The effect of water floor on the indoor climate control in passive solar house

Yuji Hori[a,*], Nobuyuki Sunaga[b], Zhejun Xian[b]

[a]*Building Research Institute, Japan;* [b]*Department of Architecture, Graduate School of Engineering, Tokyo Metropolitan University*

ABSTRACT
The solar house introduced in this paper aims to maintain the entire house temperature within the pleasant range by combining the solar heat collector with the water floor. The following three effects are expected in this water floor. First is the well stabilization of room temperature by reinforcement of indoor heat storage. Second is the uniformity of room temperature in each room by the effective heat transfer of water convection. The third effect is the improvement of pleasant thermal environment space as floor heating by arranging the thermal storage parts in the floor framing.

In this paper, the thermal performance of this system with water floor is discussed. The result of measurement, the temperature difference in the house was decreased. Moreover, this system could keep the room temperature in the comfortable range by use of solar energy only, and the water floor is effective on the indoor climate control.

INDEX TERMS
Solar heating; Solar collector; Water floor; Heat storage

INTRODUCTION
It is necessary to remove thermal stresses in the house to spend a healthy and comfortable life. In Japan, traditional house construction is made from wooden or a light panel, and heat capacity is poor. Therefore, the difference of the room temperature at daytime and nighttime is very large, and the temperature of the room not air-conditioned is approaching the outside temperature. Especially, the heat shock due to temperatures fluctuations between rooms in winter causes fatal accidents.

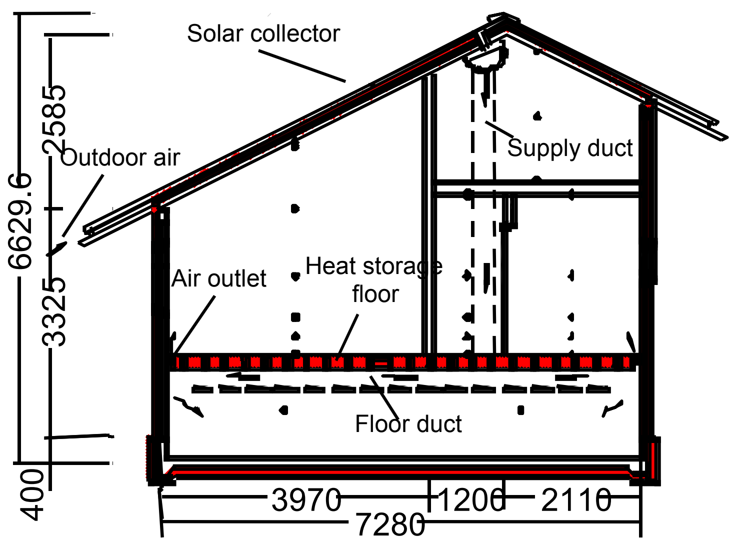

Figure 1 Section and system diagram.

* Corresponding author. E-mail: hori@kenken.go.jp

To prevent such an accident, it is needed to heat the whole of the house uniformly. However, the air-conditioning of the whole of the house needs a large amount of energy consumption. To solve such a problem, the improvement of the insulation efficiency, increasing of the amount of thermal storage, and the use of natural energy are requested. In this paper, the thermal performance of a solar heating system using air-type solar collector and 'water floor' are discussed.

Table 1 Building outline

Location	Minami-osawa, Tokyo	Solar collector	Glass-covered area 20.25
Structure	Wooden framework structure		
Floor area	1F 66.25 2F 15.06	Thermal insulation panel	Phenol form (100mm)

METHODS

To verify the effect of the system, the measurement in winter that used the test solar house was done. Figure 1 and Table 1 show the mechanism and the characteristic of the solar house used for the experiment. 'Water floor' is a device for heat storage and radiant heating like a 'water wall', but it provides more comfortable thermal environment. Water floor is composed of wooden floor and water bags in the floor framing. The water floor is used for heat storage, floor heating and decreasing the temperature difference in the house. The heat storage of water floor saves the solar heat collected in the daytime, and radiates it at nighttime when the temperature decreases. Figure 2 shows the mechanism by which the water thermal storage put in the floor part is warmed by the air collected solar heat. Moreover, the reinforcement of thermal capacity works as stabilization of the room temperature. The saved heat warms the floor uniformly by the natural convection of water. Figure 3 shows the mechanism by which the temperature of the water floor becomes uniform. As a result, the room is heated comfortably like a floor heating.

