TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

3-B/2014

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THE POSSIBILITY OF USING PCM IMPREGNATED GIPSUM BOARDS OF DIFFERENT TEMPERATURE PHASE CHANGE

MOŻLIWOŚĆ STOSOWANIA PŁYT GISPOWO-KARTONOWYCH Z DODATKIEM PCM O RÓŻNEJ TEMPERATURZE PRZEMIANY FAZOWEJ

A b s t r a c t

The paper presents results of experimental studies on components containing phase change materials. The subject of research was the simultaneous usage of two different PC materials: gypsum-carton boards with paraffin capsules of change temperature 23ºC and a board with a melting temperature of 26ºC. The tests were carried out in a climatic chamber for a light skeleton wall lined with inner facing consisting of a traditional gypsum-carton and a layer of PCM board. Measurements of temperature course were taken as well as heat flux density distribution on the surfaces of the boards for variable conditions in the climatic chamber. The results presented in the article are one of the aspects of widely planned and realized measurements aimed at evaluating and choosing the optimal material solutions, using available phase change materials.

Keywords: *phase change material*, *PCM*, *heat capacity*, *heat accumulation*

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań eksperymentalnych przegród zawierających materiały fazowo zmienne. Przedmiotem badań było jednoczesne zastosowanie dwóch rodzajów materiałów PCM: płyt gipsowo-kartonowych z kapsułkami z parafiną o temperaturze przemiany 23ºC oraz płyty z temperaturą przemiany 26ºC. Badania przeprowadzono w komorze klimatycznej dla lekkiej ściany szkieletowej, wyłożonej okładziną wewnętrzną z tradycyjnej płyty gipsowo kartonowej oraz jedną warstwą płyty z PCM. Przeprowadzono pomiary przebiegu temperatury oraz rozkładu gęstości strumieni cieplnych na powierzchniach płyt dla zmiennych warunków panujących w komorze klimatycznej. Zaprezentowane w artykule wyniki badań stanowią jeden z aspektów szeroko zaplanowanych i realizowanych pomiarów mających na celu ocenę i dobór optymalnych rozwiązań materiałowych z zastosowaniem dostępnych materiałów fazowozmiennych.

Słowa kluczowe: *materiał fazowo zmienny*, *PCM*, *pojemność cieplna*, *akumulacja ciepła*

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1. Introduction

Energy used in both commercial and apartment buildings is largely spent on their heating and cooling.

One of the solutions which makes it possible to decrease its consumption is to use phase change materials. They take heat during phase change from solid into liquid and release it when changing from a liquid state into a solid state.

When building, the use of products that contain phase change materials may contribute to the decrease of daily temperature fluctuations inside the rooms and in this way to improve the heat comfort and decrease the energy demand of buildings. In case of buildings with no cooling installations it is a passive solution which may decrease the risk of overheating.

1.1. The aim of research

The subject of the undertaken research is comparative analysis of the behavior of a light wall in which inner finishing boards were used in variable air temperature conditions. The main aim of the analysis is evaluation of accumulative possibilities of gypsum-carton boards which contain phase change materials of different change temperature.

2. Description of a measurement stand

A measurement stand was installed in a laboratory climatic chamber. A light skeleton wall of 195 cm × 210 cm was placed between the so called "cold chamber" and a "warm one" The basic layers of the partition were: expanded polystyrene board of 16 cm and an inner gypsum-carton board cladding. In order to exclude the possibility of air circulation between the thermal insulation and the gypsum- carton board, the board was additionally sealed with silicone on its perimeter.

On the partition surface from the side of the "warm chamber" three test gypsum-carton boards of 50 cm × 60 cm were mounted. Two of them contained phase change material, the third one was an ordinary board with no additions. The arrangement of the boards were made according to the scheme presented in Fig. 2. The boards mounted in the top row contained an organic material called Micronal which has an adequate melting temperature of 23ºC for the board placed on the left and the melting temperature of 26ºC for the board on the right. The phase change heat of the material used was 110 kJ/kg (according to the producer). PCM was about 30% of the board mass (about 3 kg of dry Micronal per 1 m^2 of the board. All the test boards were also sealed with silicone on their perimeters.

