Effects of naturally ventilated double skin walls on indoor thermal environment

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ABSTRACT
Natural ventilation is a prevailing way to relieve the indoor thermal environment against warm and humid climate. The field measurement of the thermal performance of a model house with naturally ventilated double skin walls compared with a conventional insulated model house was carried out. Only the gap between the double skins is ventilated, while the indoor of the conventional model is ventilated mechanically. The measurement results show that the inside surface temperature, the room air temperature and the indoor relative humidity of the double skin wall house are lower than those of the conventional model house all the year round. The natural ventilation between the double skins can keep the indoor space cooler and drier than mechanical ventilation in the conventional model. This type of outside wall is recognized to be effective against warm and humid climate.

INDEX TERMS
Natural ventilation; Double skins; Thermal performance; Model houses

INTRODUCTION
Natural ventilation is one of the most important factors in passive cooling techniques against worm and humid climate from the viewpoints of global environment and healthy dwelling environment (Tsutsumi *et al.*, 1996). It can reduce the emission of carbon dioxide by the energy consumption for air conditioning and sweep out the indoor VOCs. However, the conventional way of passive cooling by natural ventilation through widely opened windows is not suitable in built-up urban areas because of privacy and security. On the other hand, the energy saving house in Japan is recently defined as a highly heat insulated and air tightened house with air conditioning and mechanical ventilation. It is not a right way of saving energy to depend upon mechanical systems all the year round in mild climate areas like Japan.

One of new energy saving houses with natural ventilation fit for warm and humid climate and also fit for present urban conditions was proposed (Tsutsumi *et al.*, 2001). It is a house that has the outside walls made of reinforced concrete and the wooden inside walls. There are gaps between these two walls and these spaces are naturally ventilated through the louvers on the outside walls and a roof top ventilator. The indoor thermal performance of this house is reported in this paper based on a field experiment that was continued for a year. A model of this house was compared with a conventional model house of the same materials without ventilation gap in this experiment.

METHODS
Experiment Models
Skeletons of two types of model houses used in the experiment are shown in Figure 1 and the arrangement of these models is shown in Figure 2. Although the area of the floor is not enough as an actual house, the materials, the structures, the ceiling height and the detailed finishes are

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almost the same as actual houses. These model houses are set on a paved lot and all the measurements were carried out outdoors under the natural weather conditions. From these points of view, the experiment is regarded as a full-scale measurement. These model houses are arranged on a north–south line straight with a distance of 4.6 m. This distance is a minimum length to avoid the shadow of the model houses covering each other on the winter solstice in this experiment site. It is calculated from the height of the model house (3.9 m) and the latitude of the experiment site (26.2° North).

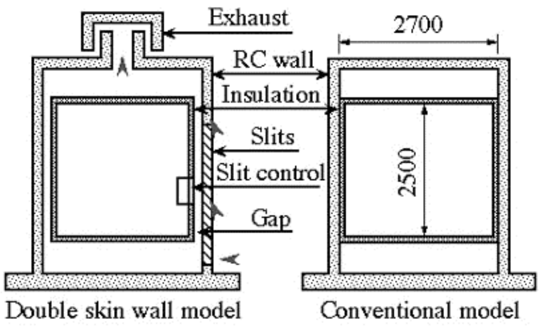

Figure 1 Experiment models.

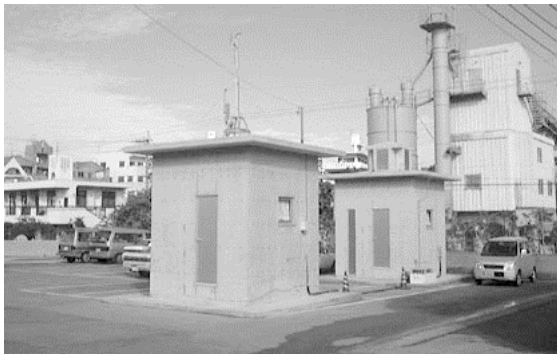

Figure 2 Photo of the model houses.

The model house of which the thermal performance is to be estimated is called the DSW (double skin wall system) model. The other one is called the conventional model, which is compared as a standard house. Structures of the walls of the two models are shown in Figure 3. They are made of the same materials, an outer concrete wall and an inner plywood board with heat insulation. The difference between two models is a gap of 5 cm width in the DSW model. The gap is connected with the outdoor air through a louver and a ventilator for natural ventilation. The louver of 30 cm wide and 2 m height is located on the left of the door and the ventilator of 60 cm height is also located on the rooftop of the back model in Figure 2. Ventilation air normally comes from the louver and goes up through the gap and discharges from the rooftop ventilator. Although the indoor space of the DSW model is not positively ventilated, it is naturally ventilated through the inner wall of not so high air tightness. Total air tightness of the DSW model is almost at the same level as the conventional model when the louver and the ventilator are closed. The conventional model has an electric fan that makes 0.5 times per hour ventilation, which is the minimum ventilation rate in Japanese codes of energy saving houses.

