ENERGY-EFFICIENT PASSIVE VENTILATION SYSTEM FOR JAPANESE CONVENTIONAL WOODEN SINGLE FAMILY HOUSE

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ABSTRACT

Purpose of this study is establishment of energy efficient natural ventilation system for Japanese conventional wooden single-family house, by using humidity-controlled extract units (code name: GHN).

To evaluate the effect on energy performance and indoor air quality by adapting the GHN to the passive stack ventilation system, airflow rate, humidity, temperature and CO_2 concentration are measured over a period of one year in an experimental house. Numerical simulation on temperature, humidity and airflow is also carried out.

Measurement results show that the GHN functions thoroughly according to indoor relative humidity and stabilizes CO_2 concentration in lower level. The result of numerical simulation indicates that this system makes it possible to avoid harsh indoor dryness and save heating energy in winter.

KEYWORDS

Passive ventilation, Airflow control, Stack effect, Over dryness, Humidity-controlled extract units

INTRODUCTION

As mentioned above, the passive ventilation system we proposed[*1] reaches the required ventilation rate only by stack effect during the heating season. With such a system, saving on heating energy and avoiding extra low humidity will be possible, if the ventilation rate is regulated according to occupants' behavior.

The opening area of the humidity-controlled extract unit (GHN) changes continuously according to indoor relative humidity. The opening area gets larger in high-humidity conditions and smaller in low-humidity. Water vapor in the room strongly depends on the contaminants caused by human activity. So the passive ventilation system regulated by the GHN is able to track indoor air quality, save heating energy and regulate moisture condition in the same time. This paper presents the application of the GHN to the passive ventilation system for Japanese conventional wooden house.

THE CONCEPT OF PASSIVE VENTILATION AND MECHANISM OF CONTROL

Figure1 shows the concept of the passive ventilation and the method of airflow control by using GHNs. Fresh air is taken through crawl space insulated on the foundation wall and then distributed to the rooms through floor openings and partition wall cavity. Air circulates between the rooms and the staircase via the door undercuts and the holes, and is finally exhausted trough the vent stacks. Humidity-controlled extract units (GHN) are placed on the indoor openings of vent stacks to control the exhaust airflow

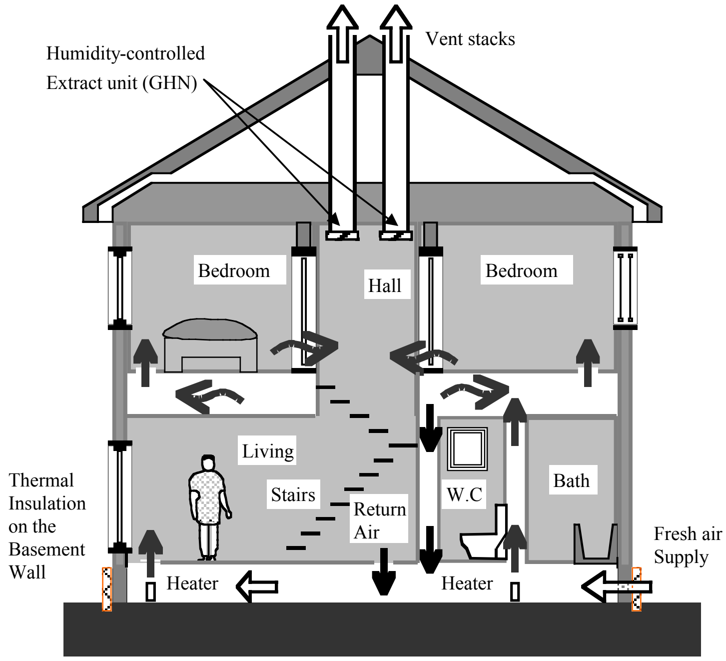

Figure 1: The concept of passive ventilation system

A nylon ribbon located in the extract unit expands and contracts according to the relative humidity in the house. It is connected to the shutter mechanically and regulates the opening area. Figure 2 shows that relation between relative humidity and airflow rate under a pressure difference of 10 Pa. There are 3 positions to control the range of relative humidity and thus the airflow : 18-53%,30-65% or 42-77%.