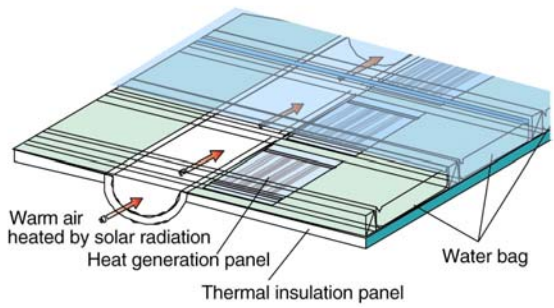

Figure 2 Illustration of the 'water floor'.

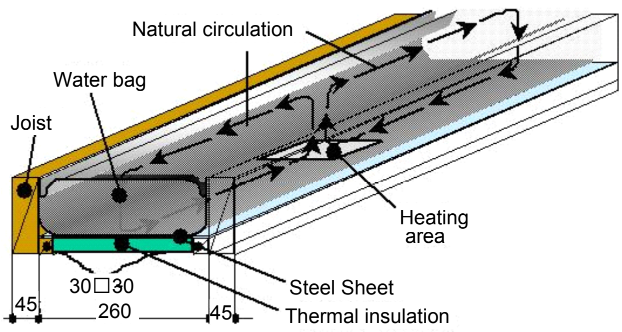

Figure 3 Water floor module.

In this solar house (Figure 4), the water floor module is spread over the floor as shown in Figure 5. The air warmed at the roof by the solar heater is carried under the floor through the duct, and warms the floor water while passing. Later, air is exhausted outside through the room.

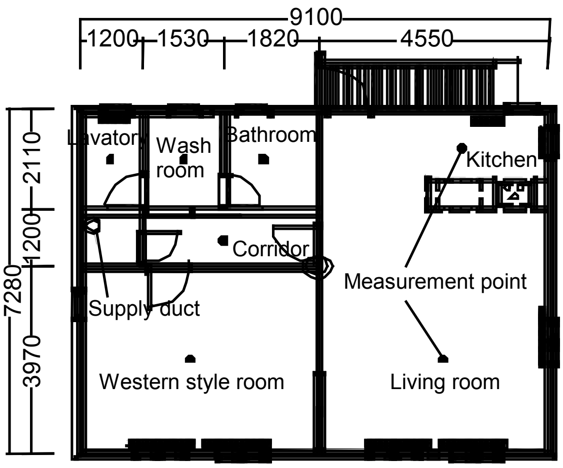

Figure 4 Planning of solar house.

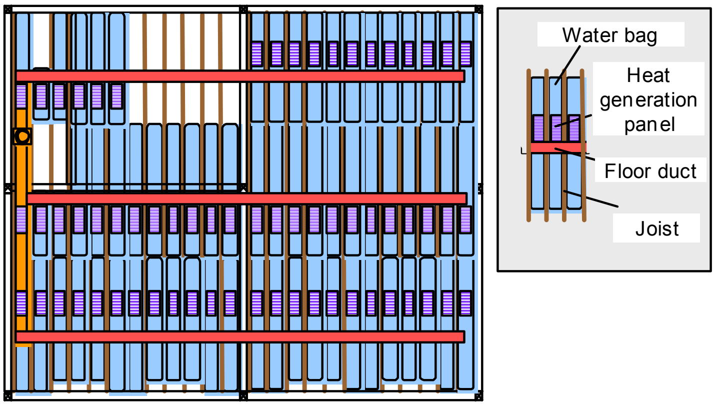

Figure 5 Arrangement of the water floor module.

In the experiment, the effect of the water floor on the uniformity of the floor temperature was verified first. Next, the effect on the room temperature control of the reinforcement of thermal storage, air-type solar collector, and auxiliary heating by cheap electric power at midnight was measured. Experiment mode is shown in Table 2.

Table 2 Experiment mode

	Solar heat	Auxiliary floor heating	Floor duct	Period
mode1	⍂	⍂	⍂	12/30□ 1/14
mode2	⍁	⍂	⍂	1/16□ 1/23
mode3	⍁	⍂	⍁	2/23□ 3/5
mode4	⍂	⍁	⍂	2/5□ 2/10
mode5	⍁	⍁	⍂	1/29□ 2/3
mode6	⍁	⍁	⍁	2/15□ 2/23

RESULTS

Effect of Water Floor on Temperature Uniformity

To verify the uniformity of the temperature of the water floor, the temperature change when the module was heated by electricity was measured. Figure 6 shows the measurement positions and the heating parts, and Figure 7 shows temperature changes of each part.

