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Evaluation of Building Energy Savings According to the Thermal Performance Experiment of PCM Floor Heating System

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Abstract **-** This study proposes a floor heating system utilizing phase change materials to reduce energy consumption and greenhouse gases in residential buildings compared to existing floor heating system. PCM floor heating system was developed by inserting PCM modules and PCM aluminium packages between mortar layer and insulation layer. Preferentially, aluminium containers with Phase change materials were analysed to evaluate the potential thermal performance for storing sensible and latent heat. After thermal performance experiment conducted by 3 different melting points of PCM, 37℃, 41℃ and 44℃, building energy saving effects were evaluated through energy simulation (Energy-Plus) of PCM floor heating system which was applied to residential building. The results of simulation were found that RT 44 PCM (melting point is 44℃) was adequate material to show thermal performance, and total energy was saved about 44.81 kWh, 0.11 kWh per square meter during winter, from October 1 to March 31.

***Keywords*:** PCMs (Phase Change Materials), Building Energy Savings, Thermal Performance Experiment, Floor Heating System

1. Introduction

In recent years, 'energy saving' has become one of the primary aims of energy policy in many countries. In Korea that relies on imports for energy needs more than 90%, especially, the efforts for energy saving are much more important. In case of building system in Korea, most of buildings use floor heating system (FHS). Due to low heat storage performance of existing FHS, however, it requires continuous hot-water supply for maintaining comfortable floor surface temperature leading to excessive energy consumption in building. Among the many ways to reduce energy consumption in buildings, PCMs (Phase change materials) are used with various building materials in order to increase thermal insulation property and their thermal mass.

Therefore, this study aimed at reducing heating energy by applying packing-type PCM to floor heating system for compensating the problems of existing FHS. Preceding researches were analysed to compute optimal temperature of floor and a thermal performance experiment was conducted by 3 different melting points of PCM, 37℃, 41℃ and 44℃. Lastly, building energy saving effects were evaluated through energy simulation of PCM floor heating system which was applied to residential building.

2. Methodology

2.1. Developing PCM floor heating system

PCM is a substance which is capable of storing and releasing large amount of energy through phase changes at a certain temperature. It has advantages in being able to adapt to various temperatures and being suitable for the fields of its usage and its purpose [1]. While FHS is organized in order with concrete, insulation, mortar and floor finishing as shown in Fig. 1 [2], PCM floor heating system was developed by inserting PCM modules and PCM aluminium packages between mortar layer and insulation layer as shown in Fig. 2. Considering height of light-weight aerated concrete of existing floor heating system, height of PCM module was adjusted to10 mm.

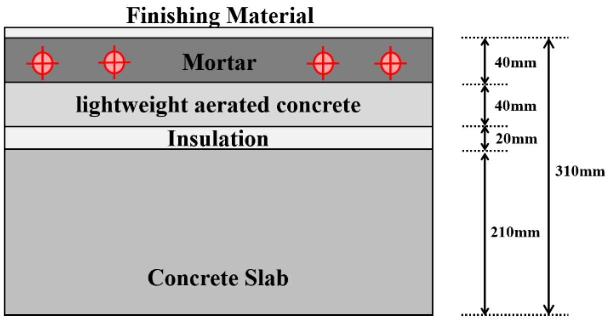


Fig. 1: Cross-sectional diagram of existing floor heating system.

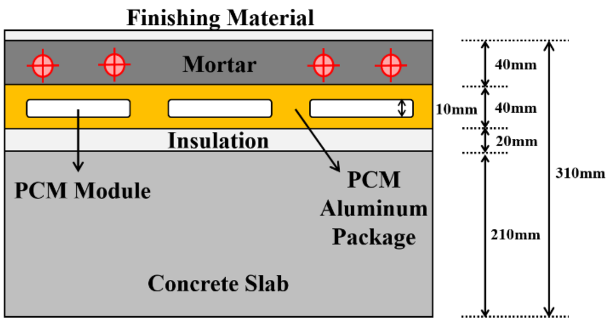


Fig. 2: Cross-sectional diagram of PCM floor heating system.

2.2. Selecting melting points of PCM

Assuming that the indoor temperature 1 m apart from the floor is 22℃, formulas and mathematical model of calculating the temperature of PCM satisfying the range of comfortable temperature are as followings, Fig. 3, equation (1) and (2) [3].

