BUDOWNICTWO
CZASOPISMO TECHNICZNE
TECHNICAL TRANSACTIONS
CIVIL ENGINEERING
WYDAWNICTWO POLITECHNIKI KRAKOWSKIEJ
2-B/2010
ZESZYT 4
ROK 107
ISSUE 4
YEAR 107

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STRUCTURES WITH INCORPORATED PHASE CHANGE MATERIALS

KONSTRUKCJE Z WYKORZYSTANIEM FAZOWO-ZMIENNYCH MATERIAŁÓW

Odpowiedzialność za poprawność językową ponoszą autorzy

A b s t r a c t

Light-weight envelopes do not have sufficient thermal capacity because of the low own mass. Thermal storage capacity of common building materials depends on the mass, thermal capacity and difference between initial and final temperatures. Latent heat storage is a promising method of improving thermal storage capacity of envelopes. The paper presents the results of practical measurement in a room with incorporated aluminium panels combined with phase change materials.

Keywords: phase change materials (PCMs), light-weight envelope, thermal stability

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

Lekkie powłoki nie charakteryzują się wystarczającą izolacyjnością cieplną ze względu na małą masę własną. Pojemność cieplna materiałów budowlanych zespolonych zależy od ich masy, mocy cieplnej oraz różnicy pomiędzy początkową i końcową temperaturą. Magazynowanie ciepła utajonego jest obiecującą metodą poprawy izolacyjności cieplnej powłoki. W artykule przedstawiono wyniki pomiarów wykonanych w pomieszczeniu z paneli aluminiowych połączonych z materiałami fazowo-zmiennymi.

Słowa kluczowe: materiały przemiany fazowej (PCMs), lekkie powłoki, stateczność termiczna

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Denotations

θ_{in} – indoor temperature [°C]
θ_{out} – outdoor temperature [°C]
θ_o – operative temperature [°C]
θ_{sa} – temperature of supply air [°C]

1. Introduction

The typical way how to store thermal energy during summer season is usage of wall sensible heat storage. Heat is stored by the material temperature increases due to the solar energy entering to the internal space. But there are limits of thermal comfort. One of solutions to prevent overheating is installation of air – conditioning unit. Every air conditioning unit produce large amount of CO_2 emissions because of need electricity for operation. Nowadays costs of electricity are increasing and the point of view of environmental impacts is very important. One of the possibilities how to make construction heat storage more efficient is using the latent heat storage such a part of energy storing method. The latent heat storage method provides much higher storage density with a smaller temperature difference between storing and releasing heat. Heat is storing by change in phase of a material. Thermal energy is released when the material solidifies. The temperature remains nearly constant during the phase change.

2. Phase change materials

Latent heat storage is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa [5]. The phase change materials (PCMs) use chemical bonds to store and release the heat [7]. PCMs absorb heat because the reaction is endothermic. Phase change materials have considerably the higher thermal energy storage densities compared to sensible heat storage materials and are able to absorb large quantities of energy at a small range of temperatures during the phase change. Latent heat storage is one of the most efficient ways of storing thermal energy [1].

The selection of PCMs is mainly based on its melting temperature. The PCMs melting temperature should be within the operating temperature range of the thermal system, which is normally within the thermal comfort temperature range for an occupied space [4].

3. Structures with incorporated phase change materials

Every latent heat thermal energy storage requires a suitable PCM for use in particular kind of thermal energy storage application [6]. The application of PCMs can be divided into two groups.

First is using of solar energy for heating or night cold for cooling. Second is using of made heat and cold in building facility. In any case, storage of heat or cold is necessary to match availability and demand with respect to time and also with respect to power [7].

Efficiency of heat storage depends on thermal conductivity of material and area for transfer. Phase change materials incorporated in envelope are very useful for this purpose. Advantage of envelopes with PCMs is that the envelope of a room offers large area for heat transfer. These envelopes can increase thermal storage capacity for utilization of solar energy for passive solar heating. PCMs incorporated into the light-weight envelopes can increase thermal storage capacity of these structures, thus reducing and delaying the peak heat load and reducing room temperature fluctuation.

PCMs could be incorporated directly in building structures such as:
- vertical load-bearing structures;
- partitions;
- horizontal load-bearing structures;
- suspended ceilings;
- floor finishing;
- light-weight external cladding;
- trombe wall.