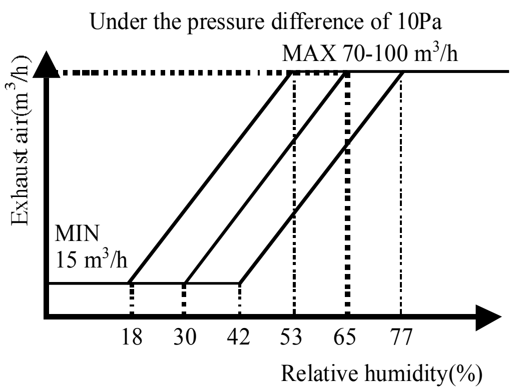

Figure 2: Characteristic of the GHN

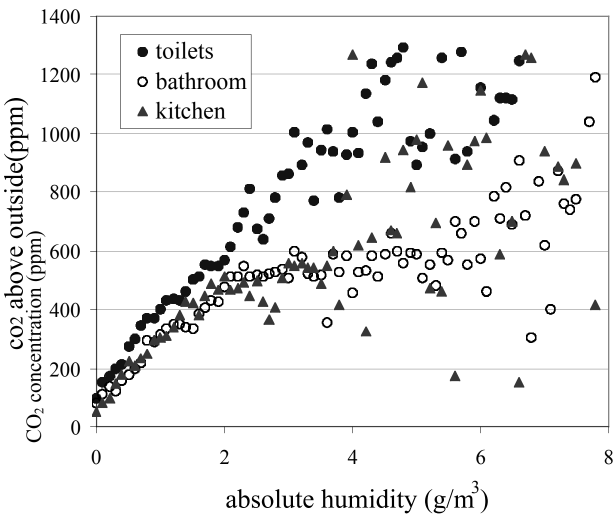

Figure 3: Absolute Humidity and CO_2 Concentration

Data in Figure 3, which were taken in an apartment, shows the correlation between indoor CO_2 concentration and absolute humidity during the heating. CO_2 concentration is strong correlated to absolute humidity in the low humidity range but frequency breaks out lower in high humidity range. These measurements shows that relative humidity can track indoor contamination caused by occupants' behavior.

THE APPLICATION OF THE GHN TO THE EXPERIMENTAL HOUSE

The experimental house and measurements

Figure 4 shows both the plan and measuring points of the experimental house. This house uses both passive ventilation and a crawl space heating system. Total floor area is about

