CHALLENGES IN THE LATENT HEAT STORAGE TECHNOLOGY FOR BUILDING APPLICATIONS

Milan OSTRÝ
Brno University of Technology, Faculty of Civil Engineering, Institute of Building Structures, Czech Republic, ostry.m@fce.vutbr.cz

Tomáš KLUBAL
Brno University of Technology, Faculty of Civil Engineering, Institute of Building Structures, Czech Republic, klubal.t@fce.vutbr.cz

Roman BRZOŇ
Brno University of Technology, Faculty of Civil Engineering, Institute of Building Structures, Czech Republic, brzon.r@fce.vutbr.cz

Summary

Indoor environment of buildings with light-weight envelope is often prone to overheating in summer due to external and internal heat gains. This problem is often solved by installation of air-conditioning that leads to increase of energy consumption. A lot of attention has therefore been paid to other means of temperature control in buildings such as night-time ventilation or/and building integrated heat storage. For thermal energy storage can be considered sensible or latent heat storage. The latent heat storage technology uses phase change materials (PCMs) as a storage medium. Phase change materials can store large amount of heat in a narrow temperature interval around their melting range.

There are many ways of integration of the PCMs into building structures, e.g. penetration of porous building materials, macro encapsulation, micro encapsulation and shape stabilized PCMs. Structures with integrated PCMs exhibit higher thermal storage capacity and allow to use directly renewable energy sources for heating, e.g. solar radiation.

Team of investigators at Faculty of Civil engineering BUT deals with the design and evaluation of PCMs integrated in building structures. In experiments are used commercial PCMs that are available in European market. The current experiments use gypsum plaster with microencapsulated PCMs as storage medium. The activation of heat storage core is provided by the system of capillary tubes with cooled water. For the water cooling system is utilized off-peak electricity and thus system contributes to the operating cost savings. Circuit of water allows to be used for cooling in summer as well as for heating in winter.

Keywords: Building structure, Phase change materials (PCMs), Latent heat storage, Sensible heat storage, Plaster, Radiant cooling, Passive cooling.

1 Introduction

Provision of thermal comfort is one the most important goals of the each modern building. A lot of attention was paid in the past on the fulfilling of the thermal comfort requirement in winter season. Currently this requirement is passed by the sophisticated heating and ventilation systems. But energy performance of a building is not only energy for heating, which is often used for labeling of buildings. E.g. energy consumption 50 kWh/(m^2·a) means that building is classified as low-energy building. Energy performance of a building is calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting. In the Czech Republic, many buildings have to be heated in winter and cooled in summer.

Energy consumption associated with cooling of buildings starts to play significant portion of annual energy consumption and therefore any kind of improvement of energy performance of cooling systems contributes to the reduction of operation cost of any building. Office and residential buildings represents buildings with high potential for use of radiant cooling techniques. Radiant cooling systems provide thermal comfort by controlling surface temperatures instead of indoor air temperature [1].

Thermally activated building structures, e.g. reinforced concrete floor structures use inherent sensible heat storage capacity as a heat sink. Internal and external heat gains generated during day are stored in heavy floor structures and wall system, which are then re-cooled at an appropriate time by means of a water pipe system and extracted energy being rejected to outside [2].

2 Thermally activated system with microencapsulated PCMs

The use of thermally activated building structures combined with the reduction of cooling loads can result in good thermal comfort in office buildings in summer [3].

The possibility of activation PCMs is a fundamental premise for the effective radiant cooling systems. The charging and discharging of heat into and out of thermal storage is naturally reversible in the Czech Republic from autumn to spring. The activation takes place at night when there is the temperature below crystallization PCMs in the interior.

The effect of latent heat storage with the use of PCMs on the indoor environment could be predicted by computer modeling [4]. There are two common approaches in PCMs modeling which are based on the enthalpy and effective thermal capacity method [5], [6]. Results from computer modeling were used for design of full-scale experiments. The results form full-scale experiments serve for validation of computer models.

2.1 Heat storage plaster with system of capillary tubes

Commercial organic microencapsulated PCMs Micronal DS 5008X from company BASF was used as latent heat storage medium in full-scale experiments. Microcapsules with paraffin were mixed with gypsum plaster. Characteristics of pure PCMs and final mixture are shown in Tab. 1. There was observed significant reduction in heat storage capacity in plaster because final mixture contains only 30 wt% of latent heat storage medium. 30 wt% is the maximum level of PCMs from the point of view of workability and fire protection. Gypsum plaster with PCMs covers system of capillary tubes for discharging of stored energy and could be used for active cooling as well.