2.1. Testing equipment

Temperature and heat flux density were the quantities measured both on the surface and between the layers of the partition. On the surface of the expanded polystyrene and on each of the fastened boards three temperature sensors (type K thermocouple) were placed and a heat meter (a square one of 120 mm ×120 mm), (Fig. 2a, 2b). Air temperature inside the chambers was measured by temperature sensors Pt 100 and Pt 1000. Registering of the measured quantities took place through data collecting system Ahlborn Almemo connected to the computer. Measurement data were written down with the aid of data collecting system Data-Control 4.2. Further data processing was conducted in Excel programme.

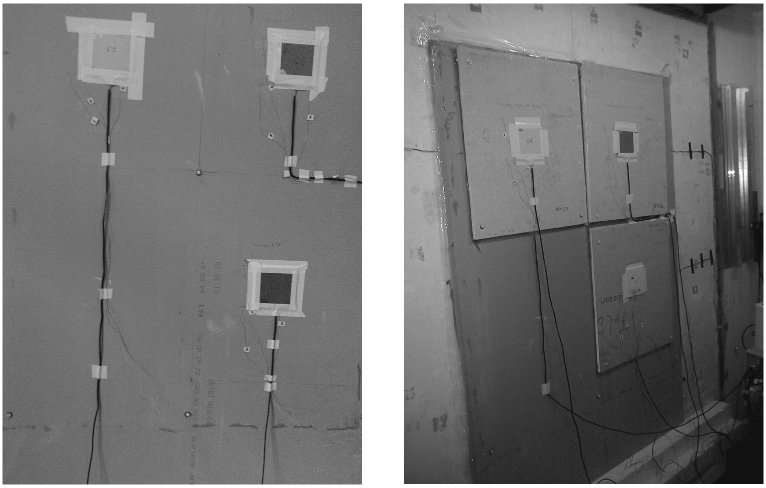

Fig. 1. Picture of the board with sensors attached to the surface

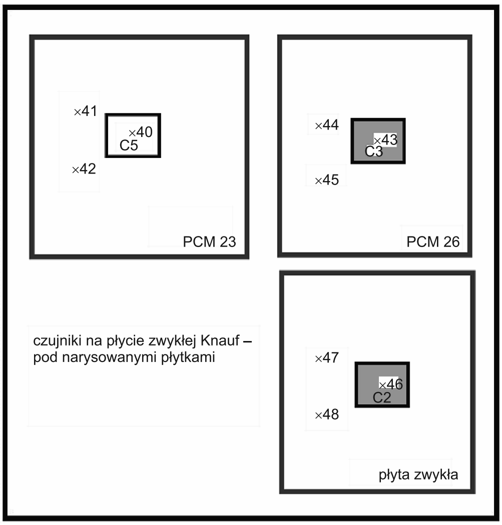

Fig. 2a. Sensor distribution scheme under the surfaces of the boards: 40, 41, 42 – temperature sensors under the surface of PCM23 board; 43, 44, 45 – temperature sensors under the surface of PCM26 board; 46, 46, 47 – temperature sensors under the surface of gypsum-carton board with no phase change material; C5, C3, C2 – square heat meters of 120 mm × 120 mm placed adequately under the surfaces of the boards: PCM23, PCM26 and an ordinary board

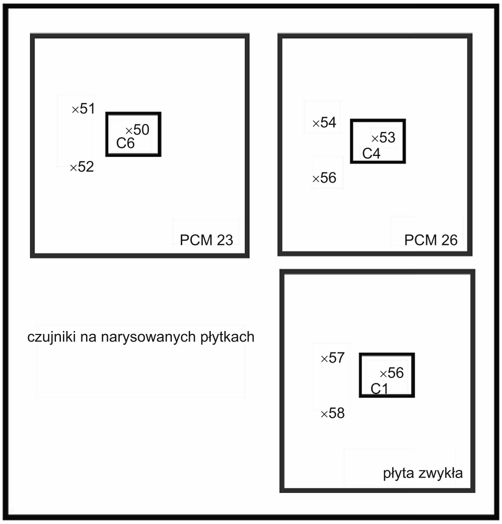

Fig. 2b. Sensor distribution scheme on the surfaces of the boards: 50, 51, 52 – temperature sensors on the surface of PCM23 board; 53, 54, 55 – on the surface of PCM26 board; 56, 56, 57 – temperature sensors on the surface of gypsum-carton board with no phase change material; C6, C4, C1 – square heat meters of 120 mm × 120 mm placed adequately on the surfaces of the boards: PCM23, PCM26 and an ordinary board

