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A Study on the Analysis of Indoor Temperature According to the PCM Temperature Applied to the Double Skin Facade System for Saving Cooling Energy During Summer Season

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Abstract

This study aims to analyze the indoor thermal environment of existing double-skin façades through a field test, and apply phase change material (PCM) to the inner layer that can be applied to double-skin façade in summer. Thus, the purpose of this study is to build the baseline data to verify the indoor energy saving effect depending on the application of solar shading blinds using PCM in the inner layer as a substitute for the blinds in the cavity.

Keywords: Double-skin Façade System, PCM(Phase Change Materials), Passive Solar System, TransparentInsula-ting Material (TIM)

1 Introduction

Cooling energy tends to increase rapidly in summer, and as external solar heat flows indoors due to the glass on the façade, use of shading devices like blinds in regular buildings may block solar energy and reduce cooling load. However, there may be a durability issue according to the outside conditions when the blinds are used outdoors. If the blinds are used indoors, they may cause an issue in the reduction of cooling load by absorbing solar radiation and affecting the indoors due to the radiation. Double-skin façade protects the shading device from the outdoor environment by installing blinds in the space of the intermediate cavity, while also enhancing the efficiency of the shading device and emitting the air filled in the cavity by using the solar radiation absorbed by the blinds to increase ventilation force in the space. Thus, unlike other general building façades that passively controls the indoor environment to deal with the external climate conditions, double-skin façade is a proactive concept of façade that responds to the external environment by adding another façade to the already existing one and forming a thermal buffer layer, or an intermediate cavity, between the two façades, thereby reducing the façade load and indoor energy load.

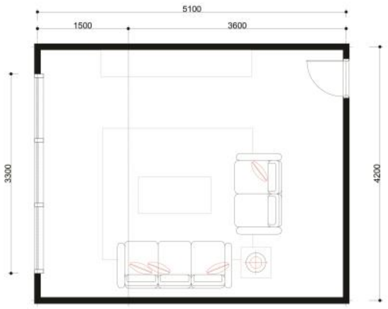
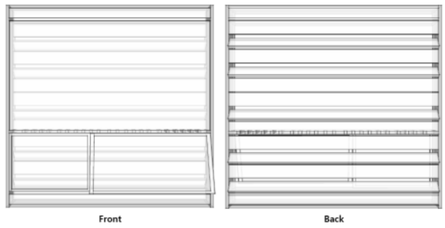
Therefore, this study aims to analyze the indoor thermal environment of existing double-skin façades through a field test, and apply phase change material (PCM) to the inner layer that can be applied to double-skin façade in summer. Thus, the purpose of this study is to build the baseline data to verify the indoor energy saving effect depending on the application of solar shading blinds using PCM in the inner layer as a substitute for the blinds in the cavity.

2 Experiment of Indoor Thermal Environment of PCM-applied Box-type Double-skin Façade in summer using an Experimental Model

2.1 Method and Conditions of Experiment

The areal extent for actual survey in this study is Seoul (north latitude, 37° 34’, east longitude 126° 57’), Republic of Korea. According to the average year data (30 years) of the Korea Meteorological Administration, the average temperature of Seoul from 1981 to 2010 is 12.5℃, and the average temperature of the coldest month is -2.4℃ in January and that of the warmest month is 25.7℃ in August. The annual average precipitation is 1450.5 mm, and wind velocity 2.3 m/s (2014. Korea Meteorological Administration). The current size of apartment buildings in Korea was examined to select the optimal unit space. According to the records of the house construction permit per dwelling size in the Statistics of Housing Construction in 2013, dwellings with the area of exclusive use space from 60 ㎡ to 85 ㎡ accounted for 42.4%, which is the highest ratio. Therefore, the optimal unit space of this study was selected as the area of exclusive use space of 84 ㎡ [1].

