Examination of Performance Improvement method of Air-based Solar Heating system in the demonstration buildings

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ABSTRACT

In this study, the targets of evaluation are the demonstration houses with air-based solar heating system which were planned and constructed in difference weather conditions in the Japan. In these buildings, we aim to reduce the half of heating, cooling and hot water load from existing system by adopting suggested factors. In the light of reviewed contents for improvement of efficiency in previous studies, the main factors are to adopt the high-performance glass in the solar collector and to install the additional heat storage such as water-filled plastic bottles. In addition to these, the performance improvement is promoted by using vacuum thermal insulation material for reducing night-time heat loss in the window, and using phase-change material (PCM) in the floor by additional heat storage. Furthermore, the solar heat utilization desiccant cooling system is installed in the buildings of 3 south warm regions, and is verified about the reduction of cooling energy consumption.

KEYWORDS

Air-based solar heating, Heat storage, Heating and Cooling load, Hot water, Measurement

INTRODUCTION

In recently, using solar heat energy has been paid attention to as effective natural energy use. In this study, we deal with air-based solar heat system, which is used for not only hot water supply but heating and ventilation by hot air. This system works as follows (shown in the Figure 1),

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a) Heating outdoor air by solar collector on the whole roof.
b) Supply heat to water tank by antifreeze fluid which received heat by heat exchanger in the air handling box in the attic.
c) Blow hot air under the floor from the fan in the air handling box.
d) Store heat into the basis concrete under the floor by hot air.
e) Heating the whole room by supplying warm air from the under floor.

In this study, we proceeded with experiment to target demonstration houses using air-based solar heating system that was planned and built in five weather conditions of Japan. It aims to reduce the half of heating/cooling and hot water energy consumption when compared the case of adopting the present system with conventional one. By contents for performance improvement in previous studies, examination system is adopted the high-efficiency solar collector, underfloor additional heat storage material (water-filled plastic bottles), interior furnishing with a built-in vacuum thermal insulation material, latent heat storage material (phase change material). In addition, solar heat utilization desiccant cooling is adopted in three warm regions of south side. Figure 2 shows improvement plan of air-based solar heating system.