3. Procedure of the carried out tests

3.1. Tests in a climatic chamber

The tests were carried out in a few stages. In the article the research results were analysed for the case of nonstationary temperature conditions existing in a heat chamber. Temperature change range inside the chamber was selected in a way that would correspond to the conditions that may occur in rooms during summer. The tests were carried out in 24 hour cycles, which would reflect the actual temperature course in a sunny room.

When taking measurements all three tested gypsum-carbon plates were subjected to the same conditions.

The first stage of testing aimed at observing changes in temperature and in heat flux on the front and back surfaces of the boards.

During twelve hours in a heat chamber there was an increase of temperature from 18ºC to 36ºC, and then a decrease of air temperature down to initial conditions. In a test cycle high temperature, above 35ºC, remained in the heat chamber for about four hours. In a cold chamber there was a steady temperature of about 18ºC. Air temperature increase in the chambers, due to technical possibilities of the controlling equipment, could reach six degrees an hour. Because of this, temperature increase was not continuous but it agreed with the scheme presented in Fig. 3. The scheme presents the course of temperature distribution for one cycle.

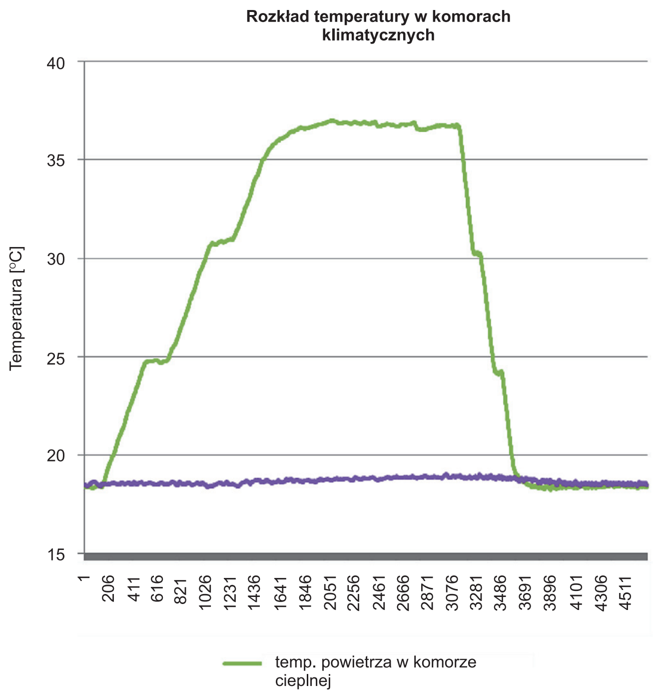

Fig. 3. Measurement of the air temperature distribution in the hot and cold chamber during testing

