to use or how affect the natural ventilation system is strongly related to the occupant's utilization and energy saving performance of the building. Showing survey to occupants and the educational activity have profound effects on occupant's utilization.

As for occupant's evaluation of indoor environment, it is shown that opening the windows is strongly related with thermal sensation. Not only lowering the temperature but also the airflow and fresh air may be gotten as the effects of opening windows. Those effects might let occupant to achieve thermal comfort and sense of satisfaction.

Although the different climate in each season could influence the result, the educational effect could achieve. The point is that educational activity in the school building encouraged occupants to use natural ventilation, and then might augment the occupant's comfort. Use of controls enhances natural ventilation, and energy saving performance of the building may also be improved. Taking into account that occupants partly replace by others every year in school building, continuing activity is necessary for the efficient use of natural ventilation system and saving energy.

References

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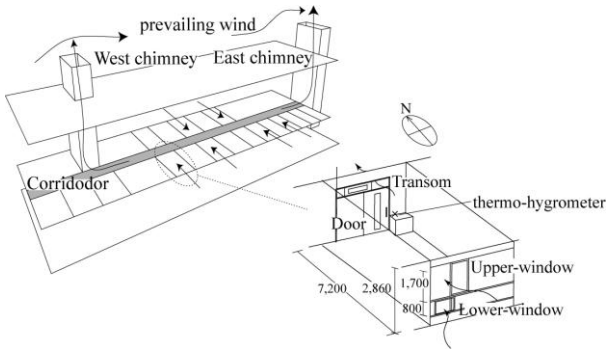