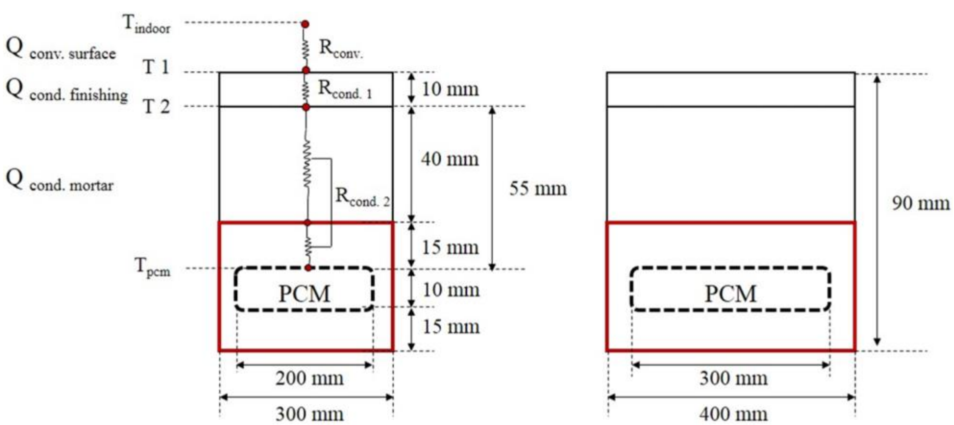


Fig. 3: Mathematical models of PCM floor heating system.

$$Q_{cond.} = \frac{T_{high} - T_{low}}{R_{cond.}} \text{ [w]} \tag{1}$$

$$Q_{conv.} = \frac{T_{indoor} - T_1}{R_{conv.}} \text{ [}w\text{]} \tag{2}$$

The surface temperature distribution of each layers showed in the [Table 1] based on the calculation of [Formula 1] and [Formula 2]. As a result of calculation by different melting point of PCM (32 ℃, 35 ℃, 37 ℃, 41 ℃, 44 ℃), the range of comfortable temperature on floor surface was from 26.2℃ to 31.1℃. According to the results of preceding research [4-5] about comfortable surface temperature of floor heating system that the temperature range was from 28℃ to 31℃, 3 types of PCM which melting point is 37 ℃, 41 ℃ and 44 ℃ were found to satisfy the comfort range.

Table 1: Calculation results of surface temperature of each layers.

No.	Indoor (℃)	Floor surface (℃)	Mortar surface (℃)	Melting point of PCM (℃)
1	22	26.2	29.1	32
2		27.4	31.1	35
3		28.2	32.4	37
4		29.1	35.3	41
5		31.1	37.4	44

2.3. Thermal Performance Experiment

A thermal performance experiment of 3 types of PCM selected by calculation results was conducted in a thermostatic chamber with a size of 450 mm × 550 mm × 500 mm [Fig. 4]. 3 types of different PCM of which melting point is 37℃, 41℃, 44℃ respectively was covered with aluminium to approve heat conductivity and the weight of each packing-type PCMs is equally 500 g [Fig. 5]. Then, the temperature change of PCM was measured by setting thermostatic chamber from 5℃ to 55℃.

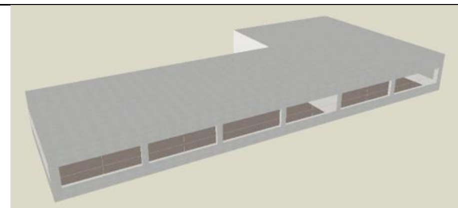
Fig. 4: Thermal performance experiment by thermostatic chamber.

Fig. 5: Packing-type PCM.

2.4. Energy Simulation

A general residential building model in Korea was analysed by Energy-Plus as shown in [Table 2]. PCM floor heating system and existing floor heating system which was applied to residential building were compared to evaluate energy saving effects in winter, from October 1 to March 31. Input data of outer walls, windows, roofs, HVAC systems, weather data and schedules are set under the same conditions presented in Energy-Plus examples.

Table 2: Overview of simulation model.

