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PHASE CHANGE MATERIALS VS. INTERNAL TEMPERATURE IN A BUILDING

MATERIAŁY FAZOWO-ZMIENNE A TEMPERATURA WEWNĄTRZ POMIESZCZEŃ

A b s t r a c t

The article presents results of simulation of building assuming presence of phase change material in wall barriers. Obtained results were compared with the ones of a building without phase change material in wall barriers. Object of comparing calculations is a model of a real service building located in Silesia. It has light-frame construction with light covering (external metal sheet, heat-insulation, interior metal sheet). In subsequent examinations, the presence of 1 cm thick PCM board placed under the inner surface of a metal sheet was assumed. Tests were conducted for organic materials that undergo phase transition in different temperatures such as 23°C, 25°C, 27°C or 29°C. Based on results of operative temperature measurements, it is possible to determine PCM influence on the building overheating risk.

Keywords: heat capacity, phase change material

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

W artykule przedstawiono wyniki symulacji budynku, zakładając wbudowanie w jego przegrody materiału fazowo-zmiennego. Wyniki porównywano do stanu wyjściowego (bez PCM). Przedmiotem porównawczych obliczeń jest model istniejącego budynku o charakterze usługowym, zlokalizowany w województwie śląskim. Budynek ma konstrukcję szkieletową z lekkim poszyciem (blacha elewacyjna, termoizolacja, blacha konstrukcyjna). W kolejnych wariantach pod powierzchnią blachy od strony wewnętrznej założono wbudowanie PCM w postaci mat o grubości 1cm. Materiałem ulegającym przemianie fazowej jest materiał organiczny. Analizie poddano warianty z zastosowaniem PCM o różnej temperaturze przemiany fazowej, tj. 23°C, 25°C, 27°C. Na podstawie wyników temperatury operatywnej można określić wpływ MFZ na ryzyko przegrzewania budynku.

Słowa kluczowe: pojemność cieplna, materiały fazowo-zmienne

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1. Introduction

The aim of placing PCM into building elements is to increase heat capacity of a building. Exessively low heat capacity results in deficiency of heat stability in very popular light-frame construction with light filling wall barriers that cause seasonal overheating of a building and large temperature oscillations of internal air during temperature changes of external air.

The idea of using phase change materials to accumulate heat is built on an energy saving process such as latent heat of organic compounds e.g., paraffins, fatty acids or inorganic salt hydrates. Accumulation or emission of large amounts of heat occurs during phase transition and is accompanied with a small temperature change of a specific PCM.

2. Purpose of the article

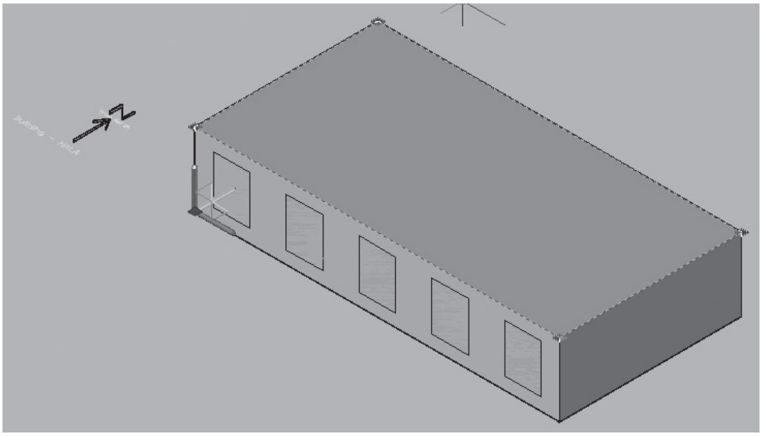
The aim is to determine the influence of phase change materials on internal temperature of an examined object and thermal stability. Both internal air temperature and internal surface temperature of wall barriers were tested. Examination was conducted with particular consideration of thermal parameters influencing thermal comfort and determination of the building overheating risk.

