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Experimental research of a partition composed of two layers of different types of PCM

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Abstract

The article presents the results of experimental studies of a partition with attached two adjacent layers of PCM with different thermal characteristics. It was assumed that a priority function of the PCM in the partition is accumulating excessive heat gains and protecting the interior from overheating in the summer. Such assumption determined conditions during the experiment. The aim of this study was to determine the actual behavior of the partition containing two different phase change materials. Benefits of simultaneous application of phase change materials of various parameters with a given, dynamically changing temperature of surroundings were defined. Various configurations of layers of PCM materials were analyzed. The analysis presented in the article can be used as a guide for working with a multilayer composite wall and allows validation of numerical models for such solutions.

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Keywords: Phase Change Materials, heat capacity, multi layers PCM, composite PCM, overheating

1. Introduction

The issue of reducing the risk of overheating light energy-efficient buildings is still current. Many studies indicate a high potential for the storage of excessive heat gain by the latent heat by the use of phase change materials (PCM) [1-8]. However, the best use of this potential is still problematic, because the effectiveness of applied solutions is often unsatisfactory.

One of the directions which is worth analyzing in the context of increasing PCM efficiency is a solution of simultaneous application of several layers of PCM materials with different thermal characteristics [9]. This subject

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was raised by several authors who have tested similar solutions in different parts of buildings. Xing Jin and Xiaosong Zhang [10] proposed a double-layered PCM floor. There are two layers, which have different melting temperatures. The components are used to store heat or cold energy during the off-peak period and release the energy during the peak period. A. Pasupathy and R. Velraj [11] analyzed the effect of double-layered phase change materials in building's roof. Diaconu and Cruceru [12], and Na Zhu, Hu Pingfang, Linghong Xu [13] in their articles include analyses of the effects of application of several PCM layers in walls. These analyses are based on numerical simulations. In their paper, Diaconu and Cruceru [12] show the results of simulation of external partition containing two different layers of PCM (as outer and inner layer). This solution resulted in reducing peak cooling demand by 35.4% and an average reduction in demand for heating purposes by 12.8%. Zhu, Pingfang Hu and Linghong Xu [13] presented a numerical analysis of double-layered shape-stabilized phase change materials wallboards. The new wall system consists of a three-layer sandwich-type panel (outer layers consisting of wallboards with PCM and middle layer consisting of conventional brick).

The credibility of the thermo-physical properties of PCM is the basis for numerical simulations. Data supplied by laboratory tests often do not fully reflect the actual behavior of these materials applied on a partition. Additionally, it is difficult to include a hysteresis feature of this type of material in the numerical model.

Therefore, it seems reasonable to conduct an experimental research of a partition comprising two immediately adjacent layers of PCM with different thermal characteristics. This article presents the results of such tests, and their analysis with an emphasis on the actual use of the potential of PCM.

2. The goal and the scope of the undertaken actions

The aim of this study was to determine the actual behavior of the partition that uses a combination of two different phase-change materials: in a dispersed form in cardboard and in a concentrated form inside a polyester film. The benefits of simultaneous application of phase-change materials of various parameters for a set, dynamically changing ambient temperature were determined. The values measured both on the surface as well as between the layers of a partition were the temperature and the density of heat fluxes. Three different configurations of PCM layers were analyzed. The influence of the length of overheating period and the ambient temperature growth rate on the modified partition's thermal conditions were also analyzed.

Based on the results, the quantity of energy stored in the PCM per mass unit was calculated and compared to the results calculated on the basis of calorimetric studies. Presentation of such results allows for a comparison of different solutions for the actual use of phase change latent heat which measures the effectiveness of the applied PCM.

The research plan included three stages. In the first and second stages, individual layers of materials were researched (PCM later used in stage three). Temperature and heat flux density were analyzed both on and under the surface of the individual layers comprising PCM and attached to the partition. On the basis of these analyses, materials whose combination can provide beneficial results were selected. The article focuses on the results from the last, third stage of the research, referencing to and based on the results from the two previous stages.

The described analysis is intended as a guide for works on a multilayer composite wall and tries to enable validation of numerical models of such solutions.

3. Environmental chamber examination of phase change materials.

The measurement station was built inside a group of climate chambers. The group consists of two chambers (so called 'warm chamber' and 'cold chamber') between which the examined partition was placed. The basic partition, to which additional layers were attached, was a light frame wall with the dimensions of 195cm x 210cm. The basic partition layers are a 15-centimeter styrofoam board and an interior drywall envelope. The surface of the partition inside the 'warm chamber' was divided into four measurement fields, to which additional layers of materials were attached.

3.1. Characteristics of used materials

The subject of the research presented in this article is the use of a combination of plasterboards containing PCM