Heat transfer of green timber wall panels

Yun-Hui Kim[1], Sang-Sik Jang[1]*, Il-Joong Shin[1]

[1]Dept. of Bio-based Materials, Chungnam National University, Deajeon 305-764, Republic of Korea

그린팀버월 패널의 열전달 특성

김윤희[1] · 장상식[1]* · 신일중[1]

[1]충남대학교 환경소재공학과

Received on 7 January 2011, revised on 25 January 2011, accepted on 9 March 2011

Abstract : 20% of total energy use to sustain temperature of building inside. In this reasons, researchers effort to improve the thermal insulation capacity with new wall system. Using appropriate materials and consisting new wall system should considered in energy saving design. OSB(Oriented strand board), Larch lining board used to consist wall system. 2x6 Larch lining board has tongue & groove shape for preventing moisture. Comparing with gypsum board and green timber lining board as interior sheathing material, temperature difference of Green timber wall system was bigger than temperature difference of gypsum board wall system. This aspects indicate that Green timber wall system was revealed higher thermal insulation property than gypsum board wall system. Gypsum board portion transfer heat easily because temperature difference gradient of gypsum board wall system was smaller than OSB wall system. Total temperature variation shape of G-4-S and G-6-S show similar model but, temperature variation shape in green timber wall portion assume a new aspect.

The purpose of this study was that possibility of thermal insulation variation and new composition of wall system identify to improve thermal insulation performance. In the temperature case, this study shows possibility of improving thermal insulation performance. Humidity, sunshine and wind etc. should considered to determine building adiabatic properties.

Key words **:** Heat transfer, Green Timber Wall panel, Thermal resistance, Boundary temperature

I. Introduction

Since the energy crisis at 1973, the interest about building adiabatic properties has been increased in order to reduce the heating and air conditioning energy which occupy 70% of consumed energy at building. The good adiabatic properties are indispensible for building to control temperature. That is, the good adiabatic properties are required to losen heating and air conditioning cost at any seasons(David et al. 1991).

There are three modes of heat transfer : conduction, convection, and radiation. Generally all three modes of heat transfer are important when calculating energy transfer. In any normal situation, all three modes of heat transfer may not occur simultaneously, or one mode may dominate other modes of heat transfer. The heat transfer mechanism should be understood in order to design such a system. The most popular insulation materials were glass fiber and urethane board in wood frame house. The exterior materials were used usually in water protected and preservatives, interior finish of wall and ceiling were used the gypsum board and the floor was used the hardwood flooring in general.

The purpose of this study was that possibility of thermal insulation variation and new composition of

***Corresponding author:** Tel: +82-42-821-7844
E-mail address: ssjang@cnu.ac.kr

wall system identify to improve thermal insulation performance.

II. Materials and methods

1. Materials

2 × 4 and 2 × 6 stud used to make 900 mm × 900 mm basic wall system. Specimens classified into three groups. Gypsum board, OSB(Oriented strand board), Larch lining board used to consist wall system. 2 × 6 Larch lining board has tongue & groove shape for preventing moisture. Process of making specimens depends on KS F 9002 : 2001(Standard practice for constructing structural parts of light-frame wood buildings). Table 1 shows name of model and point of sensors. All specimens side face covered with house wrap. General materials, thermal insulation(R-11, R-19), used to check real values for application.

2. Test methods

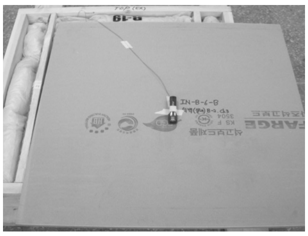
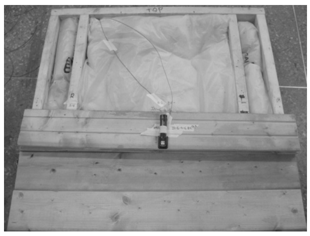
Test machine set Inside environment(25℃ , 95% RH) and exposure environment(-20℃, 30%RH) to evaluate building adiabatic properties. Over 30 mm thickness polystyrene foam cover with side faces of all specimens for preventing loss heat. In addition, side faces of specimens treat with housewrap and moisture preventing tape. Temperature and humidity of each layer measured every 30 minutes in 48 hours. Line type temperature sensor use to measure surface temperature on layers and related humidity sensor set in space of each layer to check related humidity of air. Temperature sensor set up center of stud portion because that considered major factor to evaluate thermal conductivity. Fig 1. shows testing machine, measurement instruments and sensors.