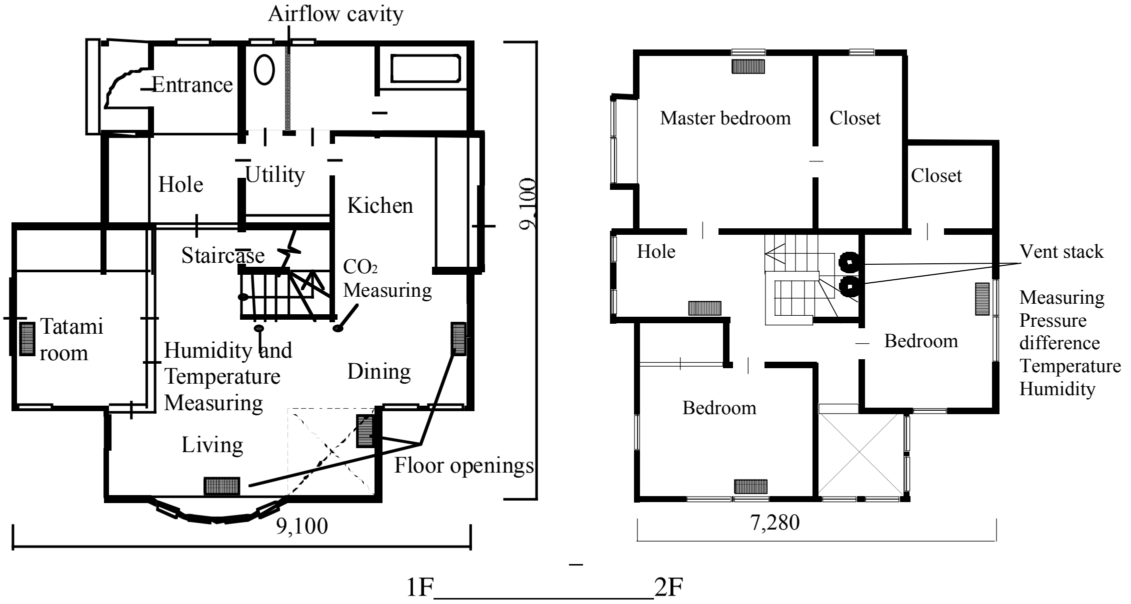

Figure 4: The plan and measuring point of experimental house

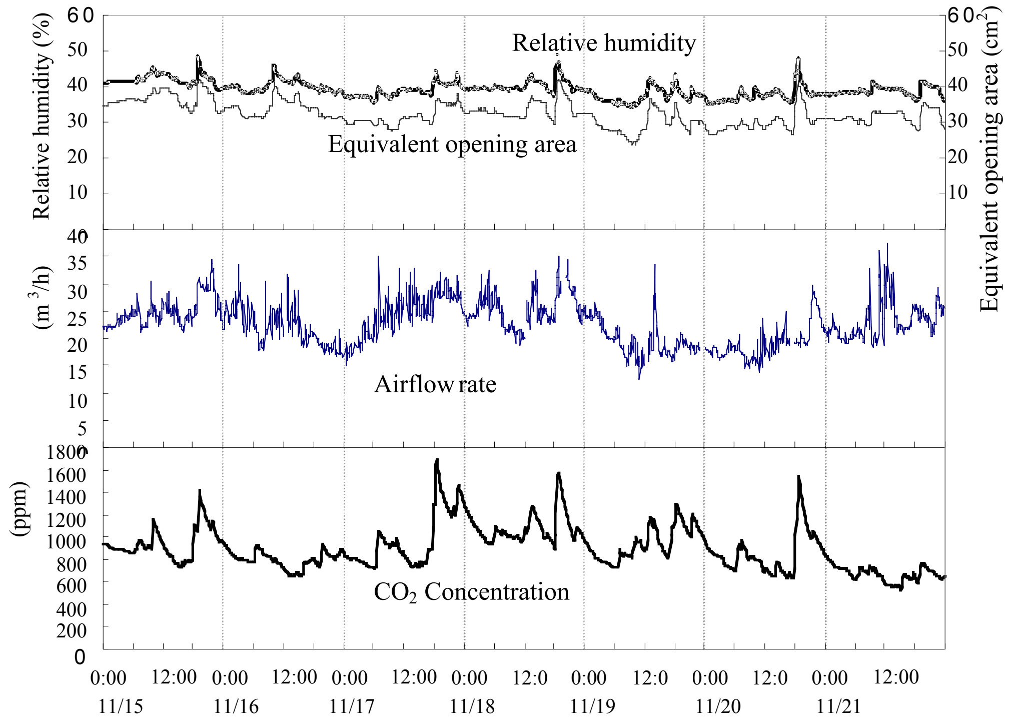

Figure 5: Measurement results

$125m^2$ with 3 occupants. The thermal performance of the living space wall, the roof, and the windows are assumed to comply the energy conservation standard of Japan, 0.35 W/m^2K for the wall, 0.17 W/m^2K for the roof, and 2.0 W/m^2K for the windows. The insulation applied to the vertical edges on the foundation wall is XPS 3b 100mm (0.028 W/mK).

Two humidity-controlled extract units (GHN) are fitted to the indoor openings of vent stack, which is placed on the ceiling above the living room staircase. The opening area of extract units is measured in every 5 minutes. And then airflow rate (through the extract units) is calculated by applying the pressure difference between both sides of the extract units to the equivalent opening area. There are two 150mm-diameter vent stacks and two same 150mm-diameter fresh air supply ducts to the crawl space. They are supposed to realize the reach a rate of 100 m^3/h when the temperature difference is 20 degree.

Airflow rate and indoor condition

Figure 5 shows the measurement results of equivalent opening area, indoor relative humidity, CO_2 concentration and airflow rate in the house. Variation of relative humidity and equivalent opening area are synchronized without time rag. Variation of CO_2 concentration is also similar to relative humidity variation. It indicates that controlling the ventilation rate by relative humidity is also a good way to control CO_2 concentration effectively.

Total amount of exhaust air from the two vent stacks stands around $50m^3/h$. It is rather small, but air leakage increases in winter and covers the required ventilation rate totally. The GHN is able to regulate the total ventilation rate within a proper range, and would work properly even in another house with different air tightness conditions.

Comparison of moisture control and thermal control

There is also another method to control the airflow, which is by temperature. The characteristic of two different control methods, one by temperature and the other by humidity, are compared through measurements of two practical houses using different regulating systems.

