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Performance study on different location of double layers SSPCM wallboard in office building

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ABSTRACT

Double layers SSPCM wall could improve indoor thermal performance and reduce building energy consumption for a whole year. SSPCM layer with higher melting temperature was active in hot seasons and that with lower melting temperature was active in cold seasons. One SSPCM layer on external and the other one on internal wall surface was named "SSPCM wall I". Two SSPCM layers on internal surface was named "SSPCM wall II". Location of SSPCM layer affected heat transfer process of building envelope. In order to improve performance of double layers SSPCM wall by optimal location, two dynamic heat transfer models of double layers SSPCM walls in Wuhan city were developed by TRNSYS. The results showed that room with SSPCM wall I could reduce energy consumption 20.51% in winter and 0.65% in summer compared with room with reference wall I. And room with SSPCM wall II could reduce energy consumption 18.75% in winter and 13.46% in summer compared with room with reference wall II. The indoor air temperatures of rooms with SSPCM wall I and II were all in comfortable range for a random selected day both in winter and summer. The optimum melting temperature of SSPCM layer was close to set point of indoor air temperature. It was 0–1 °C higher than set point of indoor air temperature in winter and 0–2 °C lower than set point of indoor air temperature in summer.

1. Introduction

Building energy consumption increased rapidly with increasing requirements on indoor thermal comfort. The heat transfer through the building envelope had a significant impact on building energy consumption and indoor thermal environment. Therefore, research on energy and thermal performance of building envelope received more and more attention. The traditional building envelope store energy in the form of sensible heat of composite structure layers, which requires a large volume of material to store required energy. In contrast, latent heat storage material had great advantage. Shape-stabilized phase change material (SSPCM) wall was a novel building envelope which use latent heat to store energy. A substantial amount of studies [1–8] are available on the applications of PCMs in buildings to enhance their energy and thermal performance.

Izquierdo-Barrientos et al. [9] established a one-dimensional heat transfer model for PCM walls in Madrid Spain. The simulation results showed that PCM wall did not always reduce total heating/cooling load compared with non-PCM walls. It depended on the heat inertia of the chosen reference wall envelope.

Ibanez et al. [10] developed a mathematical model of single-layer PCM wall by TRNSYS software, and the simulation results were validated by experiments. The mathematical model was applied to a practical project in Lleida, Spain. The simulation results gave recommended values of PCM layer's installation location, phase change latent heat and phase change temperature in this specific project.

Jin et al. [11] had conducted simulation and experiment on optimized position of PCM layer in building envelope in Lawrence, Kansas. They found that the optimized position of PCM layer would move to external wall surface with the increase of thickness, latent heat and melting temperature of PCM. The optimized position would move to internal wall surface with the increase of internal wall surface temperature. The position of the PCM layer would affect peak heat fluxes through the wall. But the author [12] also pointed out that effects of change of locations of two PCM layers on thermal performances of system were little if melting temperatures of two PCM layers were both optimized.

The above literatures [9–12] were mainly on building with single layer PCM. It could improve indoor thermal comfort in summer or winter, but it could not active all over the year in buildings both

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Nomenclature

c_p	Specific heat (kJ/(kg K))
COP	Coefficient of performance
E	Energy (kWh)
h	Convective heat transfer coefficient (W/(m^2 K))
H	Latent heat (kJ/kg)
q	Heat flux (W/m^2)
Q	Cooling/heating load (kWh)
t	Temperature (K or °C)
W	Energy consumption (kWh)
x	Abscissa (m)

Greek symbols

δ	Thickness (mm)
λ	Conductivity (W/(m K))
ρ	Density (kg/m^3)
τ	Time (s or h)

Subscripts

amb	Ambient
ave	Average
C	Cooling
con	Consumption
ext	External or outside
H	Heating
in	Inside of external wall
int	Internal or inside
lq	Liquid
m	Melting
max	Maximal
min	Minimal
n	Number of the layer
out	Outside of external wall
rad	Radiation
s	Solid
SR	Saving of SSPCM room compared with reference room
SB	Saving of SSPCM room compared with basic room

need cooling and heating. Some researchers [13–17] found that double layers PCM wall could solve this problem.