Different materials transfer heat by conduction at different rates, which is measured by the material's thermal conductivity. The heat transfer rate is usually expressed by the symbol "q". It should be noted that although we are interested in total heat transfer, heat is not a directly measurable quantity.

$$q = -kA\frac{dT}{dx}$$

where

Table 1. Wall assemblies.

		
B-B	B-S	G-G

S : 11.1mm OSB(Oriented strand board) G : 35mm larch lining board B : 12.5mm Gypsum board

Fig. 1. Instrument of thermal insulation & sensors.

q = Heat transfer rate, Btu/h or W

k = Thermal conductivity, Btu/(h ft ˚F) or W/(m ℃)

A = Area normal to the heat flow, ft^2 or m^2

T = Temperature, ˚F or ℃

$\frac{dT}{dx}$ = Temperature gradient, ˚F/ft or℃/m.

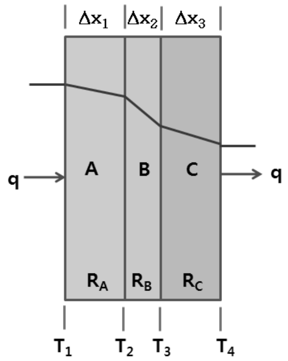


Fig. 2. One dimensional heat flow through a composite wall with the corresponding electrical analog.

The heat can flow in all three directions depending on the system. First, the energy balance equation is derived by considering heat flow in all three directions. This equation then can be simplified to address heat flow in a one-dimensional body. In the very thin layer, generally known as a boundary layer, the heat transfer may be by conduction.

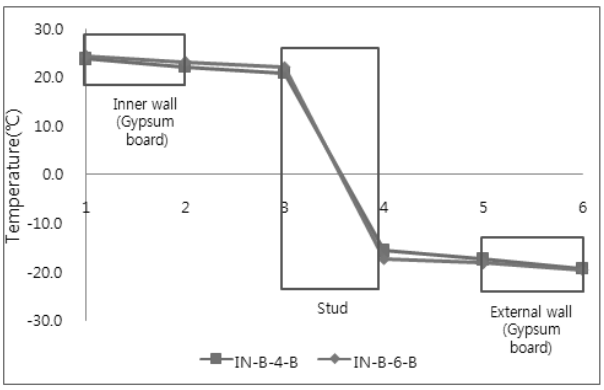
Home insulation is thus a poor thermal conductor, which keeps as much heat in as possible. Instead of being rated in terms of thermal conductivity, insulation is therefore usually rated in terms of its thermal resistance. In a steady-state conduction problem, it is possible to model heat transfer by a technique called thermal resistance. The thermal resistance(R') is analogous to electrical resistance, and q and dT may be viewed as the current and potential difference in Ohm's law, respectively. Like an electrical circuit, the thermal resistance may be in series and thus provides a very useful method of analyzing heat transfer through a composite wall or slab made up of layers of dissimilar material.

$$R' = R_A + R_B + R_C = \frac{\triangle x_1}{k_1 A} + \frac{\triangle x_2}{k_2 A} + \frac{\triangle x_3}{k_3 A}$$

The thermal resistance model works much like the electrical resistance model.

III. Results and discussion

12.5 mm gypsum board used to make specimen as sheathing material of interior wall. Thermal insulation material placed between stud, R-11 fiberglass thermal insulation for 2x4 stud and R-19 fiberglass thermal insulation for 2x6 stud. Fig 3~5. indicate surface temperature of each layer and air temperature of space layers from inside(room temperature) to outside(exposure environment). Maximum Temperature difference found in thermal insulation material portion. Temperature difference of B-6-B was 6℃ bigger than the Temperature difference of B-4-B because of stud thickness difference and thermal insulation thickness difference.