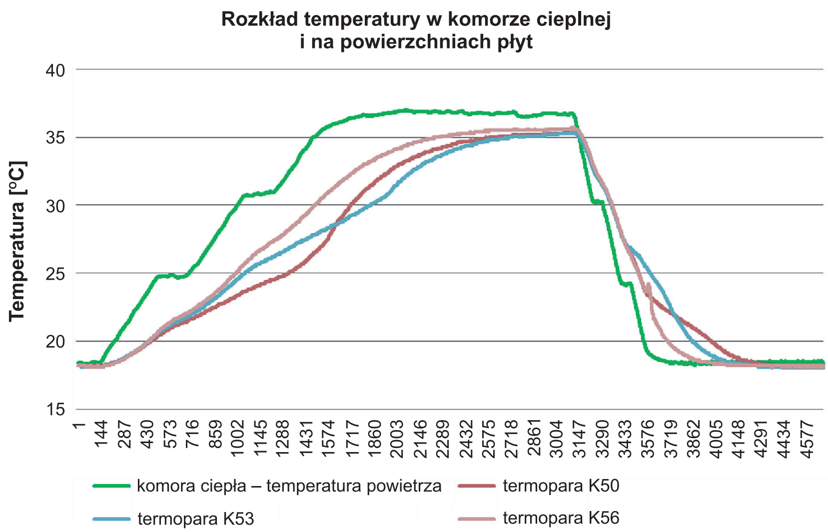

Fig. 4. Course of air temperature changes in the hot chamber and temperature distribution on the surfaces of the analysed boards. On PCM23 board – thermocouple K50, on PCM26 board – thermocouple K53, on the ordinary board – thermocouple K56

Taking into consideration heat comfort of the rooms it is essential to have information about the difference between the air temperature value in a room and the temperature of the finishing surfaces. The graph in Fig. 5 allows us to observe the course of temperature difference that could be noticed on the plate surface of an ordinary gypsum-carton board and on the surfaces of board containing PCM23 and PCM26. In the process of air temperature growth the temperature on the surfaces of the boards containing PCM was lower maximally 3.6ºC than on the surface of an ordinary board. This is beneficial for a PCM board temperature course and is connected with bigger possibilities of excess heat accumulation in such a material. It can be observed in the graph presented in Fig. 4 that in the case of boards containing phase change materials it is the temperature change that beneficially influenecs temperature distribution. In the analysed example, during air temperature growth from 18ºC to 36ºC it is more advantageous to use PCM23 board whose surface temperature is 3.5ºC lower than of an ordinary plate and 1.8ºC lower than in the case of PCM26 plate. After the heating cycle is finished and when air temperature stabilizes above 35ºC the arrangement is reversed. There follows temperature increase (over 28ºC) on the surfaces of PCM plates. Therefore, in this case, it is better to use plates of higher temperature change (the temperature of the PCM26 surface is maximally 3.2 degree lower than in an ordinary plate).

An essential aspect connected with the possibility of storing energy in PCM was the measurement of the difference in temperature that occurred in a given time period between the front and the back surfaces of all analysed boards. Fig. 6 presents temperature distribution for the case discussed.

Figure 6 presents the temperature course on the surface behind the boards containing PCM. It can be observed that the indications are 4.8ºC lower than on the surface behind an ordinary plate. These lower values are caused by absorption of heat flux penetrating this material and reaching the surface of the back board at a much slower rate. It is also important that the maximum difference of temperature indications between the back PCM23 board and an ordinary board occurs in the neighbourhood of phase change temperature (23.3ºC), while for PCM26 board it is shifted to 27.3ºC.

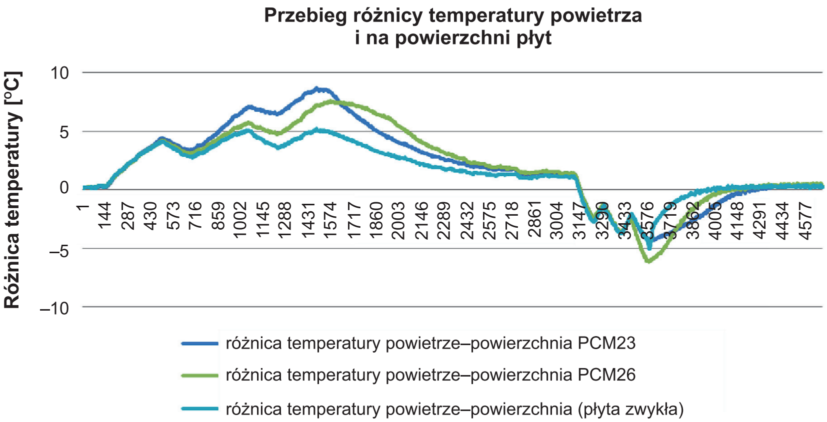

Fig. 5. Differences in air temperature course and on the surfaces of an ordinary plate and the plates containing PCM

