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ANALYSIS OF TEST STUDIES OF THE BUILDING BARRIER CONTAINING PCM

ANALIZA BADAŃ TESTOWYCH PRZEGRODY ZAWIERAJĄCEJ PCM

Abstract

This paper presents the results of experimental tests of a wall barrier containing a layer with the addition of phase-change material. The study was performed in a climatic chamber for a light frame wall in two versions: with inner lining made of plaster-cardboard panel and of panel containing PCM. Temperature measurements were made on the surface of panels for non-stationary conditions in a climatic chamber. Research stand was prepared, in which heating of coat layers was effecting from an increase of the room's air temperature rather than from direct heating of the layers. The influence of the PCM was analyzed for faster and slower pace of air heating.

Keywords: phase-change material, experimental test, heat capacity, heat accumulation

Streszczenie

W artykule przedstawiono wyniki badań eksperymentalnych przegrody zawierającej warstwę z dodatkiem materiału fazowo-zmiennego. Badania wykonano w komorze klimatycznej dla lekkiej ściany szkieletowej w dwóch wariantach: z okładziną wewnętrzną wykonaną z płyty gipsowo-kartonowej oraz płyty zawierającej materiał fazowo-zmienny. Przeprowadzono pomiary przebiegu temperatury na powierzchniach płyt dla niestacjonarnych warunków panujących w komorze klimatycznej. Przygotowano stanowisko badawcze, w którym nagrzewanie płyt okładzinowych następowało poprzez wzrost temperatury powietrza w pomieszczeniu, a nie poprzez ich bezpośrednie nagrzewanie. Analizowano wpływ PCM podczas nagrzewania powietrza w szybkim i wolniejszym tempie.

Słowa kluczowe: materiał fazowo zmienny, badania eksperymentalne, pojemność cieplna, akumulacja cieplna

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1. Introduction

Preventing heat loss in a building is one of the many aspects taken into consideration during its design. The required result can be obtained by the application of a heat-insulation of a specific thickness. Unfortunately, there is not much attention paid to the microclimate of the buildings that do not actually fulfill the thermal comfort requirements. The situation occurs more often in modern buildings, especially based on a light-frame construction. The technology allows for sophisticated architectonic forms and is easy and fast at the same time (another popular trend uses glass surfaces). They both influence the architecture and make it more interesting, however, they also gain a lot of heat (mainly from insolation) that cannot be accumulated by the building's envelope. The result is seasonal overheating of a building and large temperature oscillations of internal air, due to temperature variation of external air.

The phase-change materials accumulate considerable amounts of heat thanks to high latent heat of phase-change of organic compounds, e.g. paraffins, fatty acids or inorganic salt hydrates. During their phase transition, accumulation or emission of large amount of heat occurs and is accompanied with a small temperature variation of a specific PCM. Hence, the application of PCM in a building increases its heat capacity.

Since the 1980's, one can notice the involvement of scientists in the integration of PCM with the elements of construction wall barriers. To this end, various types of materials and methods of their use were implemented. Applications, in the form of plasterboards with the addition of PCM have been the subject of numerous studies [1–3, 5, 8]. Research by teams of L.V. Shilei, A.K. Athienitis [1, 2] were conducted on plaster panels impregnated with PCM intended for the heating period. Research by S. Scalata team [3] was carried out in a laboratory simulating conditions of both summer and winter, and analysis was made solely on the basis of air temperature in the test room (also for PCM impregnated panels). Due to concerns about durability of these materials (PCM directly in contact with traditional materials, may cause leakage and corrosion), a solution in the form of microcapsules filled with PCM is preferred. Research on plasterboard with PCM microcapsules was carried out by C. Voelker and P. Schossig [6, 8]. These analyses were made only on the basis of air temperature after application of PCM lining, but without analyzing heat flux density and amount of accumulated energy. The tests were performed on real buildings. At the same time, the studies [6] indicate a low efficiency in case of high heat load of a room and of rapid temperature increase resulting from sun exposure. They show an increase in efficiency of the application, as a result of room shading, and a very important role of sufficient cooling of the material.

Despite numerous studies on plasterboards with the addition of PCM, there are no sufficient and reliable data that can serve as a comparison of effectiveness in relation to use of other types of PCM materials. The studies are carried out with different parameters of materials and the environment, and the results relate to parameters non-comparable with each other (e.g. air temperature changes, the surface of walls and shifts during peak temperatures, the number of hours when the temperature exceeds a given amount); there is also insufficient data based on the analysis of the heat flow, and the actual amount of stored energy determined with respect to traditional solutions. The presented results of the experiment show one of the stages, which is a part of the analysis of various applications efficiency. The aim of the study on plasterboard with PCM is also to use them as a comparison element for further work on other solutions.