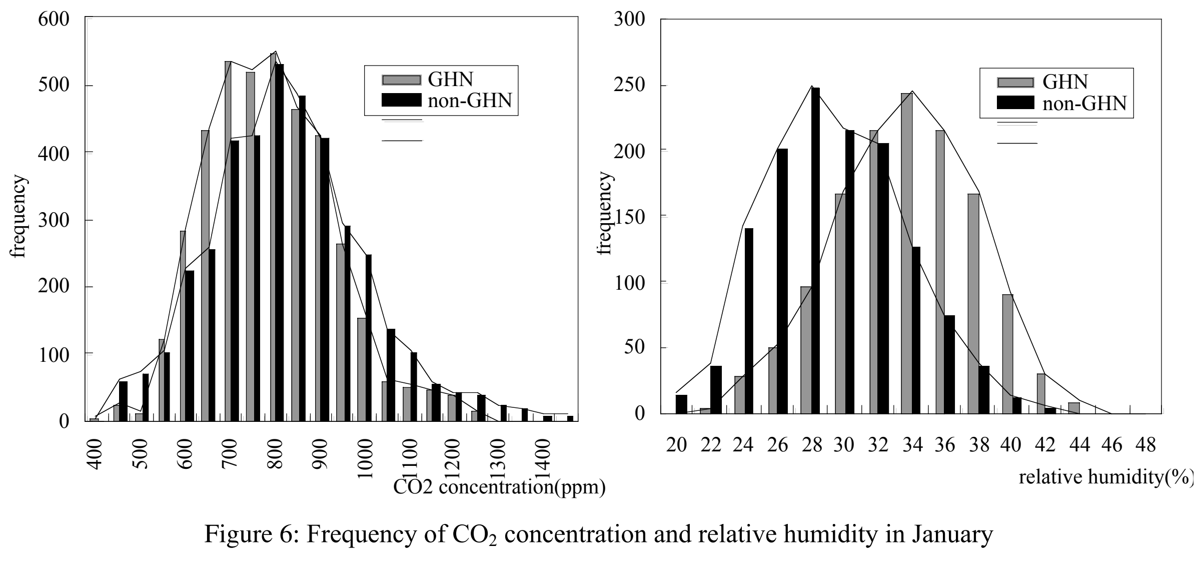

Figure 6: Frequency of CO_2 concentration and relative humidity in January

Figure 6 shows frequency of CO_2 concentration and the relative humidity in mid-winter, from Dec.18 to Jan.15. Clearly, CO_2 has a lower concentration in the "GHN house" and concentrates in narrower range than in thermal-controlled house. It indicates that the GHN performs suitable ventilation according to the contamination produced by occupants' activity. Relative humidity remains higher level in the "GHN house", showing that the GHN can ease over dryness in the house during winter.

SIMULATION TO EVALUATE THE GHN

To evaluate the GHN, temperature and humidity have to be calculated simultaneously. The program[*2] used for simulating hygro-thermal conditions combines heat and moisture balance within each space, along with multi-zone airflow models that transport heat and moisture through the occupied spaces and construction cavities in a house. The distribution of equivalent leakage area is shown in Table 1. The model is the measured house. Climatic data is Sapporo in Hokkaido, northernmost island in Japan. Occupants' behavior follows the pattern standardized by AIJ.

Table 1
The distribution of equivalent leakage area

Equivalent Leakage area	1.38[cm^2/m^2]	Partition door	255.1[cm^2]
Air inlet to the crawl space (2)	240[cm^2]	Vent stacks (2)	240[cm^2]
Partition wall cavity (upward)	2000[cm^2]	Partition wall cavity (downward)	500[cm^2]
Floor opening (upward)	2000[cm^2]	Floor opening (downward)	1500[cm^2]

Figure 7 shows correlation between exhaust airflow rate from vent stacks and relative humidity. A rate of 100 m^3/h is seen in the "non-GHN house", whereas in the "GHN house", exhaust air is kept within a 30-60 m^3/h range: the lower the relative humidity, the smaller the exhaust airflow.

Figure 8 shows correlation between total airflow rate and relative humidity. Total airflow is 80-150 m^3/h in proportion to relative humidity in the "GHN house", as opposed to 100-200m3/h in inverse proportion to relative humidity in the "non-GHN house". In general, ventilation rate increases in winter due to a greater stack effect, bringing higher heating costs and extra dryness.