3. Analysis

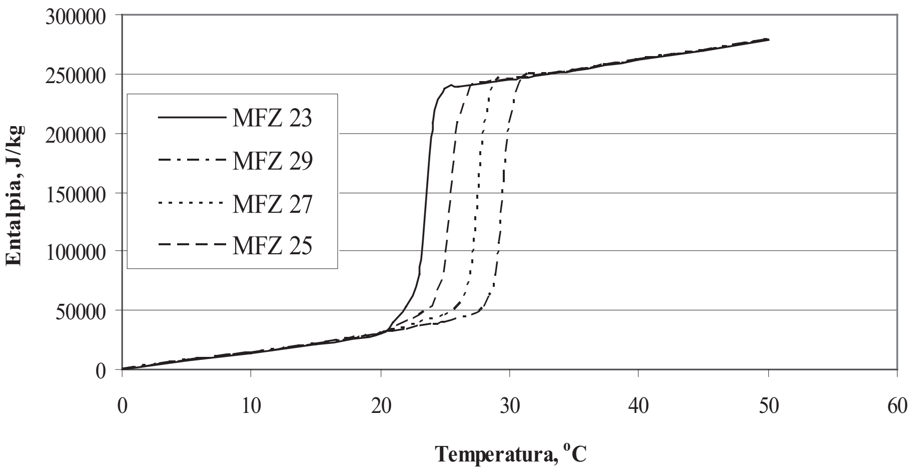
3.1. Description of the calculation model

The object of comparing calculations is a model of a real service building located in Katowice. It has light-frame construction with light covering. The floor is constructed with 10 cm layer of concrete. Object dimensions are 15 m × 30 m × 6 m (Ill. 1).

In initial condition, elevation is constructed with 15 cm thermal insulation bound by metal sheets from each side. In the next variant, the PCM was built in as a 1 cm layer, located from the internal side of a wall. To analyze this, an organic kind of Phase Change Material was used. In simulation, all available variants of PCM were used. The difference between variants was the temperature of phase changing at 23°C, 25°C, 27°C (in this article, variants were called consecutively PCM 23, PCM 25, PCM 27, PCM 29). Adopted to calculation, dependence of the enthalpy of the temperature for the PCM, is illustrated in Ill. 2 [2]. All other material data are presented at Table 1.



Ill. 1. Visualization of analyzed building



Ill. 2. Relationship between enthalpy and temperature for the analyzed PCM [2]

Table 1

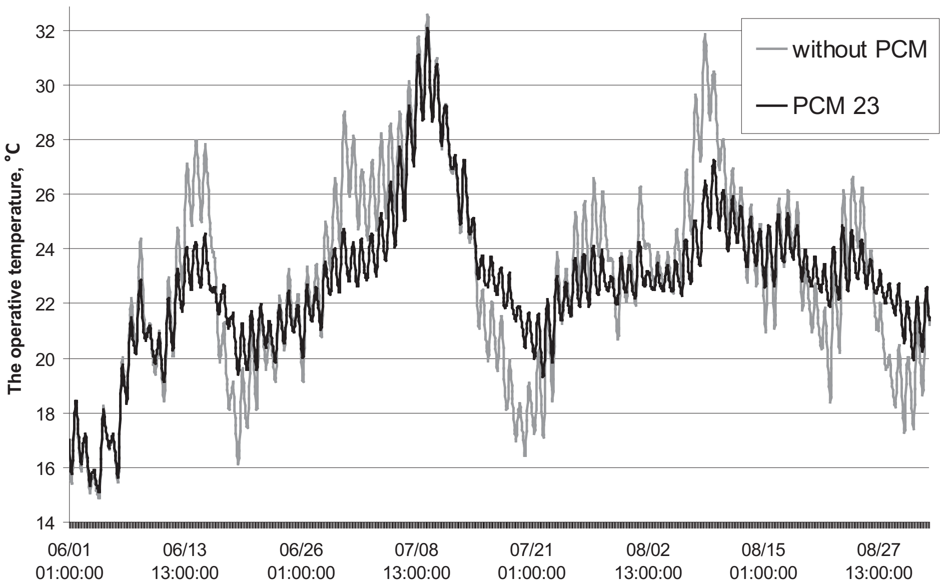
Material data [3, 4, 7]