2. The purpose of this article

The aim of this experiment is to analyze the influence of dynamics of change rate of ambient temperature on the efficiency of the phase-change material. The results may be helpful in the process of optimizing the use of these materials in relation to the likely thermal conditions in various buildings. Effectiveness was determined primarily based on the difference between the indications of heat meters placed above and below the tested panels which makes it possible to determine the amount of stored energy, compared to conventional panel. Analysis has been performed both on the basis of the temperature curve on the inner surface of the building partition, and of the heat flux density course. Amount of energy stored and donated in different phases of the energy cycle was compared.

3. Description of the measuring stand

A measuring stand consisted of two climatic chambers (called: hot and cold chambers) separated by the investigated building partition. The chambers were equipped with heating, cooling and ventilation units with automatic controls which allowed to maintain required temperature in both chambers. Controlling the internal air humidity following the required scheme was also possible.

The investigated wall was built as a light structure and it consisted of a wooden grid filled with 15 cm layer of mineral wool. The finishing layer in the hot chamber consisted of a plaster board. There were also two 1 m^2 boards fixed to the finishing layer: the ordinary plaster board (12.5 mm) and the board containing phase change material (12.5 mm), BASF brand – SmartBoard 26. The organic material used in PCM board was Micronal–its melting point is 26°C and the heat of phase transition is 110 kJ/kg (according to the manufacturer's data). 30% of the board mass was PCM. Both panels had similar densities and thermal conductivities. Parallel placement of the boards ensured identical external conditions during measurements and allowed the direct comparison of the measured parameters.

4. Measuring equipment

Temperature and heat flux were the parameters measured both at the surface and between the layers of the wall. 4 sensors Pt 1000 and 2 heat meters (the first one was round with a radius of 33 cm, and the second one was rectangular with dimensions 120 × 120 cm) were placed on the surface of each board. Four temperature sensors Pt 1000 and one circular heat meter were also placed below the surface of each board. The air temperature inside chambers was measured by temperature sensors Pt 100 and Pt 1000. The measured parameters were recorded by the Ahlborn Almejo data collecting system connected to a computer. All measured data were collected by the system Data-Control 4.2.

5. Tests in the climatic chamber

The tests were carried out in several stages. The article analyzes two cycles that vary in terms of rate of ambient temperature change. The experiment was conducted under conditions of constant temperature in the cold chamber, and of changing conditions in the hot chamber. In this chamber, dynamic changes in air temperature were observed from 18°C to 30°C. In the first cycle, these changes consisted of the rapid temperature rise in 1 hour and then equally rapid cooling of the air to the starting temperature of 18°C.

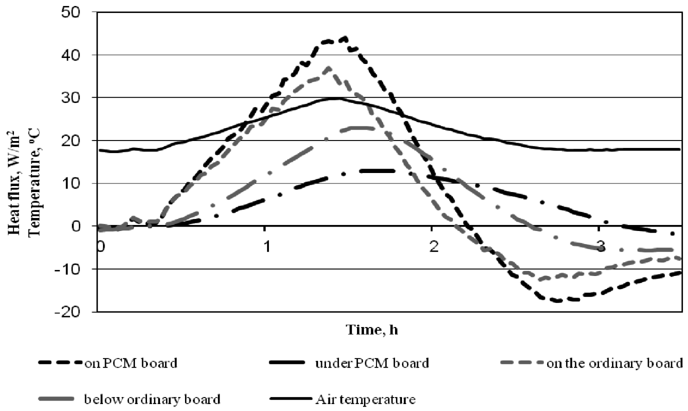

Fig. 1. Course of heat flux, according to the indications of heat meters placed on and under the surface of a regular panel and a panel with addition of PCM, and of the temperature inside the chamber for CYCLE II (with the rapid pace of change)

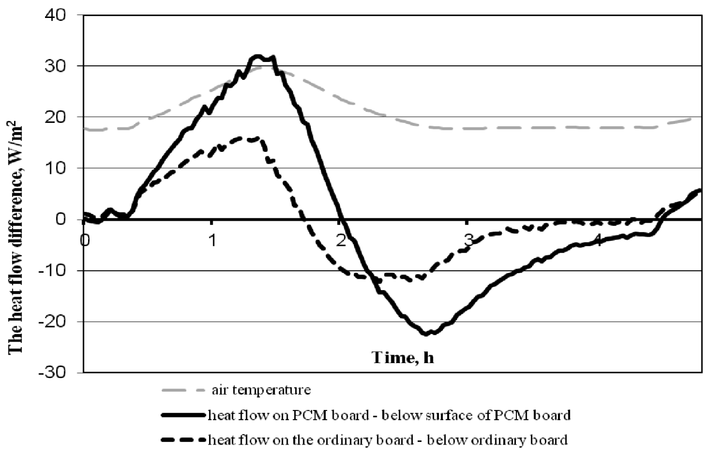

Fig. 2. Course of changes in time of indications difference between heat meters located on and under the surface of the tested panels in CYCLE II (showing the amount of energy accumulated in different phases of the cycle)

In the second cycle, heating to the temperature of 30°C occurred within 3 hours, then the temperature was maintained constant for 3.5 hours, to drop to 18°C within the period of 4 hours. Both the first and the second cycle were preceded by the 11-hour period with constant temperature of 18°C. After each cycle, the temperature was kept constant at 18°C (in the first cycle for two hours, in the second cycle for 10 hours).