By heating a lower central part of the water bag with an electric heater, the temperature in each part rose at about 10°C within 7 h. During heating, the heated part was about 7°C higher than other parts. However, temperatures fluctuate in each part except at the heating part where the temperature had been kept within 2°C. Moreover, after heating stops, the temperatures become equal to temperatures of other parts in a short time. From these results, in the heating system that used the water floor, it was confirmed that uniformity of the floor surface temperature was obtained.

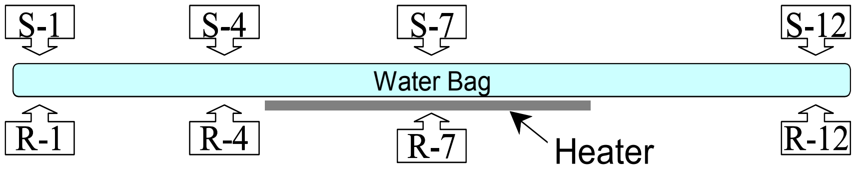

Figure 6 Measurement positions.

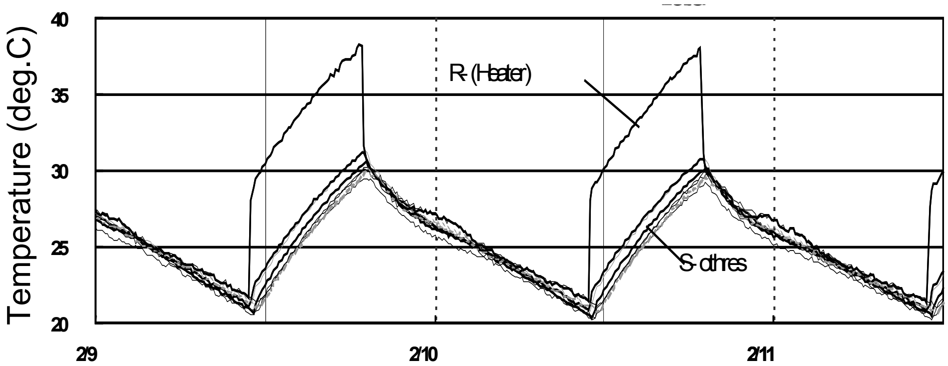

Figure 7 Surface temperature changes of water bag.

Effect of Water Floor and Air-type Solar Collector on the Indoor Climate

Figure 8 shows the room temperature change when neither auxiliary floor heating nor solar heating are done. The room temperature equally changed to the maximum temperature of outside air during the day. The change in the room temperature has been kept at about 3°C while the outside temperature was changeable by 15°C changeable in a day. Moreover, the temperature change of water bag during a day was about 1°C, and this change was one-third of room temperature's change. The water temperature decreased by about 2°C through the day when the outside temperature was low and sunshine was less.

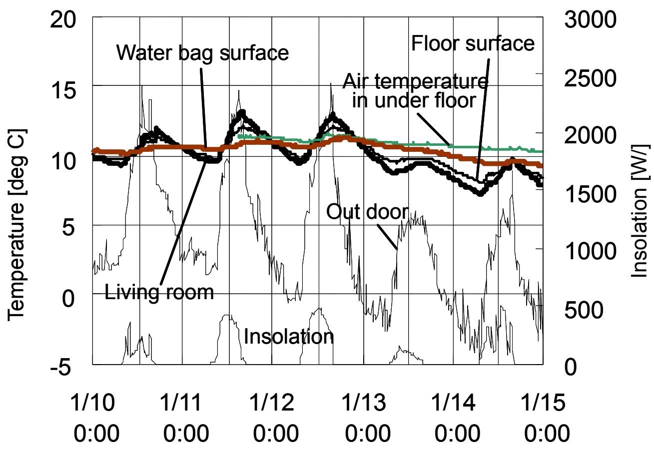

Figure 8 Temperatures and quantity of solar radiation changes (natural room temperature change).

Figure 9 shows the room temperature change when solar heating is done. The water bag was maintained at a temperature of 20–25°C. The room temperature is about 10°C, which is 5°C higher than the highest outside temperature is a good enough level for indoor environment in winter. The change of the water temperature and the room temperature are larger than natural state, but the change is steady.