Material	Thickness [m]	λ [W/mK]	Specific heat [J/kgK]	Thermal absorptance	Solar absorptance
External metal sheet	0.001	58	500	0.9	0.4
Termal-insulation	0.15	0.04	1381	0.9	0.7
PCM	0.01	0.2	c_w (T)	0.9	0.7
Interior metal sheet	0.001	58	500	0.9	0.4

The wall glazing is composed of 5 big windows with the dimensions of 3 × 4 m. The windows are located at the south side of the building. It is assumed that there are10 persons in the building simultaneously during working hours and that it is also necessary to use additional interior lighting. In order to this during working hours (i.e., 7 am to 6 pm) heat gains from people (80 W per person) and lighting (3 W/m^2) were added. In the simulation, weather data for the period from 1.06 to 1.09 was addopted. A 0,5 outdoor air change per hour was also assumed. All simulations were performed in Energy Plus ver. 7.1 application, which allows the modeling of phase transition of chosen materials and is able to provide for unsteady external conditions.

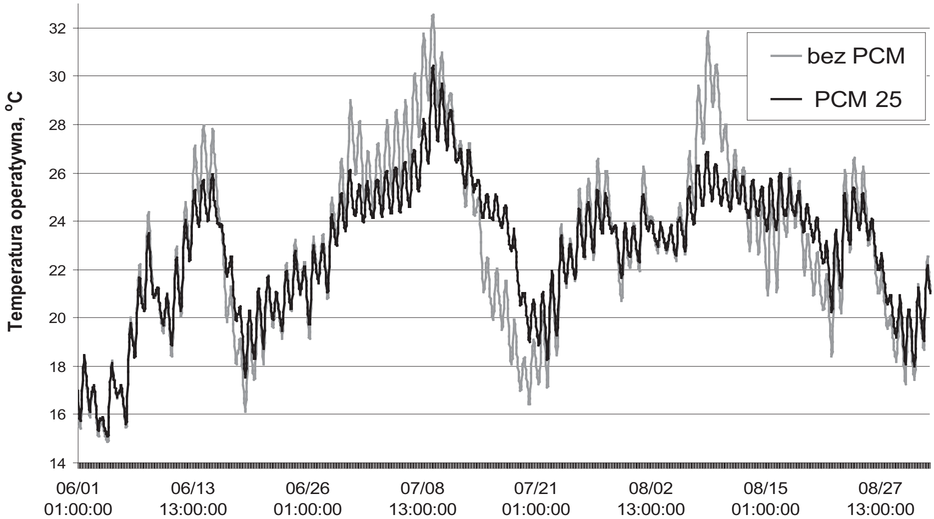
3.2. Simulation results

The operative interior temperature of the object has been analyzed. On the operative temperature (wind chill) both interior air temperature and the temperature of the barriers have influence. Ill. 3, 4 and 5 show graph of the operative temperature inside the building in the analyzed period with different material variants (without PCM, PCM with different point of phase change 23°C, 25°C and 27°C).