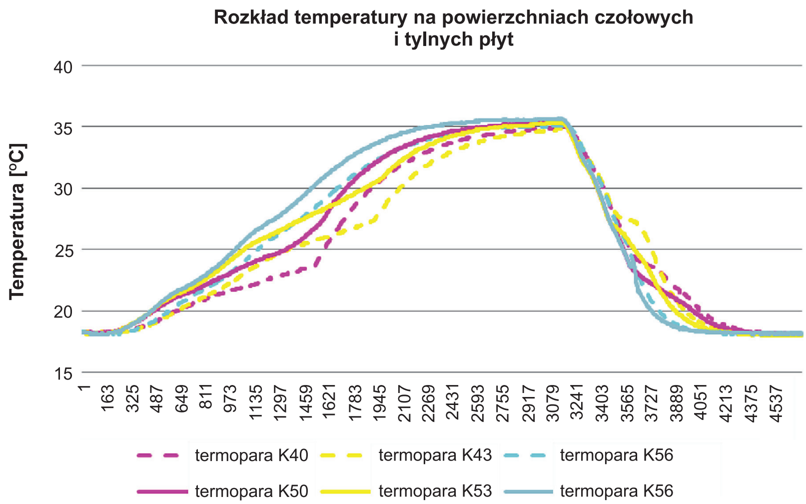

Fig. 6. Temperature change course on and under the surfaces of the analysed boards. The sensors: on PCM23 board – thermocouple K50, under PCM23 – thermocouple K40; On PCM26 board – thermocouple K53, under PCM26 board –thermocouple K43: on an ordinary board – thermocouple K56, under an ordinary board – thermocouple K46

The accumulative possibilities of the analysed boards are more clearly shown by heat flux density taken and given up by particular surfaces. The measurement results are presented in Fig. 7. The graphs show distinctly greater heat absorption for boards containing phase change materials. Due to different change temperature (23ºC and 26ºC) a clear shift in time of the extremes can be observed in the compared materials.

The integration results of the heat flux density taken by three analysed plates in the studied time period show greater possibility of heat accumulation by a plate containing PCM26. During the heating cycle it accumulates 3.5 times more heat than a gypsum-carton plate with

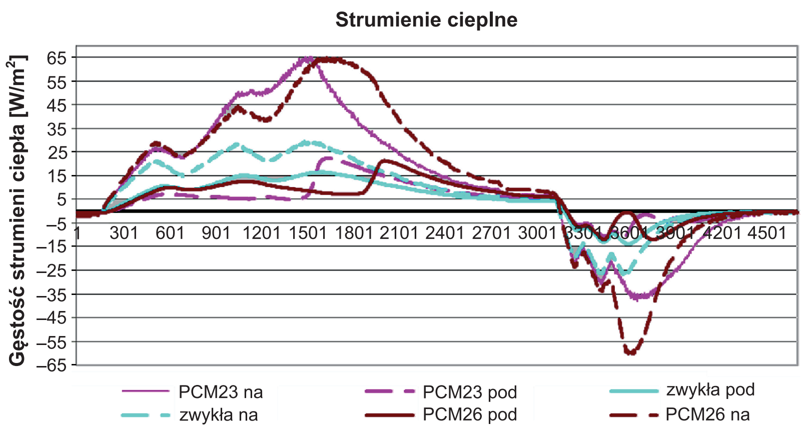

Fig. 7. Thermal flux density measurement on the front and back surfaces of gypsum boards

no addition of phase change materials. The board PCM23 was equally advantageous – during testing it accumulated nearly 3.11 times more heat than an ordinary board.

4. Conclusions

The integration results of the heat flux density taken by the two boards containing phase change materials in the studied time period indicate much greater possibility to accumulate heat than an ordinary board. It is therefore evident that it is posible to significantly increase the heat volume of a room while using the same amount of finishing material but with the addition of PCM. A partition working in the conditions of extreme temperatures of the summer time was analysed. The results presented allow us to state that phase change temperature will have a significant influence on its effectiveness. When choosing a very high maximum air temperature for the tests it seems justified to use boards of lower and higher phase change temperature.

Such analyses will be the subject of further studies.

The work reported in this paper has been partially funded by the project L-1/115/DS/2013.

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