Meng et al. [13] established a PCM room with two different melting temperatures and different directions numerically and experimentally in Shanghai, China. The effects of phase change temperature, thickness and position on the performance of PCM were simulated. It was found that this new PCM room could reduce indoor temperature fluctuation by 4.3 °C in summer and 14.2 °C in winter. In winter and summer, the difference of indoor temperature variation is 2.7 °C and 6.9 °C due to the different installation position, respectively.

Diaconu et al. [14] produced a test room with double layers PCM in all external wall except roof and floor. It was found that two PCM layer both had effect on reducing indoor cooling load in summer and heating load in winter. The effect of PCM with lower melting temperature in winter was more significant and PCM with higher melting temperature in summer was not obvious. The authors pointed out that several factors were not considered in the study, including latent heat and thickness of PCM. The load reduction would be more significant with optimized values.

Double layers PCM was installed on roof was studied numerically and experimentally by Pasupathy et al. [15]. This study was conducted in Chennai, India. It was found that PCM wall could reduce internal air temperature swing during winter seasons, but it was not suitable for summer seasons as the PCM wall remained in liquid state all the time during these months and hence the system cannot exploit the latent heat effect.

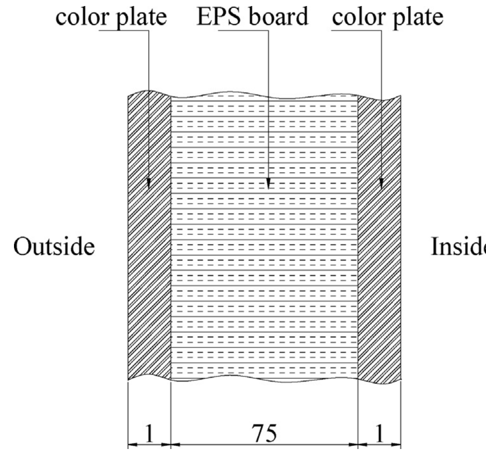

Fig. 1. The schematic of the basic wall.

Zhu et al. [16–18] studied the energy saving effects of double layer SSPCM wall in air-conditioned room. External SSPCM layer with higher melting temperature was active in summer and internal SSPCM layer with lower melting temperature was active in winter. They found that the structure could reduce energy consumption in winter significantly, but energy saving effect in summer was not obvious.

The exiting literatures had shown that double layers PCM wall could improve indoor thermal comfort and reduce energy consumption under appropriate conditions. But existing literatures on double layers SSPCM buildings found that energy saving effect was not obvious in summer, and the cooling load was generally reduced below 4% [11,16,17]. Some main factors affected thermophysical performance of buildings integrated with double layers SSPCM wallboard, including melting temperature, latent heat, thickness, orientation and location of PCM. The optimal melting temperature, latent heat, thickness and orientation of double layers SSPCM wallboard had been studied and could be gotten from literature. The optimal location of single layer SSPCM in building envelope was studied [11,12], but optimal location of double layers SSPCM was not investigated yet. The heat transfer process and thermal comfort were effected by different location of double layers SSPCM. Therefore the optimal location of double layers SSPCM was needed to study.

In this paper, different locations of double layers SSPCM wallboards on energy saving effect all over the year was studied numerically. The dynamic heat transfer models of double layers SSPCM wall in different structure were established by TRNSYS. The energy saving potential of different locations of double layers SSPCM wallboards were analyzed by simulation results, and the energy saving effect and thermal performance of two rooms with different double layers SSPCM wallboards were obtained.

2. Numerical simulation

2.1. Simulation platform

The dimension of simulation rooms were all 1.2 m in length, 1.2 m in width and 1.2 m in height. Double layers SSPCM wallboards with different locations were installed on south wall, the other envelopes were basic building materials. The basic wall consisted of two color plates with thickness of 1 mm and one EPS board with thickness of 75 mm, as shown in Fig. 1. The thermophysical parameters of basic wall were shown in Table 1. According to spec-