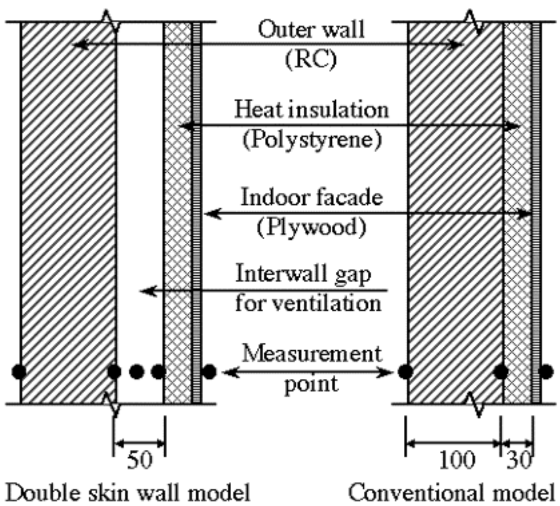

Figure 3 Structures of the walls.

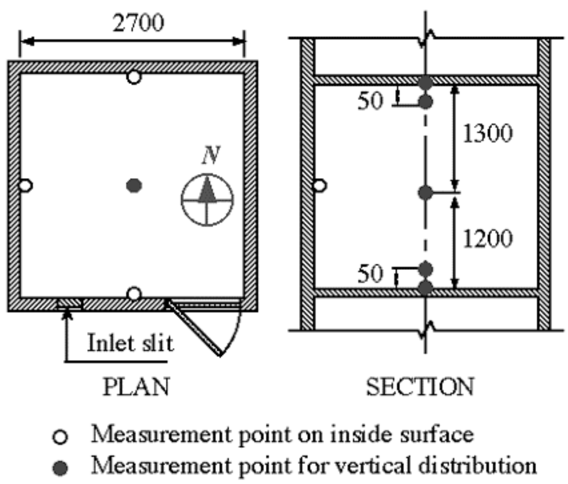

Figure 4 Indoor measurement points.

Outline of Experiments

Outdoor meteorological factors were measured above the rooftop of the conventional model. Temperatures of indoor air, inside and outside surfaces of the wall materials were measured in both the models. Measurement points around the walls are shown in Figure 3 and those for the indoor air temperatures are shown in Figure 4. Relative humidity and globe temperature were also measured at the centres of the models. All the data have been recorded every 10 min. The measurement was started in August 2000 and was continued for a year.

RESULTS

Diurnal Fluctuations of Thermal Environment

Samples of outdoor and indoor air temperatures at the centres of the models on a summer day (3 September 2000) and a winter day (6 February 2001) are shown in Figure 5. These two days are selected as typical fine days in the measurement term. The indoor air temperatures in both the models are almost the same in the morning hours on the summer and the winter days, and the outdoor air temperature is a little higher than them in this period because of the heat capacity of the structures. The indoor air temperature in the DSW model is clearly lower than that of the conventional model in the afternoon and the night-time.

Diurnal fluctuations of globe temperature and relative humidity data on the same days as Figure 5 are shown in Figure 6. The fluctuations of the globe temperatures are almost the same as those of the air temperatures. The relative humidity in the DSW model is clearly lower than that of the conventional model all day long, while the difference is very small in the early morning.

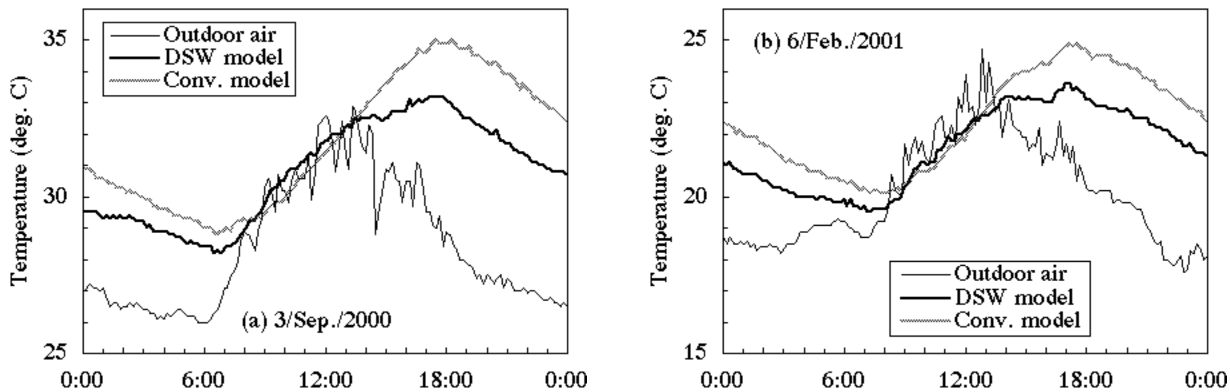

Figure 5 Diurnal fluctuations of outdoor and indoor air temperature data.