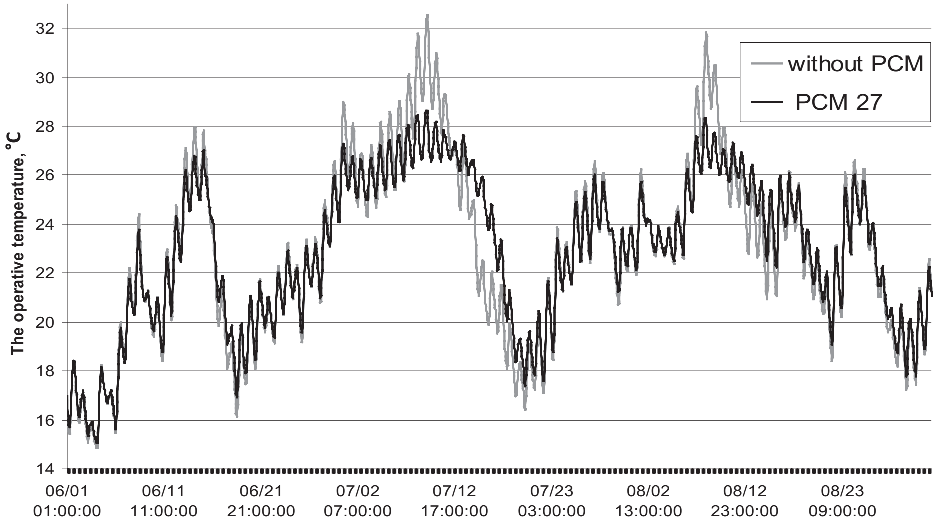


Ill. 3. The operative temperature inside the building in analyzed period without PCM and with PCM 23

Regardless of the type of PCM installation it is always visible that the graph is smoother in comparison to the baseline. That demonstrates the much higher thermal stability of the object and reduction of the impact of outside temperature. Maximum wind chill that occurs in this variant is at 32.57°C (base variant), 32.07°C (with PCM 23), 30.45°C (with PCM 25)



Ill. 4. The operative temperature inside the building in analyzed period without PCM and with PCM 25



Ill. 5. The operative temperature inside the building in analyzed period without PCM and with PCM 27

and 28.65°C (with PCM 27). Thus, the largest reduction of the maximum temperature can be achieved by using PCM 27. Material variants were also analyzed in terms of efficiency; the difference between the interior operative temperature with incorporated PCM and without PCM, were calculated at each time step. The maximum difference of instantaneous values occurred at variant PCM 23 with the value of 5.44 K (in next variants: PCM 25 Δt_{max} = 5.25 K, PCM 27 Δt_{max} = 5.10 K). In order to take into account the frequency, all positive Δt were integrated. As presented in Table 2, the maximum sum of positive Δ, the frequency of occurrence and the average value of Δ indicate that PCM 23 has the highest efficiency.

Table 2

Analiza rozwiązań z różnymi rodzajami PCM

Wariant	PCM 23	PCM 25	PCM 27
max $\Delta t = t_{operative} - t^{PCM}_{operative}$, K	5.44 K	5.25 K	4.1 K
Sum $\Delta t > 0$, °C	1601	1155	677
Frequency $\Delta t > 0$	1231	1098	973
Mean Δt, °C	1.30	1.05	0.70

As presented in Table 3, using the PCM 23 causes the biggest reduction of total time with the temperature over 24°C (limit of thermal comfort). The length of that term was shortened by over 38% in comparison to the variant without PCM. When PCM 25 is incorporated, a very large (over 75%) reduction of term with temperature over 27°C is achieved. It is very important due to the thermal sensitivity of people because temperature above 27°C is not tolerated by the human body. The application of PCM 27 will completely remove the term of maximum temperature (above 29°C), but at the same time maintains a long total period exceeding both temperatures of 27°C and 24°C.

Table 3

Number of hours when internal temperature was over internal temperature setpoint

Temperature, °C	**> 24**	**> 25**	**> 26**	**> 27**	**> 28**	**> 29**	**> 30**	**> 31**	**> 32**
Variant									
without PCM	855.85	630.25	442.85	285.30	181.20	115.00	61.00	25.85	6.30
PCM 23	**527.95**	296.05	190.60	140.00	93.85	62.95	32.85	11.30	1.80
PCM 25	898.35	477.30	187.10	**79.55**	45.75	18.65	4.80		
PCM 27	933.95	706.70	429.05	159.50	32.85				

4. Conclusions

The incorporation of PCM inside external barriers of the building causes a risk of interior overheating. Results of the simulation indicate that the most efficient solution is the incorporation of a material which has the point of phase change at 23°C. This is probably due to the high frequency of occurrences of that temperature range and the point of phase change of the material in that range. Using PCM 23 causes the greatest reduction of total time with the temperature over 24°C. Solutions with PCM 25 and PCM 27 perform effectively only in the case of higher temperature. To determine which option is more comfortable for the people inside a building, it would be required to deeply analyze the problem in terms of the thermal comfort, with consideration to the length of the peak temperature period for each day.

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