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Experimental Study on Thermal Performance Improvement of Building Envelopes Integrated with Phase Change Materials in an Air-conditioned Room

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Abstract

Phase change materials (PCMs) are used to decrease the indoor temperature swing, keep the indoor environment comfortable and increase energy efficiency of buildings by enhancing the thermal storage capacity of building walls. This paper studied the thermal performance of the PCM wall and the reference wall when the air-condition ran continuously and intermittently through experiment. An experimental building with these two kinds of wall units was chosen, and the inner surface temperature and heat flow were measured. Results showed that the PCMs reduced the inner surface temperature 1°C and the inner surface heat flow about 40% during continuous air conditioning. Otherwise, when the air-condition ran intermittently by the working schedule, the cold releasing time of PCM wall was 2 hours longer than the reference wall. The PCMs can improved the thermal performance of building envelope significantly.

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Keywords: Phase change material; Building envelope; Thermal performance; Indoor thermal environ-ment; Energy efficiency

1. Introduction

Integrating phase change materials with building envelope is able to reduce energy consumption, improve indoor thermal comfort and shift the peak electricity load. Compared with sensible heat storage system, latent heat storage system with PCMs has higher energy storage density while requiring smaller masses and volumes of material, so that

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PCMs are widely used in the heat storage of building envelopes. PCMs absorb heat while changing from solid to liquid with the increasing temperature and release heat while changing from liquid to solid with the decreasing temperature. Integrating PCMs with building envelope can increase the heat capacity to use the renewable and non-renewable energy rationally. Wang et al. [1] evaluated the thermal performance of ultrathin envelope integrated with PCMs by aid of numerical simulation for PCM heat conductivity coefficient, phase change heat, phase-transition temperature and PCM layer position. Feng and Liang [2] built experimental rooms with phase change wall and ordinary wall, and used household air-condition for cooling. Results showed that the indoor air temperature of room with phase change wall was 1°C or 2°C lower than that of room with ordinary wall, and heat flow was reduced by the phase change wall. Yan et al [3] studied the thermal properties of the PCM wall formed by different methods, and found out that the surface temperature and heat flow through the PCM walls prepared by different methods were lower than that of traditional wall. Castell et al [4] did comparison experiments on two cubicles integrated with different PCMs, and results showed that PCMs could reduce the peak temperature by up 1°C, while reducing the air conditioning energy consumption by 15% in summer. Kuznik and Virgone [5] did experiments on the indoor thermal environments of PCM room and ordinary room in summer, winter and the transition seasons. Experimental results showed that the phase change wall could reduce the indoor temperature fluctuations. Behzadi and Faril [6] did computer simulations on PCMs impregnated in building materials, and carried out that the use of PCMs could effectively reduce the daily fluctuations of indoor air temperature to 4°C and maintain it at the desired comfort level for a long period without air conditioning. Lei et al [7] studied the energy performance of building envelopes integrated with PCMs for cooling load reduction in tropical cli-mate through simulations. The results showed that PCMs could effectively reduce heat gains through building envelopes throughout the whole year.

Existing studies show that PCMs can significantly improve indoor thermal environment in buildings with natural ventilation or continuous air conditioning. However, the thermal performance of PCM wall during continuous air conditioning and intermittent air conditioning are different. This paper presents an experimental study about the inner surface temperature and heat flow of the PCM wall and the reference wall when air condition runs continuously and intermittently. The results can provide theoretical guidance for indoor thermal environment regulation through improving thermal performance of building envelope by integrating with PCMs.

2. Methods

A dynamic test experimental building was built in Sichuan University to study the thermal performance improvement of building envelopes integrated with PCMs, as shown in Figure 1. There were two rooms in the building, and the size of which were both 3.5m (length)×3.0m (width)×2.2m (height). The PCM wall unit and the reference wall unit were embedded in the north external wall of Room1 (Fig. 1(b)). The two wall units with size of 600mm×600mm×260mm were in the same indoor and outdoor environment, which made the test results more comparable. Supported by steel frames, the two wall units were surrounded by 80mm EPS to reduce the heat transfer between units, ensuring one-dimensional heat transfer in the central area of each one. A split air conditioner (KFR-35GW/HFJ+3) was installed on Room 1's south wall.