Thermal stability of attic spaces with integrated PCM in light building constructions during the climatic year

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Abstract **This paper how PCM react during the whole year, how they impact the summer temperature stability of a room and how they react in the transtition period and in the heating period. Measuring was carried out in the experimental and reference room in the attic of the Institute of Building Structures. The layout of these identical rooms enables to compare the measured values. The measuring of the indoor climate which had been carried out during the whole year in the reference and experimental room was analysed.**

Keywords – **Phase change materiel, heat storage, summer overheating, light weight envelopes.**

I. Introduction

Practical verification of effectiveness of phase change materials (PCM) was performed on an experimental building. As it was necessary to compare the results, a model of two identical rooms was used. An experimental building constructed like this makes it possible to declare the basic behaviour of phase change materials and their impact on the thermal stability of a room. The rooms are in the attic.

II. Measuring in Experimental rooms

A. Measuring and monitoring technology

Due to the necessity to compare the results, the experimental and the reference room is fitted with several kinds of sensors. In order to collect climatic data, a meteorological station HUGER was installed on the roof of the Institute of Building Structures. The measured values were saved every 15 minutes. Average values from the respective periods were recorded. Sensors for measuring surface temperature, air temperature, global temperature and global solar radiation were used for measuring with the Amemo AHLBORN device.

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The controlled ventilation system makes it possible to supply fresh air and conduct exhaust air away in two different ways (Pict. 1). The first option is to supply fresh air through a ceiling textile inlet and to conduct the exhaust air away through lamellar outlets above the floor in the corners of the room. The second option is a cross one, i.e. the air is supplied through a lamellar inlet above the floor and conducted away through ceiling outlets.

Pict. 2. Controlled ventilation system

B. Comparison of the reference and the experimental room without load

Comparative measuring in summer 2008 verified the identical properties of the two rooms. Measuring was used to check fitting of the sensors and maximum temperature deviation between the experimental and the reference room. The values ranged up to 0,7 °C, the average deviation was 0,3 °C. Based on the analysis of the acquired data the location of thermocouple interior air temperature sensors was adjusted. The experimental room was then marked as suitable for experimental verification of PCM effectiveness.

C. Measuring in the period with natural ventilation

The first experimental verification of the influence of PCM on the internal environment was with natural ventilation. Panels with PCM were installed on the inner surface of the walls and of the ceiling (Pict. 2). Natural ventilation was maintained by a casement opened to the position of ventilation. There were no thresholds at the entrance doors in order to increase the ventilation of the space. Measurement with natural exchange was chosen in order to reduce power consumption for forced ventilation to minimum.

Pict. 2. Experimental room with panels of PCM

D. Measuring in the summer

The task in the summer was to prove the efficiency of accumulation of latent heat into accumulation PCM panels in the form of aluminium panels filled with DELTA®COOL 24 mixture. Heat accumulation during phase transformation was presented on weekly and daily progress of temperature. The main task in the summer was to prove the efficiency of accumulation of latent heat into the accumulation PCM panels. The first measuring on the experimental object started at the end of August 2008. It was possible to make only one experimental measuring with the climatic conditions presenting hot summer climate before the end of the summer season.

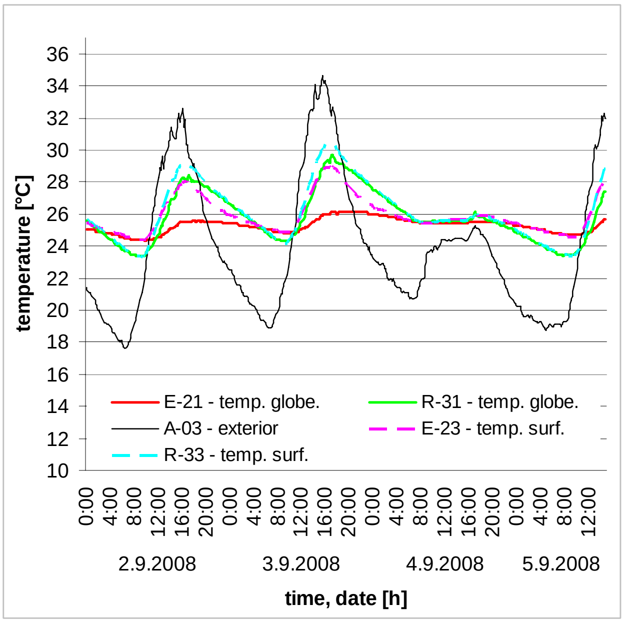

Fig. 1. Air temperatures in experimental (E) and reference (R) room in summertime