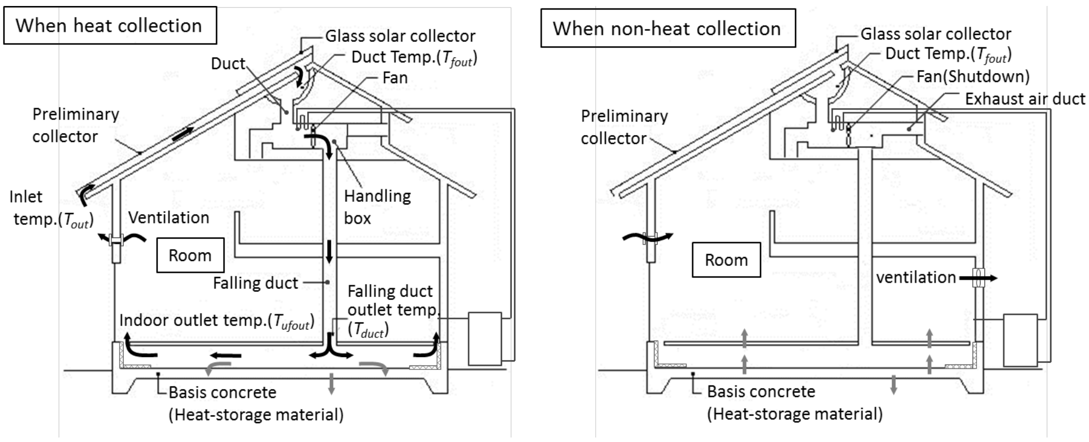


***Figure 1**. Conceptual diagram of the existing system*

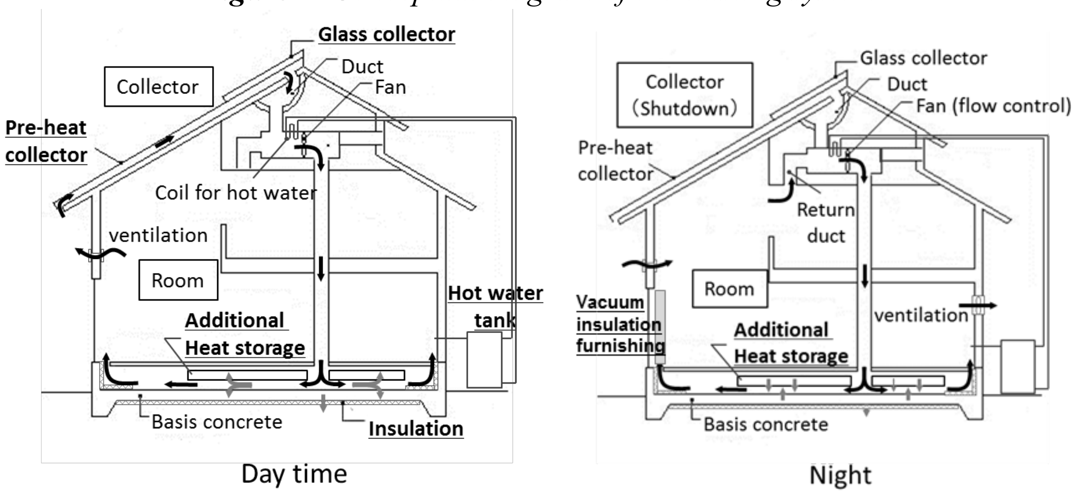


***Figure 2**. Improvement plan (system improvement is underlined)*

RESEARCH OUTLINE

In winter season, the heated air by solar collector is sent to underfloor space by handling box (HB). The heat sent to underfloor space is stored in additional heat-storage material (water-filled plastic bottles) and latent heat storage material (PCM). In night time, stored heat is radiated in underfloor space, moving indoor space by air circulation. Furthermore, night time insulation is strengthened by closing a built-in vacuum insulation material of windows. Figure 3 shows location of target demonstration houses, and Figure 4 shows the applied systems for system improvement in present study.

