An Influence of Thermal Storage Wall and Intermediate Space on the Trombe Wall System on the Energy Gain

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ABSTRACT

Recently, there is growing interest in the passive solar system in order to realize energy saving in structures. However, among the passive solar systems, there is lack of appropriateness evaluation on the conditions of composition of the trombe wall system's thermal storage wall. This study employed TRNSYS 17 in order to evaluate the thermal performance of the trombe wall according to the conditions of composition of the thermal storage wall in the structures using the trombe wall system. Comparing the thickness, interval between intermediate spaces, materials, and inlet area of the thermal storage wall, this study evaluated the thermal performance of the trombe wall system. And it has found that there was great effect according to the conditions of composition, and there was particularly great thermal performance according to the materials used. And if there are experiments and examinations based on actual measurement for the conditions and materials being presently applied, it is expected that the materials for excellent thermal storage performance and insolating performance and also the optimal conditions of composition will be possibly applied to the trombe wall system.

KEYWORDS

Passive Solar System, Trombe Wall, Energy Simulation

INTRODUCTION

Solar energy has rich energy resource without pollution and it is also easy to use that it has been very popular as the powerful alternative energy source. Therefore, there have been numerous studies to advance the technology by effectively using the solar energy as new recycled energy. (Wei Sun et al. 2011, Noh Ji-Hee et al 2004, Yoon Jong-Ho et al 2008) From the methods to facilitate the solar energy into building structures, the trombe wall system of passive solar system has its advantage in relatively easy to introduce with not much of initial

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investment cost as well as semi-perpetual availability that the Korean government also positively support the system. (S.S. Chandel et al 2008)

In addition, buildings that applied the passive solar system reduce the indoor heating and cooling energy while improve the pleasant interior temperature (Samar Jaber et al 2011) but the quantitative evaluation has yet to be sufficient. Energy gain and performance of trombe wall system are significantly influenced by materials used in the thermal storage wall.

In This study selected concrete, earthen bricks, and water were used as materials of thermal storage wall. the energy simulation was used to evaluate the energy capability of the trombe wall following the thickness of thermal storage wall, interval of intermediate space, materials and vent outlet area of the trombe wall system. Furthermore, by reviewing the trombe wall and energy flow into the inside, it evaluates the usefulness of the trombe wall system.

RESEARCH METHODS

The Previous studies were limited to the thermal capability evaluation following the materials of the thermal storage wall (Noh Ji-Hee et al 2004, Kyung-Su Park et al 2012), but In this study the energy simulation program, TRNSYS 17, was used to review the energy capability of the trombe wall following the thickness of thermal storage wall, interval of intermediate space, materials and vent outlet area of the trombe wall system.

The unit module was set to make the thermal capability evaluation of the trombe wall system and it applied one-year worth of climate data in the Gwangju area of Korea in the TMY 2 (Typical Meteorological Year version) type as provided by TRNSYS 17. By comparing the surface temperature of the wall and energy volume of the thermal storage wall, the thermal capability of the trombe wall system was reviewed, and, for making a little bit more detailed interpretation, the representative dates (Jan. 1 ~ Jan. 3) were set forth to make the comparative analysis.

In order to evaluate the capability of the trombe wall system, it used the Type 36 (Thermal Storage Wall). It applied Mode 4 that controls the air flow formed from the intermediate space between the thermal storage wall and the external glass due to the temperature difference. The thermal interpretation on the module of standard unit used Type 56 (Multi Zone Building) that makes detailed interpretation for dynamic thermal phenomenon of buildings. Figure 1. shows the cross section of the standard model. It was structured in the width of 4m, height of 3m, and length of 5m.

Characteristics for each material of the trombe wall system for the heat capability simulation is shown on Table 1.

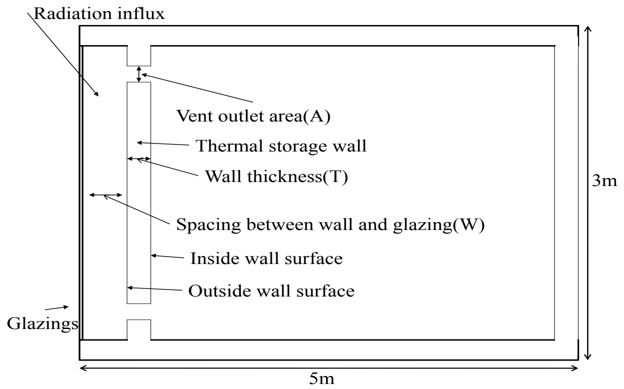


Figure 1. *Cross-section drawing of the subject space*

__Table 1.__ Characteristics of trombe wall for each material

	Concrete	Earthen bricks	Water
Wall conductivity(W/mk)	1.4	0.73	0.6
Specific capacitance of wall (kJ/m^3K)	2060	1300	4186
Spacing between wall and glazing(m)		0.1, 0.3, 0.6	
Wall thickness(m)		0.3, 0.6, 1	
Vent outlet area (material)		0.1, 0.3, 0.5	
Wall height		2.7m	
Wall width		3.4m	
Wall solar absorptance		0.9	
Wall emittance		0.94	
Glazing emittance		0.9	
Number of glazings		2	
Extinction		0.0524	
Refractive index		1.526	
Distance between vents		2m	