The measuring was carried out from 29 August to 5 September. The overview of the difference air temperature in the rooms in the monitored summer season is given in tables. The differences in the maximum daily temperature ranged between 1,2 and 4,1 °C. The difference in the temperature at night ranged between 0,4 °C and 1,0 °C. The experimental room with the installed PCM revealed higher thermal stability. There were no significant differences in the maximum daily temperature of air in the interior $\theta^*_{ai,max}$ during the monitored week in the summer. All the time, the maximum temperature of air was moving around the value $\theta^*_{ai,max} = 26$ °C.

TEMPERATURE DIFFERENCES BETWEEN ROOMS IN DAYTIME .

Date	Temperature differences - day $\Delta\theta^*_{ai,max}$ (°C)
29. 8. 2008	1,2
30. 8. 2008	4,1
31. 8. 2008	3,4
1. 9. 2008	1,5
2. 9. 2008	2,5
3. 9. 2008	3,6

TEMPERATURE DIFFERENCES BETWEEN ROOMS IN NIGHTTIME .

Date	Temperature differences - night $\Delta\theta^*_{ai,max}$ (°C)
29. 8. 2008	0,6
30. 8. 2008	1,2
31. 8. 2008	0,9
1. 9. 2008	0,8
2. 9. 2008	0,4
3. 9. 2008	1,0

Graphs (Fig. 1, 2) show that due to higher thermal storage capacity of the PCM packaging design in the experimental room, the highest temperature of air in the experimental room dropped in comparison with the temperature of air in the reference room. Higher temperature of air in the experimental room at night is caused by the fact that thermal energy accumulated in the PCM discharges.

E. Transitional period

In the transitional period the temperature of air in the exterior was lower than the values enabling a phase change from solid into liquid. An analysis of the acquired data revealed that PCM have a positive impact on the thermal stability of a room. It is manifested by higher temperature of air in the interior θ_{ai} over a long period. The temperature of air in the interior θ_{ai} of the experimental room which was cooling down was for four days by 2 °C higher that the temperature of the identical reference room.

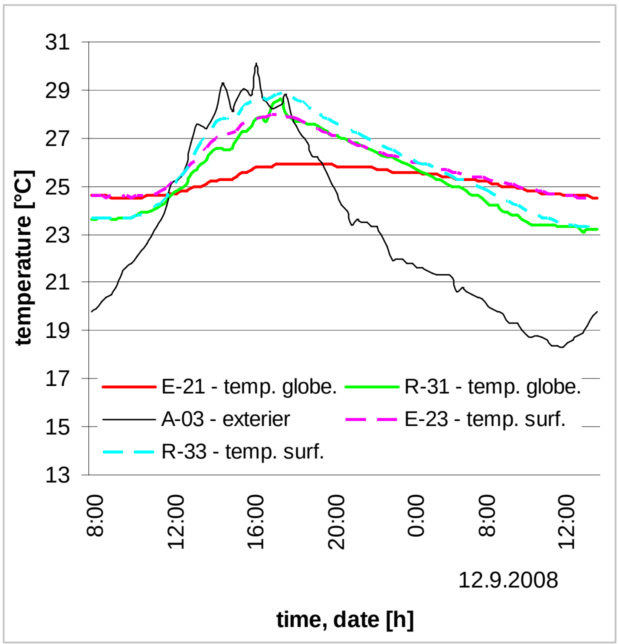

Fig. 2. Focus on one typical summer day. Reducing temperature by PCM panels (E21, E23)

F. Heating season

The experiment with monitoring the influence of PCM on the parameters of the interior environment in the heating season was carried out with heaters turned to maximum power. The experiment was supposed to demonstrate the behaviour of PCM when faced with different parameters of the phase change (phase change around 20 °C). Digital timer and an electricity consumption meter were installed on the power supply.