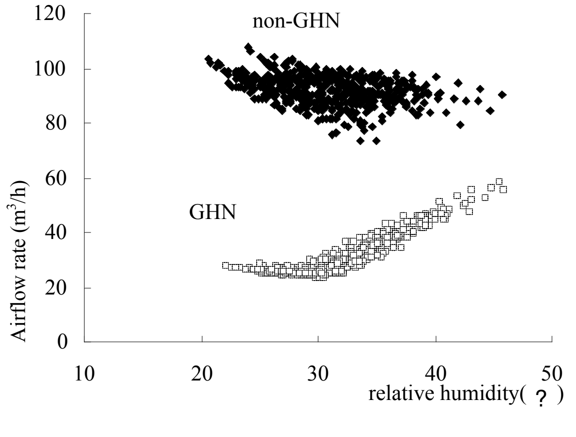

Figure 7: Exhaust airflow rate from vent stacks

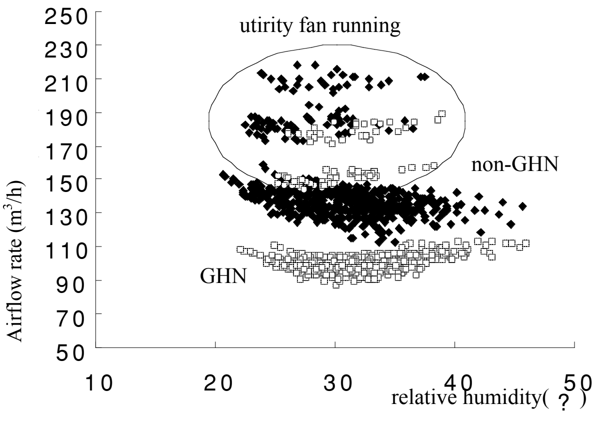

Figure 8: Total airflow rate

(The results of numerical simulation)

Figure 9 shows the variation of both temperature and relative humidity. In the 20-35% range, relative humidity is higher in the “GHN house” than in the “non-GHN house” by several percentage points.

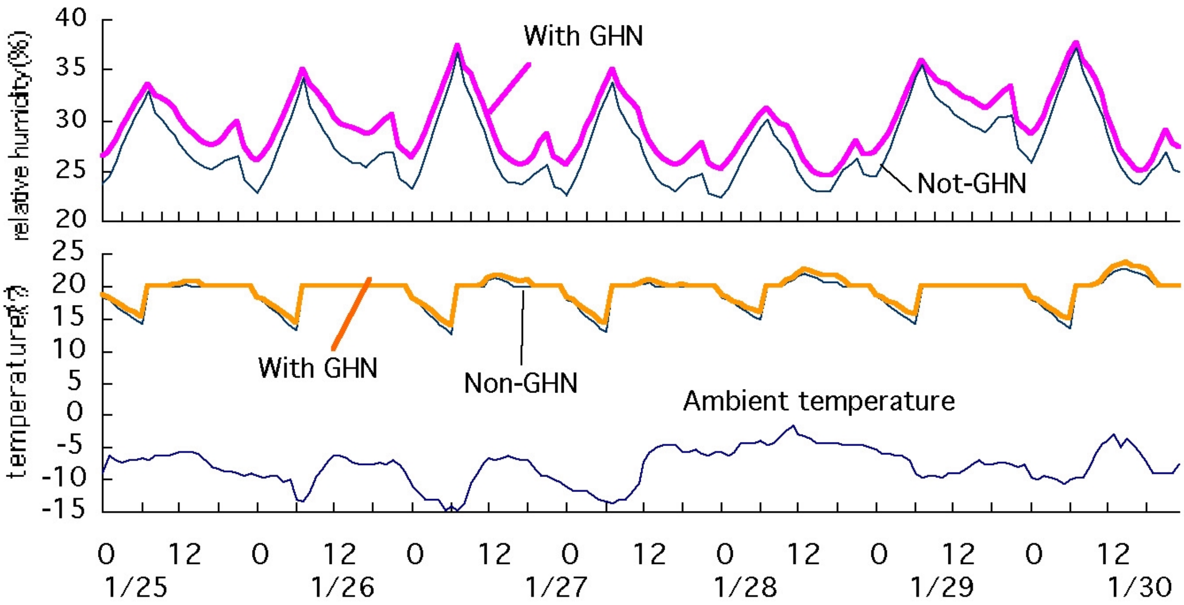

Figure 9: Variation of relative humidity and temperature in the living space

The difference of seasonal heating load hovers around 10%. As a result, passive ventilation system using GHN can counterbalance the increase of stack effect in winter, reduce the energy used for heating, and limit over dryness.

CONCLUSION

The characteristics of passive ventilation system regulated by humidity-controlled extract units (GHN) are discussed in this paper through measurements performed in practical houses, and also through numerical simulations. The results are as follows:

- Measurement results show that the GHN functions thoroughly according to indoor relative humidity and stabilizes CO_2 concentration in lower levels. The result of numerical simulation shows that relative humidity in the room of the “GHN house” is several % higher than in the “non-GHN house” in the range under 35%. This indicates that the GHN makes it possible to avoid harsh indoor dryness.
- The GHN can maintain the total ventilation rate in proper range, and do so even in another house with different air tightness.
- Passive ventilation system using GHNs limits the increase of natural ventilation in winter and may avoid heating-energy surcharges.

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