Fig. 1 Natural ventilation system

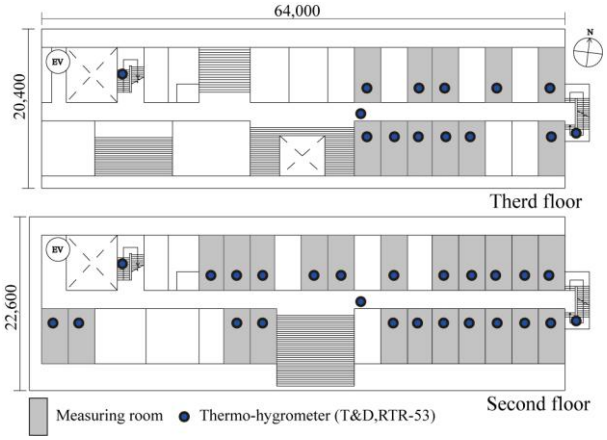

Fig. 2 Floor plan of second and third floor

Fig. 3 Poster for educational activity

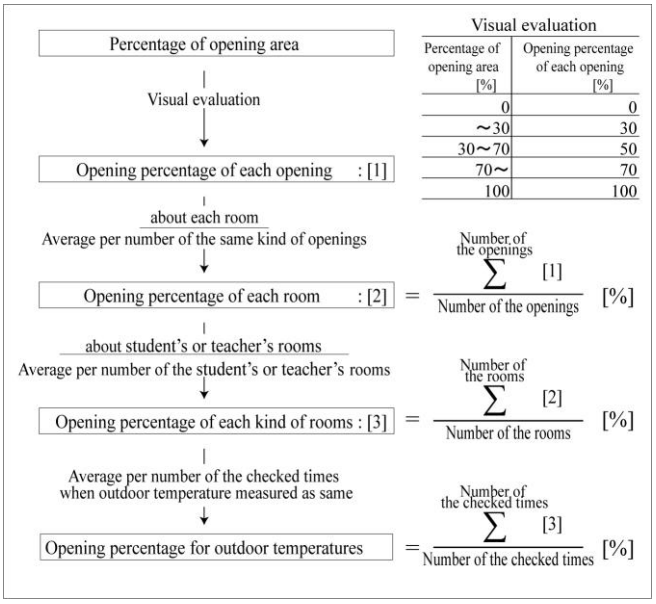

Fig. 4 Definition of Opening-percentages

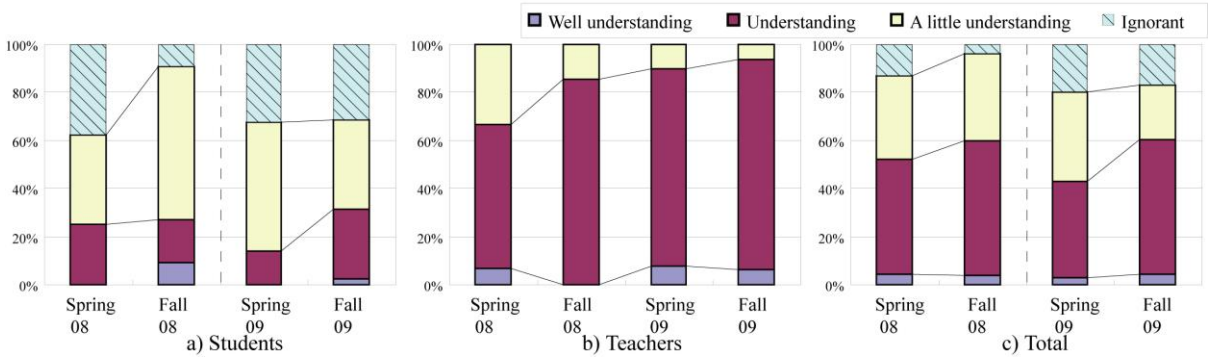

Fig. 5 Result of understanding questionnaire

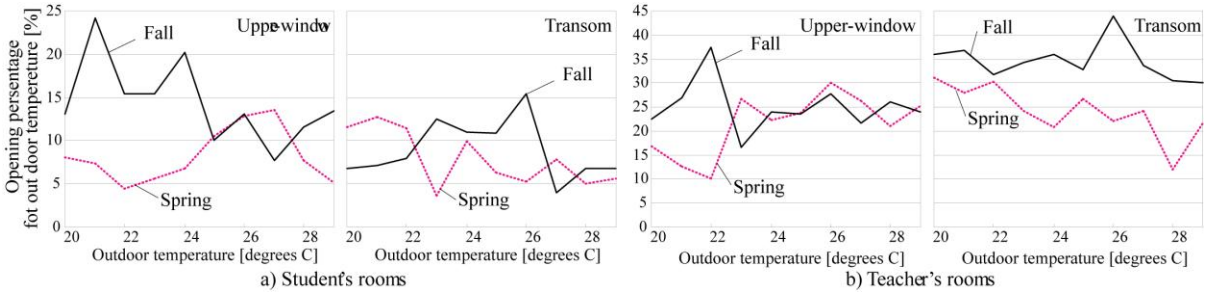

Fig. 6 Relation between outdoor temperature and Opening-percentage for outdoor temperature

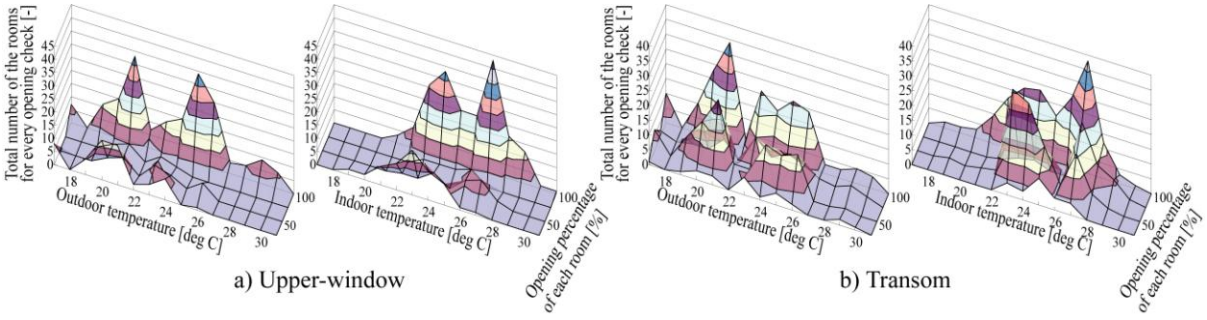

Fig. 7 Relation between air temperatures and Opening-percentage of each room

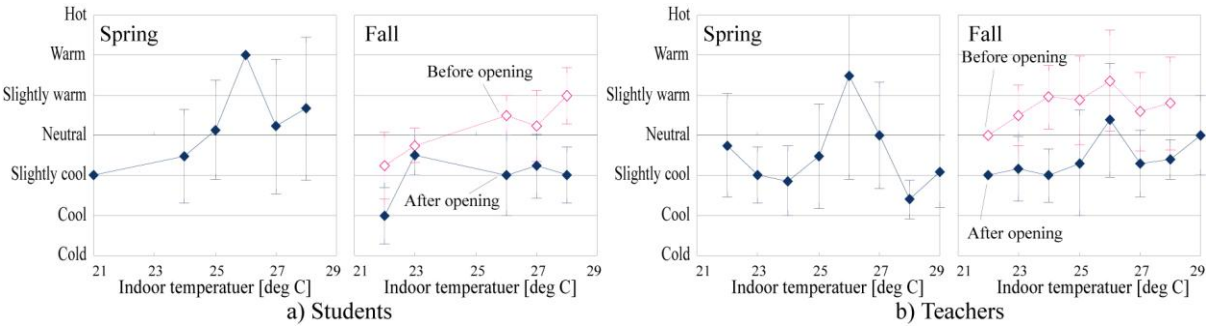

Fig. 8 Relation between indoor air temperatures and the occupant's evaluation

Table 1 Survey periods and the number of the respondents

Spring in 2009		First period 5/18～5/22					Second period 6/1～6/5					Therd period 6/29～7/3				
Respondent days		5/18	5/19	5/20	5/21	5/22	6/1	6/2	6/3	6/4	6/5	6/29	6/30	7/1	7/2	7/3
The number of respondents	Thermal questionnaire	35(14)	28(12)	26(11)	29(15)	27(11)	43(17)	29(12)	29(12)	30(14)	29(11)	31(14)	33(16)	20(9)	23(11)	23(12)
	Understanding questionnaire	33(11)					37(14)					33(13)				

Fall in 2009		First period 9/16～9/25					Second period 9/28～10/2					Therd period 10/19～10/23				
Respondent days		9/16	9/17	9/18	9/19	9/20	9/28	9/29	9/30	10/1	10/2	10/19	10/20	10/21	10/22	10/23
The number of respondents	Thermal questionnaire	52(12)	21(12)	20(12)	21(11)	20(13)	17(7)	19(7)	23(10)	22(10)	21(9)	17(10)	15(8)	18(10)	18(10)	16(8)
	Understanding questionnaire	30(13)					22(10)					18(10)				

The number of the teachers involveed in respondents is shown in parentheses