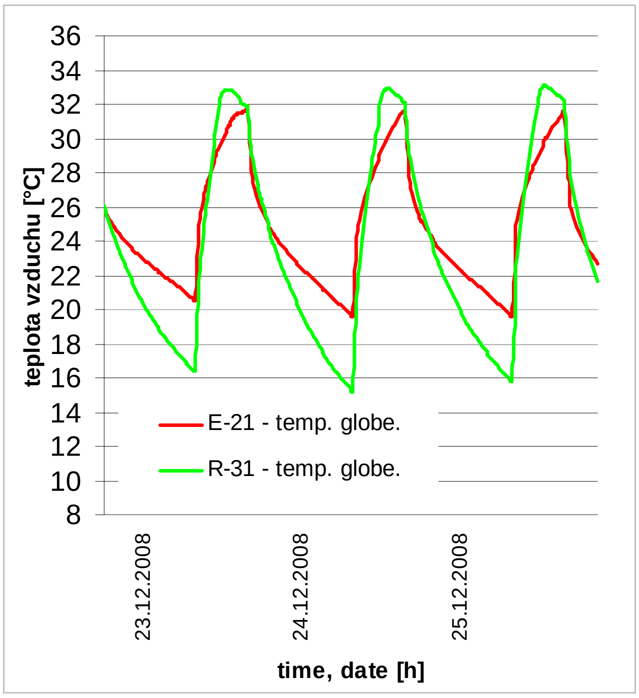

Fig. 3. Air temperatures during the heating season.

Measuring with an intermittent heating method was carried out. Heating was regulated only by thermostats in the heaters. Heating of the air in the interior was maintained by electric convector heaters with the power of 750 W. If phase change occurs repeatedly in PCM during the heating season, reduction of temperature amplitudes of air in the interior occurs even here too. When electric convector heaters were used to warm the air in the room, the installed PCM were actively accumulating the heat distributed from the heaters. Therefore, the growth of temperature of air in the experimental room and the growth of temperature of air at the outlet of the heater was not as steep as in the reference room. In February 2009, it was being monitored how PCM participate in the energy consumption of the heating system. Heating was regulated by bimetallic thermostats which are part of heaters. The thermostats were set to level 6 in both rooms (temperature 27 °C). The power consumption during the week when monitoring took place (16 February – 23 February. 2009) was 118,6 kWh in the reference room and 127,4 kWh in the experimental room. The difference of 8,8 kWh in the monitored period was caused by the consumption of accumulation boards for the phase change of PCM at the beginning of the measuring. The daily readings of power consumption were identical since the third day. At the end of the heating season the energy was given back to the environment via radiation during inverse phase change, as in the previous period.

G. Conclusions of the Experimental Method

The experimental method made it possible to describe in detail the behaviour of PCM installed in building constructions during one whole climatic year. Comparative measuring confirmed the possibility to carry out comparative measuring on an experimental object, using a reference and an experimental room. In the summer latent heat accumulation into PCM proved to be effective. When PCM were used, the condition on the maximum daily temperature in the room was demonstrably met. The experimental room showed higher thermal stability in the transitional period in autumn. For four days the temperature of air in the experimental room was higher by approximately 2 °C than in the reference room. Measuring of the parameters of the interior environment in the winter revealed identical power consumption needed for heating in both rooms. Therefore, it can be concluded that PCM do not have negative impact on the power consumption needed for heating (1).

IV. The Impact of PCM on the Indoor Environment of Buildings During a Climatic Year

On the basis of measuring carried out in 2008 and 2009 it can be concluded that:

In the summer the experimental room with an installed PCM revealed higher thermal stability. The differences in the maximum daily temperature ranged between 1,2 °C and 4,1 °C. At night the difference in temperature ranged between 0,4 °C and 1,0 °C. The maximum temperature of air in the experimental room was all the time around the value $\theta^*_{ai,max}$ = 26 °C. The maximum daily temperature in the reference room in the same period ranged between 25 and 30 °C,

It was found out that in the transitional period PCM have positive impact on the thermal stability of the room. This is manifested by higher temperature of air in the interior θ_{ai} over a long period. For four days the temperature of air in the interior θ_{ai} of the experimental room which was cooling down was by 2 °C higher than in the identical reference room.

In heating (winter) season and with standard way of heating the materials participate only in accumulation of perceptible heat. If the temperature of air in the interior does not reach the temperature of the phase change, accumulation of latent heat does not occur. If the temperature of the phase change is lower than the temperature of air in the interior, accumulation of both latent and sensible heat occurs. However, this phenomenon has no negative impact on the total power consumption for heating.

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