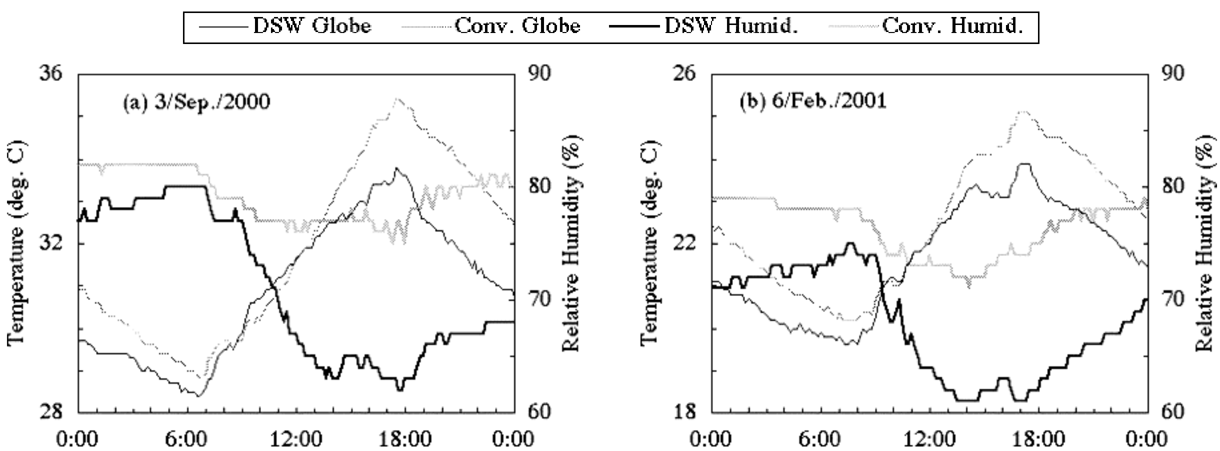

Figure 6 Diurnal fluctuations of indoor globe temperature and relative humidity.

Annual Fluctuations of Thermal Environment

A period from 17:00 to 19:00 is regarded as a representative hours to express the differences of the thermal performances between two models from Figure 5 and 6. Monthly averages of the air temperature and the relative humidity at the centre of the models in the representative hours are shown in Figures 7 and 8. These monthly data are simple averages of the raw data obtained on fine days in each month. These figures are regarded as the annual fluctuations of indoor thermal environment. Although the figures are drawn from January to December, actually the data from August to December are observed in 2000 and from January to July are in 2001.

Both the air temperature and the relative humidity in the DSW model are lower than those in the conventional model all the year round, which means that the absolute humidity in the DSW model is lower than that in the conventional model. The temperature differences are clear in summer and autumn, which exceed over 1.5° in August, September and October. The relative humidity differences are rather larger in winter, which reach over 10%. The indoor air temperature and relative humidity differences are smaller on cloudy days and almost the same conditions in two models on rainy days.

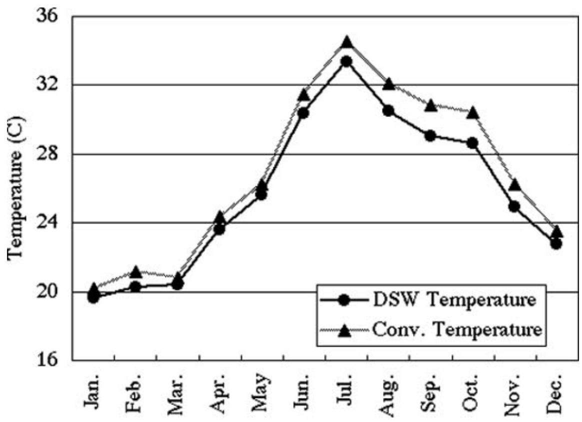

Figure 7 Annual fluctuations of monthly average indoor air temperature in 17:00-19:00 on fine days.

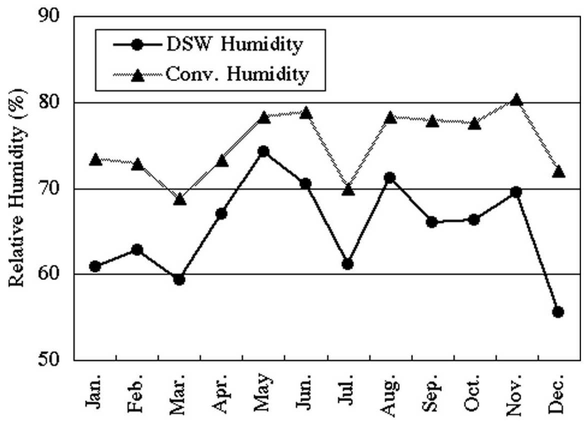

Figure 8 Annual fluctuations of monthly average indoor relative humidity in 17:00-19:00 on fine days.

CONCLUSIONS

It is clear that the naturally ventilated double skin walls examined here have remarkable thermal effects on indoor thermal environment. It can keep the room air temperature and humidity lower than ordinary structures. Especially, to reduce the humidity is a significant effect, because not only it makes the indoor thermal sensation lower, but also it can keep the room clean from fungi mould in worm and humid climate. The gap in the wall is thought to be working well as an exhaust duct of heat and humidity from the indoor space by natural ventilation. Therefore, the material of the inside wall should be examined much more.

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