Table 1. Specifications of unit space [mm]

Specifications of unit space	Proposal of PCM-applied Box-type Double-skin Façade
	

When applying PCM to PCM-applied Box-type Double-skin Façade, there was an issue regarding the process of inserting PCM into glass unlike the inner layer of existing double-skin façade Thus, to calculate the thickness of PCM, this study aims to compare with the pair glass of existing PCM-applied Box-type Double-skin Façade and insert PCM into polycarbonate, which is one of the types of transparent insulation materials, through the aforementioned literature review. Then, it aims to design the inner layer in the form of blinds instead of installing blinds in the cavity unlike the existing double-skin façade. [2]

2.2 Analysis of Indoor Thermal Environment of PCM-applied Box-type Double-skin Façade using an Experimental Model

For follow-up research on calculating and applying the temperature range of PCM to be applied to the inner layer to make a proposal to apply a new system of PCM-applied Box-type Double-skin Façade, indoor temperature was measured during the survey experiment of the PCM-applied Box-type Double-skin Façade from September 16 to 18, 2013 (48 hours). The specimen used in the experiment is made by reducing the size into one-sixth of the selected unit space. Then, it aims to design the inner layer in the form of blinds instead of installing blinds in the cavity unlike the existing double-skin façade. [2].

Table 2. Test measurement data of Double Skin Façade system [3]

DATE	Type	Temperature [℃]		
		Min.	Max.	Avg.
2013-09-16	Outdoor	12.4	38.7	22.1
	Cavity	13.7	74.1	34.8
	Indoor	13.9	63.0	32.1
	Humidity [%]	65		
2013-09-17	Outdoor	14.0	37.3	22.9
	Cavity	15.9	70.2	34.4
	Indoor	15.8	60.7	32.0
	Humidity [%]	65		
2013-09-18	Outdoor	14.1	39.5	24.4
	Cavity	16.2	72.6	36.6
	Indoor	16.3	63.5	34.2
	Humidity [%]	69		

The result of the experiment showed that the average temperature outdoors is 32℃ and the cavity temperature increased due to the inflow of external solar heat. However, it was found that the cavity acted as a thermal buffer space and thus the indoor temperature had at least a 10℃ difference from the cavity temperature. By proposing a system that applied PCM in the inner layer of PCM-applied Box-type Double-skin Façade, it is possible to use the characteristic of PCM that absorbs or releases heat as the phase changes from solid to liquid or vice versa in certain temperatures. By absorbing the chilly air of the indoors due to air-conditioning and releasing the chill when not operating the air conditioner, the indoor temperature can be maintained consistently and thus save cooling energy. Moreover, to deal with solar heat flowing in from the outside, this study presents a plan to respond to the external environment by using the transparent insulation material attached to the inner layer and the cavity. In addition, it aims to design the inner layer in the form of blinds instead of installing blinds in the cavity unlike the existing PCM-applied Box-type Double-skin Façade.

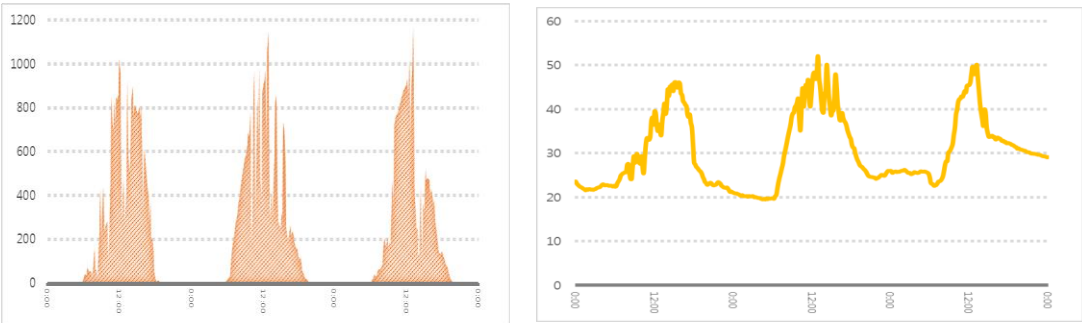
To determine the PCM temperature applicable to a double skin facade and to compare the indoor thermal environment, a total of four types of mock-up models were prepared including the basic double skin facade and other three models to which outer skins having different PCM phase change temperatures were applied. The first one was the conventional double skin facade type (Type-1: Basic Type). The second to fifth models were those to which different PCM phase change temperatures were applied: 18℃ (Type-2), 24℃ (Type-3), and 28℃ (Type-4).