PCMs could be successfully incorporated into building materials such as gypsum wallboard, wooden board, lightweight concrete, slip-cement board, concrete structures or floor tiles to enhance the thermal energy storage capacity of envelope.

PCMs in the building light-weight structures allow to reduce the overheating during summer time. Ceiling panels were to be designed for use in standard office building with high thermal loads. The ceiling panels incorporate paraffin in microencapsulated form. This ensures that minimal quantities of phase change material will remain permanently enclosed in the capsules even when subjected to frequent cyclical loads, what has been determined as a problem with PCM-impregnated wallboards [2].

In passive systems the heat stored is automatically released when indoor or outdoor temperature rises or falls beyond the melting point. During the 1980s several forms of bulk encapsulated PCMs were marketed for passive solar applications [7].

The advantage of envelopes with PCMs is that the envelope of a room offers large area for passive heat transfer. These envelopes can increase thermal storage capacity for utilization of solar energy. The wallboards are cheap and widely used in a variety of applications, making them very suitable for PCM encapsulation [1]. The main problem with gypsum is the quantity of PCMs that can be incorporated. The maximum weight ratio is about 30 wt% [3].

4. Example of installation of PCMs in testing rooms

For the evaluation of the influence of PCMs on the indoor environment is necessary to provide the comparative measurement in two identical testing spaces. Our testing rooms were built in free attic space in the object of our Faculty of Civil Engineering. The principle of comparative method is in measurement of the ambient and internal temperatures in the same time in the experimental room with incorporated PCMs and in the referential room with common envelope. The external and internal structures of testing rooms were made only from light-weight materials. Floor area of each testing attic room is 14.9 m^2. The rooms are positioned side by side with the skylight. System allows change of quality and characteristics of glazing. Using of special sun blinds with electric drive is possible. Orientation of skylights and external envelope is south-west. The test rooms consist of galvanized steel frame structures insulated with mineral wool with thickness 200 mm. Outdoor air is supplied to the rooms by an air-handling unit.

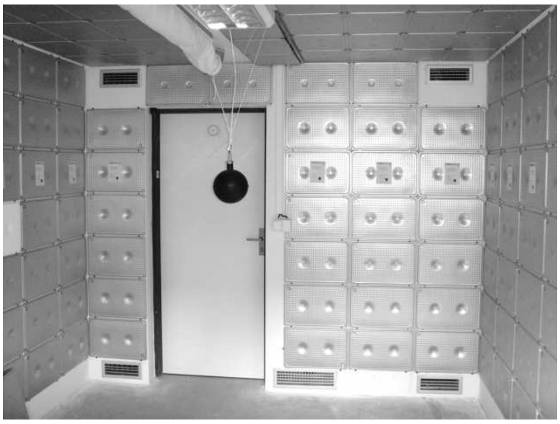

Fig. 1. View of the experimental room with aluminum panel filled by PCMs

Rys. 1. Widok pokoju eksperymentalnego z aluminiowymi panelami wypełnionymi PCMs

For increasing of thermal comfort in experimental room were installed special aluminium panels with PCMs on the salt hydrates base. There were installed the panels filled with PCMs on the internal surface of three walls, on the horizontal suspended ceiling and sloped ceiling of the roof structure. We installed totally 240 panels filled by DELTA®-COOL24 from Dörken GmbH & Co. KG.

As encapsulant was used double coated aluminium with superior heat conduction. The panels are statically stable and easy for cleaning. The PCMs is stable under cycling and hermetically sealed in panel. Panels are fixed on the gypsum wallboards only by the screws in each corner of panels. For measurement of indoor environment were installed thermocouples FTA3900 and spherical thermometers in each room. For data acquisition was used data logger ALMEMO 5690-2M.

First measurement in August 2008 was focused on the influence of PCMs on the indoor environment under the natural ventilation during day and night. Air change was provided only by windows and doors. The measurement under similar conditions continued during spring and the first part of summer 2009. During the measurement were investigated problems with discharging of stored energy in PCMs. Therefore we considered scenarios of air-change during day and night. In July 2009 was finished installation of air-conditioning unit that can control air-change in testing rooms. Inlet with textile sleeve is situated in the middle of the suspended ceiling and two outlets are in the bottom part of external wall.