Figure 2. shows the gross solar radiation and ambient temperature of the representative heating period in winter and, in order to analyze the simulation result in effective ways, it is set forth as the standard model to compare the value applied. The materials of the standard model are concrete, earthen brick and water, and all have the interval of intermediate space for $0.3m^2$, thermal storage wall thickness of 0.3m, and vent outlet area of $0.1m^2$. And, with the interpreted result, effective model was found to make the comparison and analysis with the model applied with the variable.

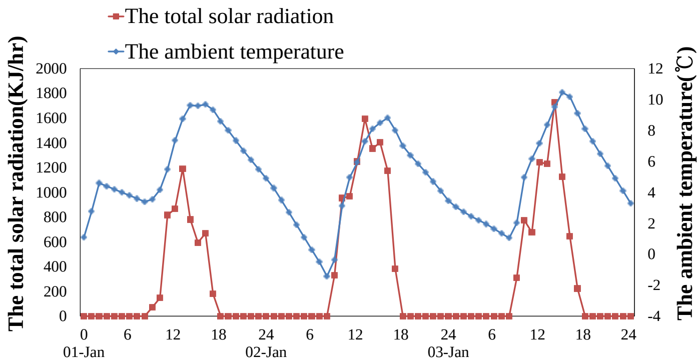
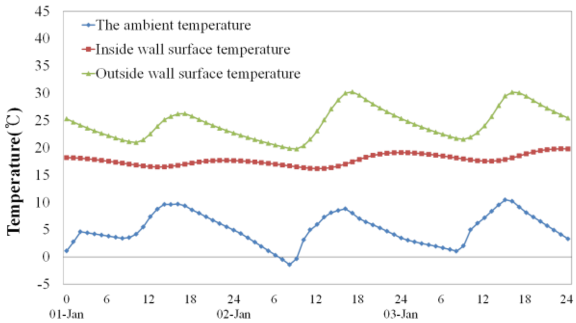


***Figure 2** Total solar radiation and ambient temperature of representative date*

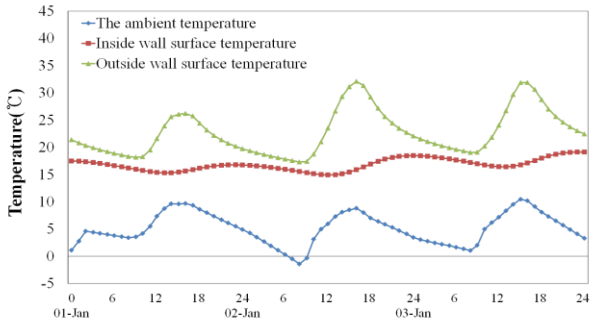
RESULTS

In order to make the detailed thermal capability evaluation of the winter trombe wall system, three days of winter (Jan. 1 ~ Jan. 3) were analyzed and the ambient temperature of the standard model and the surface temperature of inner and outer thermal storage wall are shown in Figure 3. The surface temperature of inner and outer thermal storage wall was higher in the earthen brick thermal storage wall than the concrete thermal storage wall and the water thermal storage wall than the earthen brick thermal storage wall.

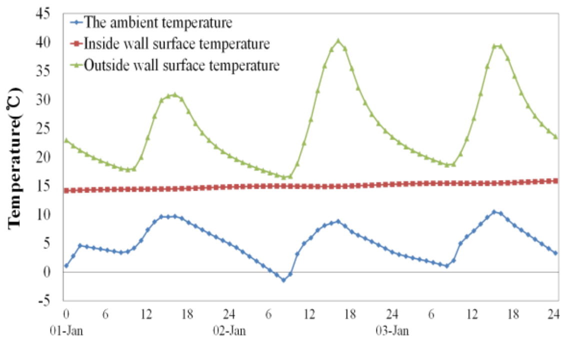
The energy gained for each material of 3 representative days is shown on Figure 3. The concrete thermal storage wall was 69.1 MJ and, in the event of the earthen brick thermal storage wall, it was 74.1MJ. And, in the event of the water thermal storage wall, it acquired 77.4MJ. Comparing the concrete thermal storage wall and the earthen brick thermal storage wall, the thermal capability of the earthen brick thermal storage wall was inferior to the thermal capability of the concrete thermal storage wall. However, the reason for having such a result is attributable to have low heat loss from the low heat acquisition and heat transfer rate by the atmospheric flow which is a characteristics of the trombe wall. In the event of the water thermal storage wall, it has high thermal storage capability with lowest heat transfer rate that it has the most outstanding capability as the thermal storage wall from the materials. Looking into the change of the interior surface temperature of the thermal storage wall for each material, the water thermal storage wall that has relatively lower heat transfer rate and higher thermal storage capability showed smaller interior temperature change to be more advantageous condition to build pleasant inside space.