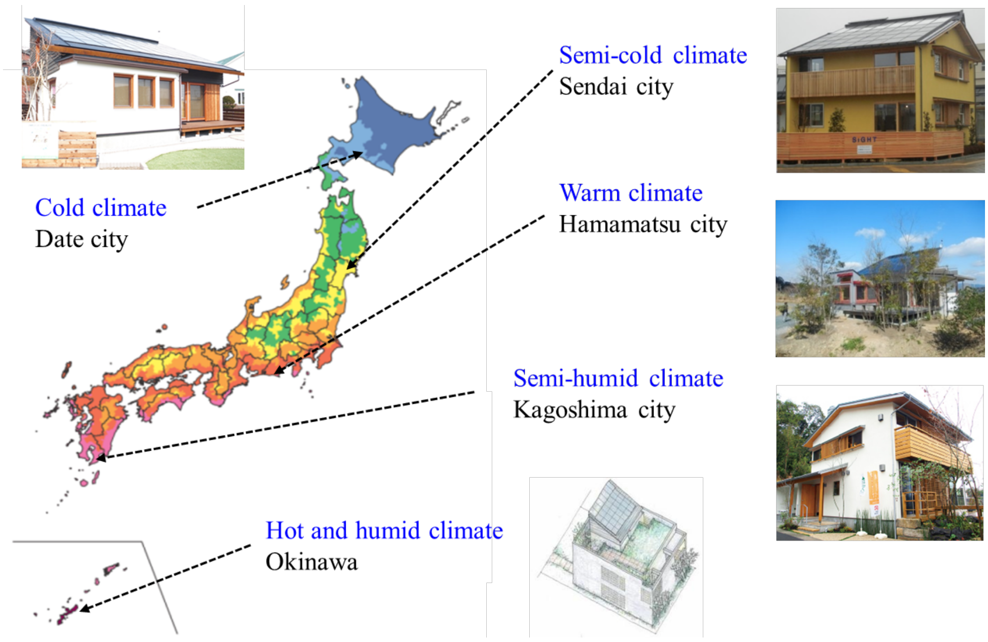


***Figure 3**. Location of target demonstration houses*

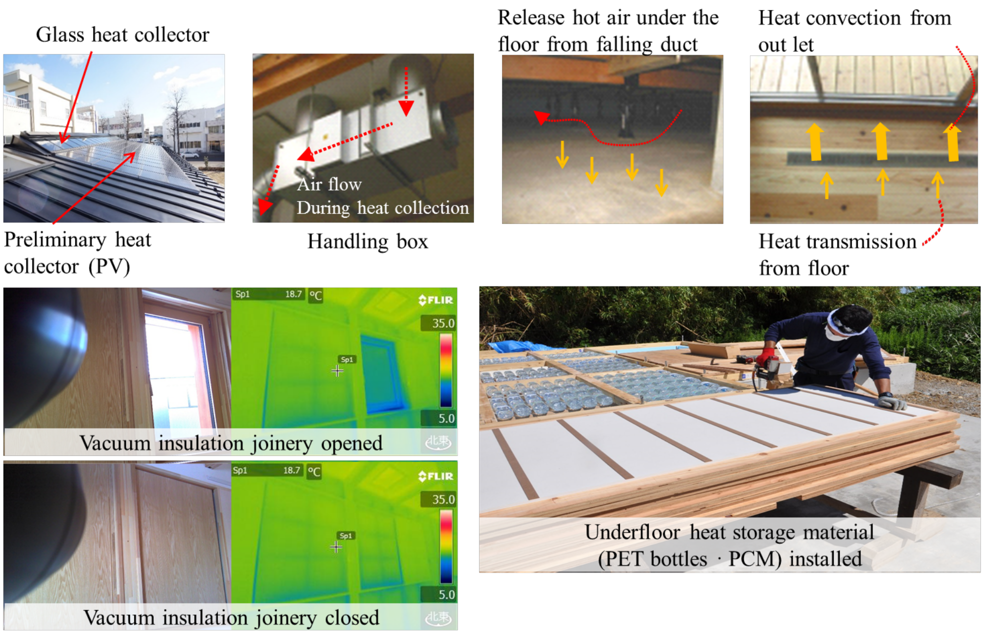


***Figure 4**. Applied systems in present study*

In this paper, the data in April 2015 to March 2016 is been evaluation target. Table 1 shows measurement schedule and condition. In April to June, the system was operated in imitation of actual condition for a week of every month. In July to September, the effects of solar cooling and solar shading were evaluated. In November to March 2016, the effect of reducing heating and hot water load was examined when using suggested system.

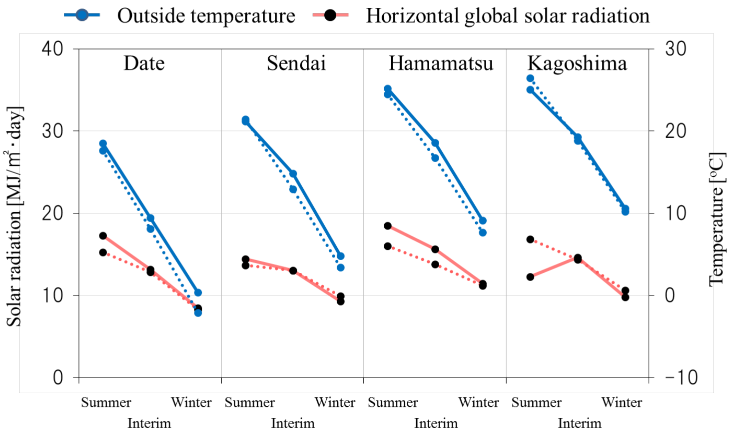
***Table 1**. Measurement schedule and condition (April 2015 to March 2016)*

	2015									2016		
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Heat collection	Winter mode	Interim period mode		Summer mode			Winter mode					
Air conditioning	Heating 20°C	Cooling 27°C		Cooling 26°C		OFF	Heating 20°C					
Ventilation	ON											
Vacuum insulation	6PM~8AM Close			Open			6PM~8AM Close					
Solar shading	Open	Close (shading)					Open					
Heat gain	24h Four 100W light bulbs							24h Two 100W light bulbs				
Hot water	Automatic hot water usage : 40°C 450L/day											

MEASUREMENT RESULTS

Weather condition

In this paper, it is indicated data of 4 regions (Date, Sendai, Hamamatsu, Kagoshima) which were measured over the whole year. Figure 5 shows weather conditions of 4 target regions. The measured data of outside temperature is similar with averaged weather data (Expanded Amedas weather data, 1991~2000 year). However, the measured summer solar radiation of Kagoshima is almost 30% smaller than standard data. By the reason, the amount of solar collection is smaller than that of common year.