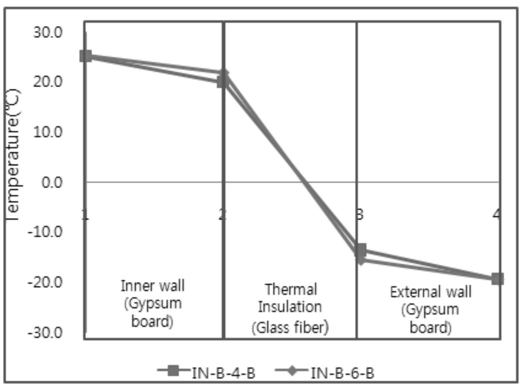


Fig. 3. Temperature of B-B wall system layers.

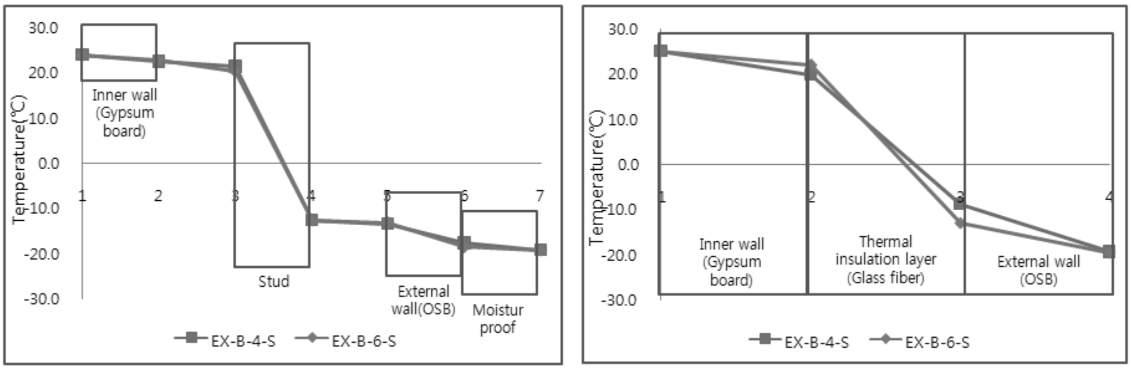


Fig. 4. Temperature of B-S wall system layers.

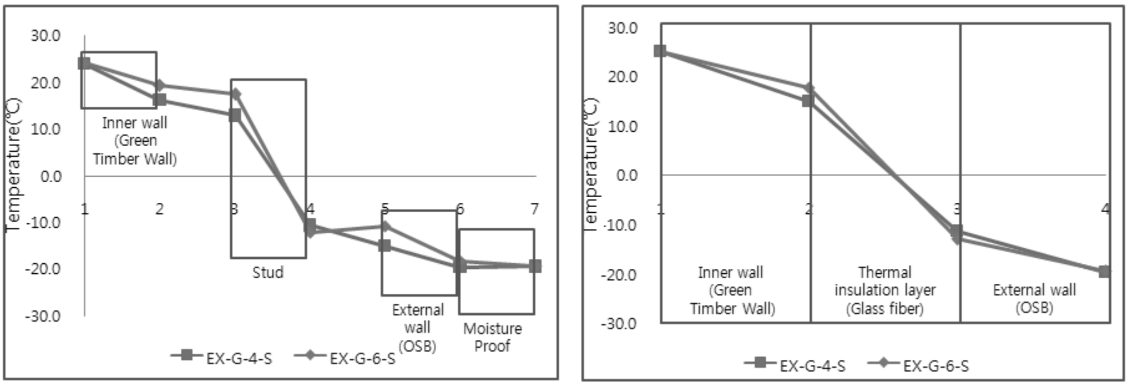


Fig. 5. Temperature of G-S wall system layers.

11.1mm OSB used to consist of exterior wall as sheathing material and 12.5mm gypsum board used to make interior wall as sheathing material. Thermal insulation thickness difference shows 4.1℃ temperature difference variation with B-6-S and B-4-S.