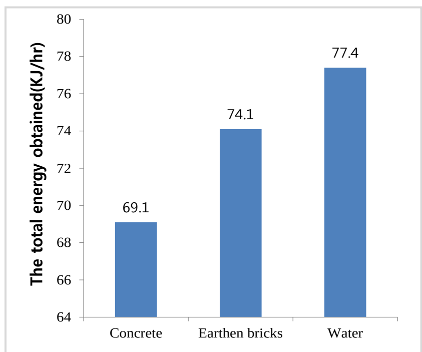
(a)Material(Concrete)



(b) Material(Earthen bricks)



(c)Material(Water)



(d) The total energy obtained

Figure 3 *Surface temperature of the water thermal storage wall and the total energy obtained for each material*

The interpretation result showed that the energy gain in water thermal storage wall was the highest and the energy gain of water thermal storage wall is shown as Table 2. The gross energy acquisition volume of the water thermal storage wall was 77.4MJ, and in the event that the intermediate space had the interval of 0.1m, it was the same for 77.4MJ, but in the event that it was set for 0.3m, it acquired for 72.2MJ. And, in the event of 0.6m, it acquired 68.6MJ. Looking at this fact, the intermediate space showed more advantageous aspect in acquiring the energy as the intermediate space interval is narrower. The reason is that the narrow intermediate space interval has small air flow to reduce the heat loss from outside where the air layer is formed.

When comparing the energy acquired by inputting the variables with the thermal storage wall thickness, 0.3m had 77.4MJ, and 0.6m had 65.7MJ, and 1m had 63.2MJ. This result showed that the thickness of the thermal storage wall did not make the heat storage capability better. The reason is that the thicker thickness takes long time to deliver the impact to the interior that it may be lost in the intermediary term or have small volume to deliver. When comparing the energy acquired by inputting the variables with the inflow area, 0.1m^2 had 77.4MJ, 0.3m^2 had 79.1MJ, and 0.5m^2 had 76.2MJ. The value for 0.3m^2 was the largest since it had the most appropriate intermediate space interval for 0.3m^2. 0.1m^2 had the narrow vent outlet area that the heat was not effectively delivered while 0.5m^2 had broad vent outlet area that the heat flew in well but also had significant heat loss.

Table 2 *The energy gained from water thermal storage wall*

Spacing between wall and glazing(m)	Wall thickness(m)	Vent outlet area (material)	The total energy obtained(MJ)
0.1	0.3	0.1	77.4
0.3	0.3	0.1	72.2
0.6	0.3	0.1	68.6
0.1	0.6	0.1	65.7
0.1	1	0.1	63.2
0.1	0.3	0.3	79.1
0.1	0.3	0.5	76.2

CONCLUSION AND IMPLICATIONS

In this thesis, the evaluation was made for the heat storage capability of the trombe wall for thermal storage wall material, thickness, intermediate space interval and vent outlet area. The standard model of the trombe wall by using concrete, earthen brick and water of thermal storage wall was set with the thermal storage capability simulation with the following result.

During the heating period (Jan. 1 to Jan. 3), one that has the highest total energy gain was the trombe wall that used water, and this is attributable to low heat transfer rate and high heat storage capability. As a result of comparing for analysis with each of the variables, the intermediate space interval was efficient for 0.1m while the thermal storage wall thickness was efficient for 0.3m. And, the vent outlet area was analyzed as efficient for 0.3m^2.

In the intermediate space interval, 0.1m had small air flow to prevent the interior heat loss. The reason that the thickness of thermal storage wall for 0.3m had relatively fine was that the thermal storage capability is not great if the thermal storage wall thickness is thin and the heat transfer into the interior is slower. In other word, the thickness was appropriate. And, the efficiency following the vent outlet area was efficient for 0.3m^2. The reason is that, if the vent outlet area is too narrow, the heat flow is not well made, and if it is too large, the loss is greater that appropriate area has to be determined.

This thesis was limited to analyze the heat storage capability of the trombe wall system for each variable and for each material through the simulation. However, the material in water has outstanding heat storage capability but it has some problem in applying for the thermal storage wall. In order to apply water as the thermal storage wall, it would require the development of effective container through many advanced researches. Thereafter, it requires the study to verify the model to evaluate the energy capability of the trombe wall system. And, it requires the optimization of verified model and the CFD interpretation is used to make the detailed interpretation and intermediate space on interior heat and air flow transfer.

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