During the measurements, both plasterboards were subject to the same conditions.

This stage of the study was to observe changes in the temperature on the surfaces of the panels and the heat flux density on and under the analyzed panels, in case of dynamically changing indoor environment while, on the other side of the partition, the temperature conditions are stable.

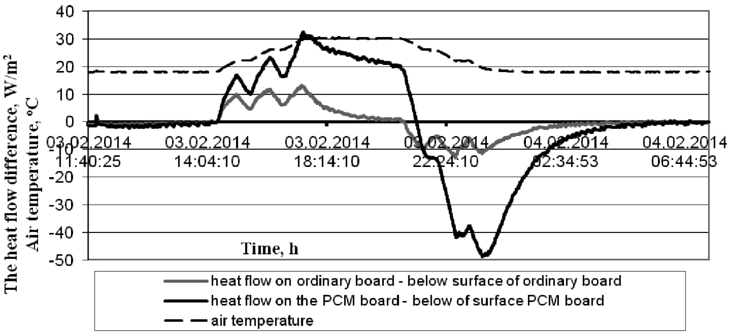

Fig. 3. Course of changes in indications difference between heat meters and located on the surface of the tested boards in CYCLE I (showing the amount of energy accumulated in the different phases of the cycle)

Table 1

Comparative analysis of energy stored in different stages of the cycle CYCLE I and CYCLE II

		The amount of stored energy		Comparison	Balance of stored energy	
Time	Phase of the cycle	Regular panel	Panel with PCM			
	CYCLE I	OB	PCM	OB/PCM	OB	PCM
3 [h]	from 18 [°C] to 30 [°C]	3250	6930.7	2.13	3250	6930.7
3.5 [h]	30 [°C]	1145	9206.4	8.04	4395	16137.1
4 [h]	from 30 [°C] to 18 [°C]	–3803.7	–13288.4	3.49	591.3	2848.7
2 [h]	18 [°C] (2 [h])	–396.2	–2189.2	5.53	195.1	659.5
8 [h]	18 [°C]	–198.2	–621.4	3.14	–3.1	38.1
	CYCLE II					
1 [h]	from 18 [°C] to 30 [°C]	1514.4	2579.08	1.70	1514.4	2579.08
1 [h]	from 30 [°C] to 18 [°C]	–954.4	–54.4	0.06	560	2524.68
2 [h]	18 [°C]	–496.44	–1942.96	3.91	63.56	581.72

The results of integrated difference of heat flow for both cycles demonstrate that plasterboard panels with PCM are more efficient for slower heating process (in case of heating time of 3 hrs. the panel with PCM accumulated 2.13 times more energy than a conventional panel; for the faster cycle it was 1.7 times more). In the course of a further maintenance of 30°C temperature inside the chamber, the panel modified with PCM accumulated over 8 times more energy than a traditional panel. The amount of stored energy has a direct impact on the difference between the surface temperature of the two panels in different cycles during the heating process–: in the first cycle it is up to 1.35 K (when the temperature of 30°C is maintained, it rises to 1.65 K), in the second cycle it is 0.93 K. Studies show the need for a longer cooling time for the partition containing PCM, than the second cycle allowed (energy balance shows only negligible (approx. 2%) loss of energy when lowering the temperature inside the chamber, and at the end of the cycle there is still more than 22% of previously accumulated energy). During the slower (4 hour) rate of ambient temperature decrease, over 82% of the stored energy is released. Two hours of maintaining a constant temperature at 18°C results in almost complete discharge of the panel (there is only approx. 4% of previously stored energy).

6. Conclusions

The case study demonstrates an increased efficiency of PCM for a slower rate of ambient temperature changes. It is also preferred due to its longer cooling time. The study shows that the rapid reduction in the temperature, a PCM panel–as opposed to a regular panel –does not allow for enough time to emit the stored energy to its ambient, which is likely to result in the lower efficiency in subsequent cycles. There are also plans for the further analysis involving different PCM materials and various heating and cooling rates, which will contribute to the optimal selection of the PCM material (e.g. for use on surfaces not exposed directly to sunlight, or with a low probability of very rapid temperature fluctuations).

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