3 Determination of a PCM temperature applied Box-type Double-skin Façade

The analyzed measurement experiment results were the data measured in a ten-minute interval for three days from 00:00 on July 31 to 23:59 on August 2, 2014.

3.1 Climate data during the experimental period

The average highest temperature of the external space during the experimental period was 52.1℃, and the average lowest temperature was 19.5℃. The relative humidity was 65.5% in average. The maximum solar radiation was 1111 W/㎡. Fig. 1 and Table 3 show the climate data for the three days during the experiment period.



(a) Isolation [W/㎡]

(b) Outdoor temperature [℃]

Figure 1. Climate data during the experimental period

Table 3. Climate data during the experimental period

Type	Temperature [□]˜			Humidity [%]˜	Isolation [W/㎡]˜	Sunshine Duration [hr]※	Cloud Cover [10%]※
	Avg.	Min	Max	Avg.	max		
07.31	28.7	21.1	46.2	74.7	1023	7.9	6.8
08.01	30.7	19.5	52.1	100	1146	9.5	4.9
08.02	31.6	22.6	50.1	56	1165	6.6	7.7
Avg.	30.3	19.5	52.1	65.5	1111	8	6.4

Note)˜ Survey Data

˜˜ Korea Meteorological Administration

3.2 Test measurement data

Measurement results with the mock-up models: The temperature of the intermediate air space layer and the indoor space of the five types of mock-up models during the experiment period are shown in Table 4. The measurement values are different each day because the experiment was performed under natural climate. The lowest temperature values might have been varied due to the effect of the external air temperature. The highest temperature might have been varied due to the external temperature which was also affected by the variation of the solar radiation depending on the fine dust concentration and the amount of clouds.

Table 4. Test measurement data

Type		2014-07-31			2014-08-01			2014-08-02			Test Period		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Cavity	Type-1	23.9	52.3	34.8	22.6	59.5	36.8	27.3	61.9	38.0	22.6	61.9	36.5
	Type-2	24.2	53.2	35.1	22.8	62.1	37.2	27.5	63.4	38.3	22.8	63.4	36.8
	Type-3	24.0	50.7	34.3	22.5	60.7	36.5	27.3	61.9	37.7	22.5	61.9	36.1
	Type-4	24.9	51.8	34.4	24.3	55.8	36.6	27.2	57.8	37.4	24.3	57.8	36.1
Indoor	Type-1	24.0	50.3	33.6	22.7	53.3	35.3	27.2	55.4	36.4	22.7	55.4	35.1
	Type-2	24.3	49.4	33.5	23.1	52.0	35.2	27.5	54.1	36.4	23.1	54.1	35.0
	Type-3	24.6	47.0	33.0	23.3	50.9	35.0	27.7	52.3	36.2	23.3	52.3	34.7
	Type-4	27.5	47.1	36.7	24.9	49.9	32.1	27.0	49.7	32.7	24.9	49.9	33.8