(Solid line: measured data, dotted line: Expanded Amedas data)

***Figure 5**. Weather data (measured data and Expanded Amedas –average data)*

Amount of solar collection

Figure 3 shows the solar collection amount per collector area in 4 target buildings. The distribution of solar collection, in winter season, is utilized generally all for heating and hot water supply. In interim season, the collected heat is used for heating and hot water supply, and the remained heat that cannot be heat exchanged is exhausted. In summer season, the collected heat by solar collector is used primarily for hot water supply. In Hamamatsu and Kagoshima, the effect of solar cooling was examined during summer season.

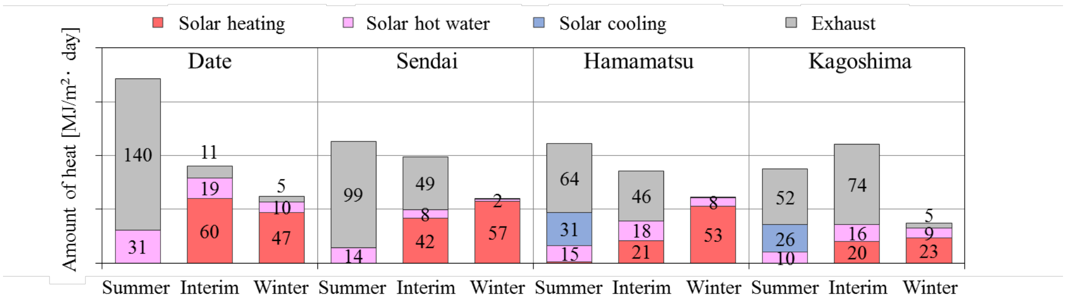


Figure 6*. Amount of solar collection*

Effect of reducing hot water load

Figure 7 shows amount of hot water load reduction for each season in 4 demonstration houses. The rate of hot water load reduction by solar collection is annual average 41% in Date, 13% in Sendai, 37% in Hamamatsu, and 41% in Kagoshima. In this study, the effect of hot water load reduction by solar collection is shown about 20~40%.

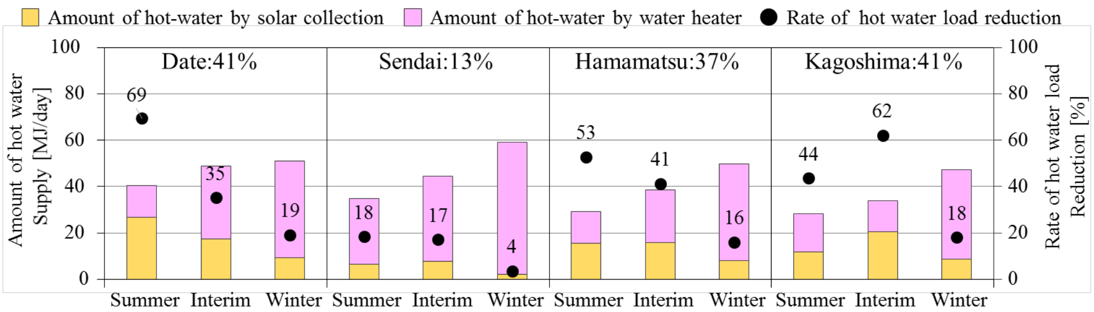


Figure 7*. Reduction effect of hot water load*

Effect of reducing cooling load by solar cooling and shading

Figure 8 shows thermal images at the time of presence or absence of solar shading (outside louvers) in Kagoshima of Sep. 8th 2015. In these images, the window surface temperature is reduced about 2~3 ºC by adapting solar shading and it is considered to contribute to reduce cooling load. Also, by calculation of light environment simulation Honeybee using the engine of Radiance, it is confirmed the amount of obtaining solar radiation is reduced about 30%. The processing heat amount of solar cooling is shown about 30% by calculation using wind volume and difference of enthalpy in supply and return air (figure 9).