Item	Factor	Simulation Model
Story height	3.6 m	
Area	400 m^2	
Total area	400 m^2	
Direction	South	

3. Results

3.1. Thermal performance measurement of PCM

[Fig. 6] showed a pattern of temperature change by PCM type. Packing-type PCM got sensible heat from 5℃ until constant temperature which means melting points of PCM. From this section, about 30 minutes later, PCM started to store the latent heat. After saturation point, PCM stored sensible heat again forming thermal equilibrium with indoor air temperature of thermostatic chamber. Above all, PCM with meting point 44℃ shown to be having more time to store latent heat than other types of PCM.

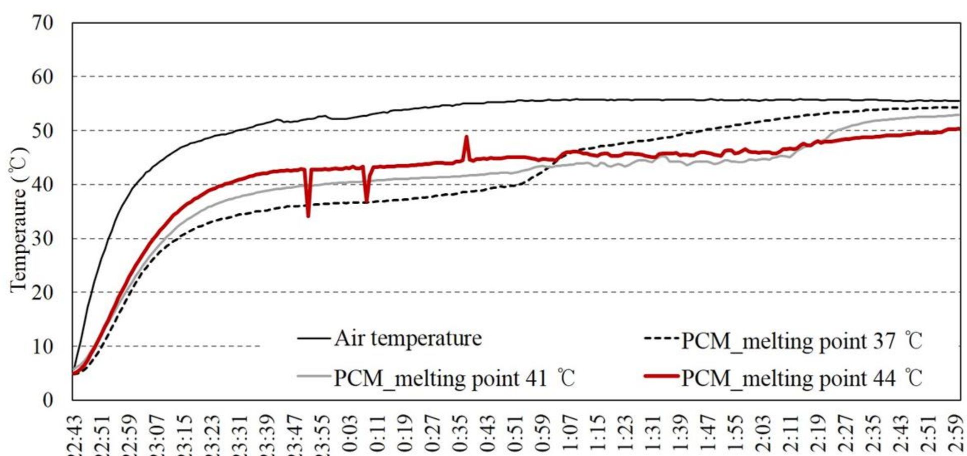


Fig. 6: Temperature changes of packing-type PCM.

3.2. Results of Energy savings

The results of energy simulation was carried out with comparing the heating energy consumption of residential building adopted by PCM heating floor system and normal heating floor system. As shown in [Table 3], total energy was saved about 44.81 kWh and 0.11 kWh per square meter during winter, from October 1 to March 31. Especially, heating energy savings was 30.23 kWh taking portion of 67.5% to total energy savings.

Table 3: Energy consumption of FHS and PCM FHS.

	Normal Floor Heating System	PCM Floor Heating System
Total Energy	51174.28 kWh	51129.41 kWh
Energy per m^2	128.04 kWh	127.93 kWh

4. Conclusion

This study developed the floor heating system utilizing phase change materials to reduce energy consumption and greenhouse gases in residential buildings compared to existing floor heating system. Thermal performance experiment on PCM was conducted to figure out the adequate type of PCM, and energy saving effects of PCM floor heating system were analysed by energy simulation during winter. And the conclusions can be drawn as follows:

(1) According to the results of preceding research* about comfortable surface temperature of floor heating system that the temperature range was from 28℃ to 31℃, 3 types of PCM which melting point is 37 ℃, 41 ℃ and 44 ℃ were found to satisfy the comfort range.

(2) PCM with meting point 44℃ shown to be having more time to store latent heat than other types of PCM.

(3) In case of using PCM floor heating system, total energy was saved about 44.81 kWh, 0.11 kWh per square meter and heating energy savings was 30.23 kWh taking portion of 67.5% to total energy savings during winter, from October 1 to March 31.

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References

[1] H. Kim, S. Bang, J. Park, E. Rhee, “A study on reducing cooling load using PCM & Cool Roof,” *The Society of Air-conditioning and Refrigerating Engineers of Korea*, vol. 319, 2015.

[2] C. Lee, “Standard for noise prevention of floor impact sound isolation,” Ministry of Land, Infrastructure and Transport, pp. 55-70, 2015.

[3] T. Akihiro, C. Yoon, “A comparative study on thermal responses of male and female in thermal environmental conditions in floor heating system,” *Architectural Institute of Korea*, vol. 15, no. 5, pp. 127-134.

[4] A. C. Yunus, Introduction to Thermodynamics & Heat Transfer, Inter Vision Co., Ltd., pp. 20-36.

[5] RUBITHERM, [Online]. Available: http://www.rubitherm.eu/en/