As shown in Table 4, the analysis result of temperature on cavity space during the test period showed that the average temperature on Type-1 (basic type) was 36.5℃, and the average temperature on Type-3 (PCM temperature of 24℃) and Type-4 (PCM temperature of 28℃) was same as 36.1℃. The analysis result of indoor temperature showed that the indoor temperature of Type-1(basic type) was 35.1℃, and according to the temperature of PCM, the indoor temperature of Type-2 (PCM temperature of 18℃) was 35.0℃, the indoor temperature of Type-3(PCM temperature of 24℃) was 34.7℃ and the indoor temperature of Type-4 (PCM temperature of 28℃) was 33.8℃, confirming that the indoor temperature was low. It was confirmed that the PCM material reduced the temperature lowering effect through the accumulation of sensible heat after the accumulation of latent heat during daytime. The appropriateness for blocking solar radiation was confirmed through this, and it is judged that changes in indoor temperature due to the accumulation of sensible heat obtained through PCM applied on the internal surface, not blocking of solar radiation, caused influence on cooling energy saving. It is determined that Type-4 (PCM temperature of 28℃) showed the best PCM temperature that could apply to the double skin facade system for reducing the indoor cooling energy during summer season.

4. Conclusion

As the external solar heat flows indoors due to the glass on the building façade, use of shading devices like blinds in regular buildings may block solar energy and reduce cooling load. However, there may be a durability issue according to the outside conditions when the blinds are used outdoors. If the blinds are used indoors, they may cause an issue in the reduction of cooling load by absorbing solar radiation and affecting the indoors due to the radiation. Double-skin façade protects the shading device from the outdoor environment by installing blinds in the space of the intermediate cavity, while also enhancing the efficiency of the shading device and emitting the air filled in the cavity by using the solar radiation absorbed by the blinds to increase ventilation force in the space. Therefore, this study aims to analyze the indoor thermal environment of existing double-skin façades through a field test, and apply phase change material (PCM) to the inner layer that can be applied to double-skin façade in summer. The analysis result of indoor temperature according to the temperature of PCM applied to the box-type double skin facade system showed that the indoor temperature of Type-4 (PCM temperature at 28℃) was lower than the indoor temperature of previous double skin facade system, and this will reduce the usage of indoor cooling energy during summer season. However, the temperature used during the summer season and winter season varies due to the characteristics of heat performance of PCM, so it is judged that Type-3(PCM temperature of 24℃) can bring indoor energy saving for summer season as well as heating energy saving during winter season. It is necessary to carry out studies to see what influence the temperature of PCM gives to indoor energy saving in future with regard to the variables according to the operation method of double skin facade system, and the performance evaluation on the latent heat and heat storage of PCM also should be carried out..

References

[1] Ryu, Ri, A Study on Determination of Appropriate Temperature of Phase Change Material Applicable to Double Skin Facade for Heater Energy Load Reduction (2014)

[2] Ri Ryu, Jang-Hoo Seo, Young-Seong Kim, Basic Research on Double-skin Façade to Reduce Indoor Energy Load in Summer, Advanced Science and Technology Letters, Vol.55 (Architecture and Civil Engineering 2014), pp.17-20

[3] Kyuyoung Lee, Ri Ryu, Janghoo Seo, Yongseong Kim , Study on PCM applied Thermal Storage Wall System to reduce Cooling Energy, Korean Journal of Air-Conditioning and Refrigeration Engineering (2014)

[4] Park, Jung, Gun, A Study on Cooling and Heating Loads and Consumption Savings of Double-Skin Buildings , Seoul National University of Science And Technology , Master's thesis (2006)

[5] Ryu, Ri, A Study on Determination of Appropriate Temperature of Phase Change Material Applicable to Double Skin Facade for Heater Energy Load Reduction (2014)

[6] Lee Keon-ho, Kim Hyeon-soo, Jang Dae-hee, Moon Soo-young, Experimental Study on Developing of Double Facade System dealing with the various climatic Conditions, Vol. 5 No. 2, pp 19-26. (2005)

[7] MOLIT-Related Statistics (http://stat.molit.go.kr), Housing Supply Ratio, Approval No. 11628

[8] Yoon, Jong-Ho, Kin, Byoung-Soo, A Study on the Heat Gain Control of Transparent Insulation Mass-Wall System for Overheating Prevention of Cooling Season, Architectural Instituted of Korea, Vol. 19 No. 11, (2003)

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