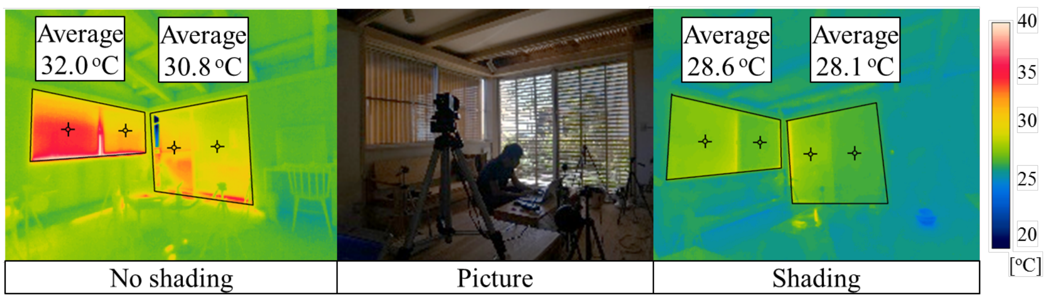


Figure 8*. Effect of solar shading*

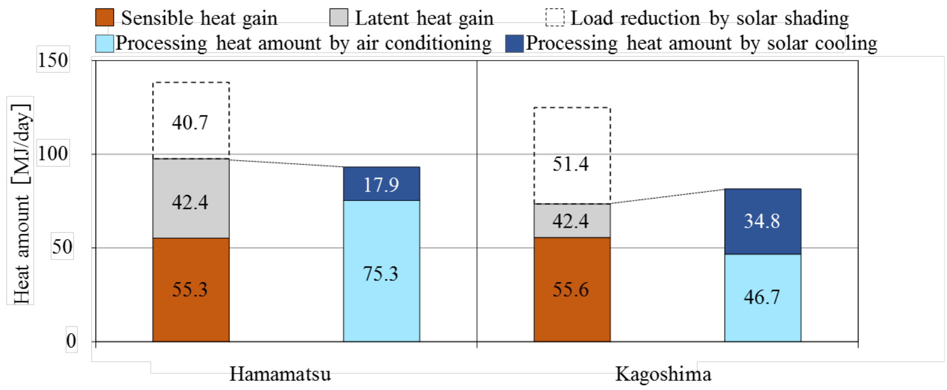


***Figure 9**. Heat balance in Aug. to Sep. 2015 (Hamamatsu and Kagoshima)*

Effect of reducing heating load

Figure 10 shows heat balance of 4 buildings in winter. It can be seen that solar heat (solar collector and direct gain through windows) is obtained average 27% in Date, 64% in Sendai, 76% in Hamamatsu, and 45% in Kagoshima.

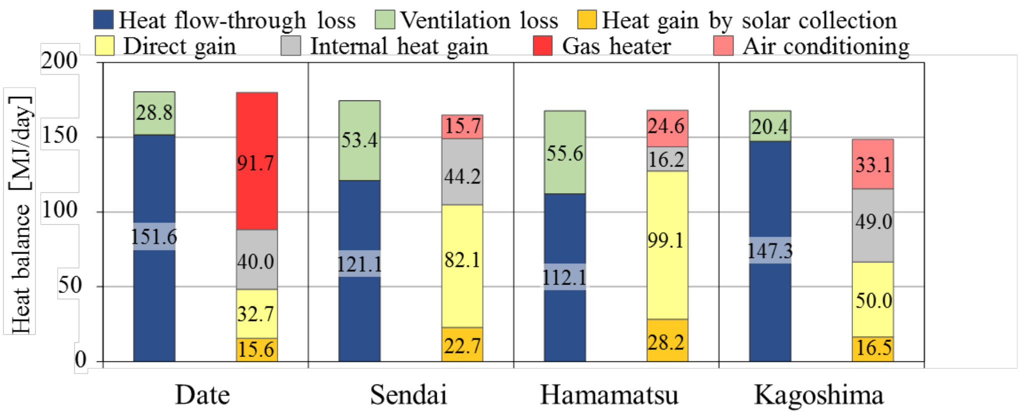


***Figure 10**. Heat balance of 4 target buildings*

CONCLUSION

In this paper, we show the measured results of the year of 4 properties demonstration houses located in different regions and weather conditions.

1) The heat of about 70~180MJ/m^{2}day is obtained by solar collection. The heat was utilized depending on the season for each of the applications. In the hot water, the annual load is reduced about 20~50% by solar collection.

2) The cooling load was reduced about 30% by solar shading and 30% by solar cooling system.

3) In winter, heating load was reduced about 60% by solar heat gain such as solar collection and direct gain.

REFERENCES

Shuya MORITA, Youngjin Choi, et al. 2015. A Study of Demonstration Houses with Air-Based Solar System, 1~3, The Society of heating, Air-Conditioning and Sanitary Engineers of Japan