Special ordered Green timber lining board applied to wall system as interior sheathing material and 12.5mm gypsum board applied to exterior sheathing material. Total temperature variation shape of G-4-S and G-6-S show similar model but, temperature variation shape in green timber wall portion assume a new aspect. Also, the temperature difference gradient of thermal insulation material portion steeper than the temperature difference gradient of green timber sheathing panel portion in the Fig 3~5. Heat transfer coefficient of fiber glass is a quarter of heat transfer coefficient of timber. This property could be a main factor to improve thermal insulation performance.

Comparing with gypsum board and green timber lining board as interior sheathing material, temperature difference of Green timber wall system was bigger than temperature difference of gypsum board wall system.

This aspects indicate that Green timber lining board was revealed higher thermal insulation property than gypsum board.

Gypsum board transfer heat easily because temperature difference gradient of gypsum board wall system was lower than OSB wall system. Dew condensation occurred in every wall systems like Fig 6~8.

Energy instrument measured energy to sustain inside environment, 25℃, RH95%. On contrary to 2 × 4 wall system, 2 × 6 wall system help reducing energy using amounts.

Fig. 6. Failure mode of B-B wall systems.

Fig. 7. Failure mode of B-S wall systems.

Fig. 8. Failure mode of G-S wall systems.

B-B

	R
External wall	0.050
Gypsum board	0.089
Glass fiber	2.968
Gypsum board	0.089
Inner wall	0.13
Total	3.326
K	**0.30**

B-S

	R
External wall	0.050
OSB	0.074
Glass fiber	2.968
Gypsum board	0.089
Inner wall	0.13
Total	3.311
K	**0.30**

G-S

	R
External wall	0.050
OSB	0.074
Glass fiber	2.968
Green Timber Wall	0.233
Inner wall	0.13
Total	3.455
K	**0.29**

Fig. 9. R-value of wall systems.

IV. Conclusions

1. Green Timber Wall system has more high Insulation performance than Gypsum board wall system because slope of thermal at Green Timber wall system steeper than Gypsum board wall system.
2. Heat resistance rates of Green Timber wall system similar to OSB Wall system.
3. Thick wall system has more high insulation performance in same insulation material.

According to this results, light frame wall system need to change wall insulation system depend on requiring 0.10~0.15 W/(m^2K) of Heat transfer coefficient (U-value) at Passive house. Moreover, appropriate wall composition and thickness should consider to make effective structure. This paper shows that Green Timber wall system has good insulation performance depend on heat transfer. This paper in order to check Insulation performances of Timber construction wall systems in part of heat transfer and make improving methods. However, moisture, sunshine, wind, fire resistance and other factors should consider to determine Insulation performances of wall system.

Acknowledgement

This work was supported by 'Development Technology of Agriculture and Forestry Project (2009)' funded by the Korea Institute of Planning and Evaluation for Technology of Food, Agriculture, Forestry and Fisheries, Republic of Korea.

References

1. Kawasaki T, Kawai S. 2006. Thermal insulation properties of wood-based sandwich panel for use as structural insulated walls and floors. J. Wood Sci. 52: 75-83.
2. Shim KB, Lee JJ. 1995. Finite element analysis of adiabatic properties for the wall system in wood frame house. Kor. Wood Sci. 23(3): 48-57. [in Korean]
3. Holman JP. 1990. *Heat Transfer*. 2nd ed. McGraw Hill.
4. Kim MH. 1991. A study of the adiabatic materials and adiabatic method. Review of Architecture & Building Sci. 35(5): 29-35. [in Korean]
5. Kim SW. 1992. Inside and outside insulation for building. Review of Architecture & Building Sci. 36(6): 28-31. [in Korean]
6. KS. 2008. Building components and building elements -Thermal resistance and thermal transmittance - Calculation method. In *KS L ISO 6946:2008*. [in Korean]
7. KS. 2010. Test methods for thermal transmission properties of thermal insulations. In *KS L 9016:2010.* [in Korean]
8. Larsen SF, Filippin C, Lesino G. 2009. Thermal behavior of building walls in summer : Comparison of available analytical methods and experimental results for a case study. Building Simulation 2(1): 3-18.