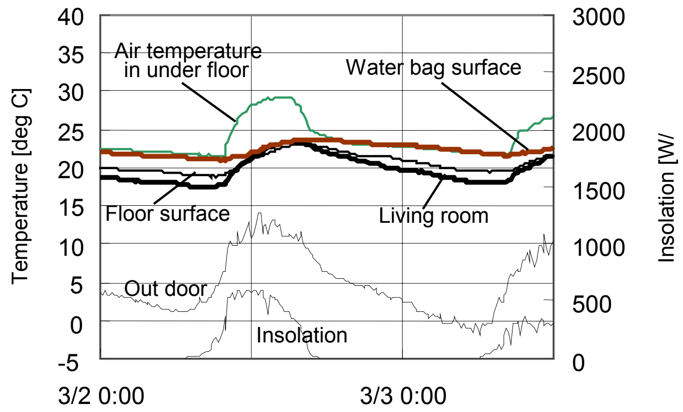

Figure 9 Temperatures and quantity of solar radiation changes (when air-type solar collector is used in daytime).

Figure 10 shows the room temperature change when auxiliary heating at nighttime is used together with air-type solar collector at daytime. The temperature decrease in nighttime is suppressed by using auxiliary heating. Moreover, the water temperature rises to make the room temperature change constant in nighttime and heat is saved. The room temperature is maintained almost 25°C or more by simultaneous use of heating by solar and electric power. However, this could lead to excessive heating of the indoor environment in winter.

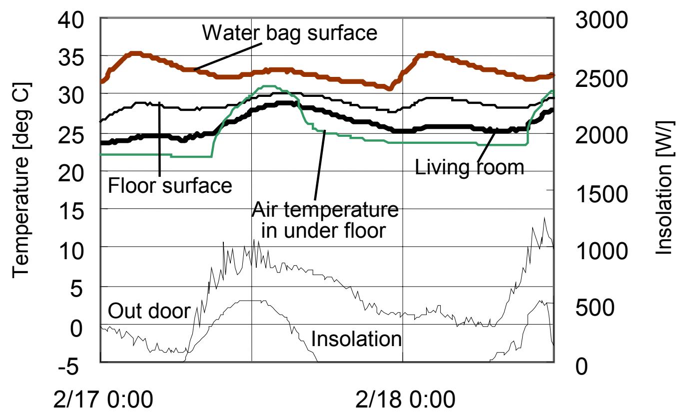

Figure 10 Temperatures and quantity of solar radiation changes (when solar and auxiliary heating are used).

DISCUSSION

In this experiment, the maximum effect of heating in this system was verified from the viewpoint of the reduction in the amount of the heating energy. In other words, to measure how the room was heated by this system, but the room temperature was not controlled. Moreover, during air-conditioning in summer, the characteristic by which a high room temperature is maintained even if it was not heated is disadvantageous. Therefore, the control of a moderate room temperature is needed for an actual introduction of this system.

CONCLUSION AND IMPLICATIONS

As a conclusion of this research, in Tokyo city that had an average climate of Japan, it was clarified that it is possible to keep the whole of the house at a uniform and comfortable temperature by using only natural energy in winter by the use of this system. Moreover, it was confirmed that this water floor system had the characteristic of working of thermal storage and maintains uniformity of floor temperature. However, further research is necessary for the adjustment to various regions where temperature and the quantity of solar radiation, etc. are different. As for research in the future, necessary amounts of thermal storage, area of air-type solar collector, and the amount of supplementary heating are required to be maintained from the measurement and the simulation to various climate conditions.

REFERENCES

Hori, Y., Ito, N., Komano, S. and Maeda, S. (2000). Thermal environment of KARUIZAWA I-House Part 1. Measurement result of 1999 winter season. Analysis by simulation. *Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan*, D2, pp. 463–464.

Ito, N., Hori, Y., Komano, S. *et al.* (1999). Study on winter thermal characteristics of integrated solar house planned with solar air collector and solar power generation on the roof and thermal storage aqua bag under the floor. Part 2. Analysis by simulation. *Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan*, D2, pp. 471–474.

Sunaga, N., Xian, Z., Hori, Y. Muro, K. *et al.* (2001). Study on the solar floor heating system with water floor by experimental house. Analysis by simulation. *Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan*, D2, pp. 517–520.

Xian, Z., Sunaga, N., Hori, Y. *et al.* (2001). Floor heat-storage system for indoor climate control by natural energy. *Summaries of Technical Papers of Annual Meeting Japan Solar Energy Society*, Japan Solar Energy Society, pp. 257–260.

Xian, Z., Sunaga, N. and Hori, Y. (2002a). Thermal performance of solar heating system with water floor. *The 19th PLEA Conference—PLEA 2002*, pp. 339–344.

Xian, Z., Sunaga, N., Hori, Y. and Muro, K. (2002b). Study on the solar floor heating system with water floor by experimental house. Analysis by simulation. *Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan*, D2, pp. 1127–1128.