5. Results and discussion

Chart in Figure 2 shows the behaviour of the operative temperatures in referential and in experimental room in selected 2 days in May 2009. With this type of air-change can be observed the problem with discharging of stored energy.

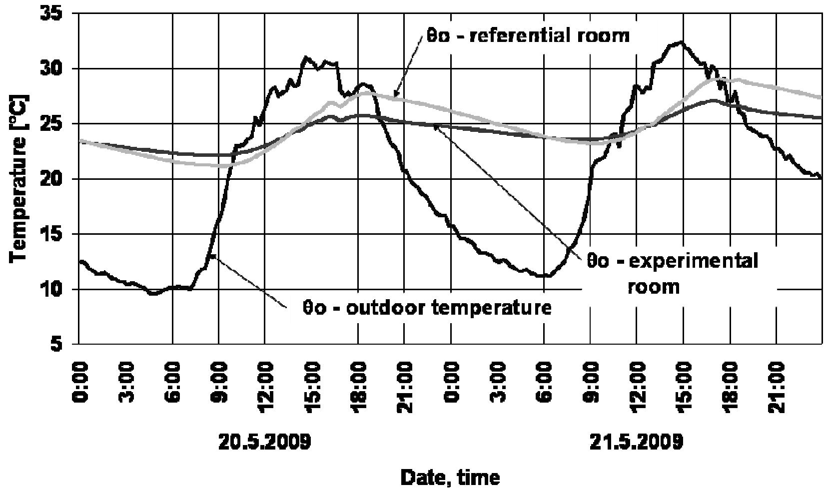

Fig. 2. Operative temperatures from measurement with natural ventilation

Rys. 2. Pomiary temperatur operacyjnych w przypadku zastosowania wentylacji naturalnej

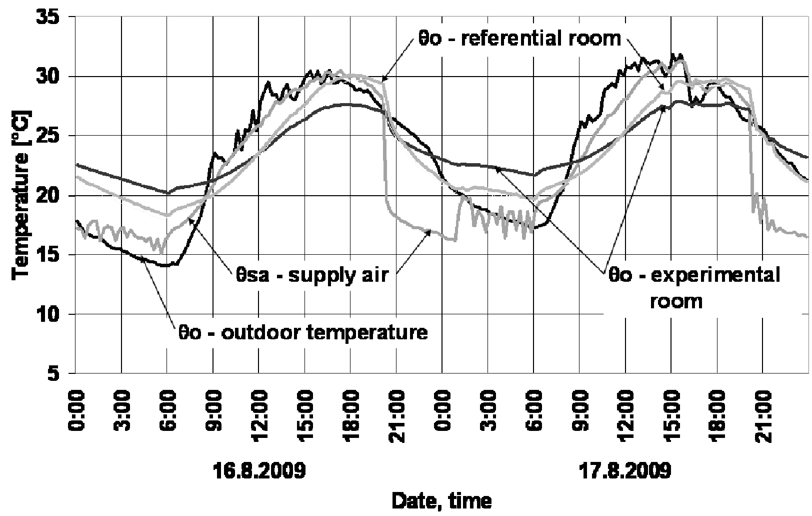

Fig. 3. Operative temperatures from measurement with night cooling

Rys. 3. Pomiary temperatur operacyjnych z nocnym chłodzeniem

In Figure 3 is shown behaviour of operative temperatures in experimental and in referential room for selected 2 days in August 2009. Chart shows discharging of energy stored in PCMs that causes the higher operative temperatures in experimental room compared with temperatures in referential room.

The results from measurement prove fact that for utilization of latent heat storage is necessary to provide discharging of stored energy. Night intensive ventilation of the experimental object is one way how to discharge a big amount of energy stored in PCMs.

6. Conclusions

PCMs incorporated in building structures can contribute to decreasing of indoor air temperature fluctuations and improving level of indoor thermal comfort. The main problem with using of PCMs in building structures is discharging of stored energy. Natural ventilation can be effective only in some part of spring or autumn with relatively high daily temperatures and low night temperatures. In hot summer time with high daily and night temperatures the heat stored in PCMs can not be discharge in the night. Temperature of supply air is similar to the melting temperature of PCMs. For sufficient discharging of stored heat is necessary to increase air-change during night.

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This work was supported by the Project of specific research BUT No. FAST-S-10-33.