Tab. 1 *Selected characteristics of pure Micronal DS 5008X and gypsum plaster with Micronal DS 5008X during heating (melting)*

Material	**Peak temperature [°C]**	**Onset temperature [°C]**	**Stored heat [kJ.kg^{-1}]**
Micronal DS 5008X	24.3	19.8	86.8
Plaster with 30% Micronal	26.2	24.5	23.4
Difference	1.9	4.7	63.4

2.2 Comparative measurements

The comparative method based on experiments in two identical spaces was used for practical assessment of the influence of thermally activated system on the indoor climate. In order to assess the impact of the PCMs-based latent heat storage indoor environmental conditions in a referential room must be monitored under the same boundary conditions as in a referential room. Two identical test rooms were built for that purpose in the empty attic space of an administrative building of the Faculty of Civil Engineering:

- referential room – room with a common composition of light-weight structures;
- experimental room – room with structures with installed plaster with capillary tubes.

Both rooms have the same floor area and the indoor space volume. Surface of floor is approx. 14.9 m^2.Assembled panels with plaster and capillary tubes were installed on the side walls, oblique and horizontal ceiling in the area about 17 m^2.

3 Results and discussion

Fig. 1 shows results from the period with the following water cooling in capillary tubes:

- during night periods from 1:00 to 1:45 a.m. and from 3:00 to 3:30 a.m. the chiller was switched on due to the activation of stored energy in PCMs;
- during day the chiller was switched off.

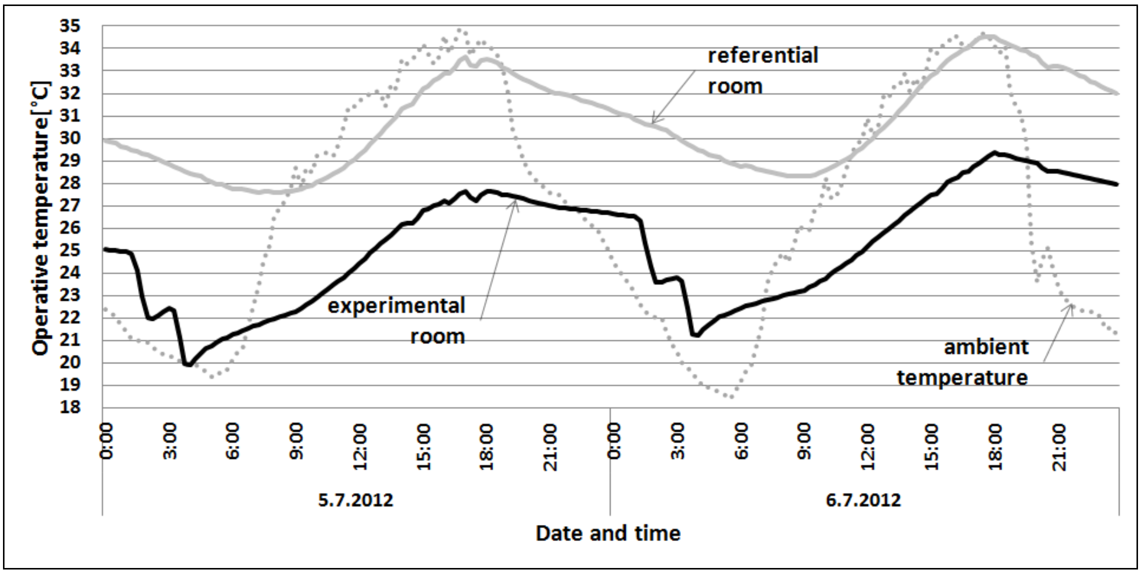

Fig. 1 *Development of operative temperatures in referential and experimental room*

The temperature in the experimental and referential room was not influenced by active cooling during the day. Installed system of capillary tubes with heat storage plaster in experimental room reduced peak temperatures about 4 °C compared to referential room. For the activation of PCMs (discharging of stored energy) was used only 1.25 hour of off-peak electricity. But the system does not keep requirement on the maximum daily operative temperature in office room that is 27 °C. That means that for the keeping of required state of indoor environment is necessary to use short-time daily cooling of water flowing in capillary tubes.

4 Conclusions

Thermally activated system with microencapsulated PCMs represents alternative radiant cooling system to common air-conditioning. The main advantage is in shift of electricity consumption from the peak to off-peak hours. Experiments carried out at Faculty of Civil Engineering shows some difficulties in the use of this system in very hot summer days. For these cases system must enable short active cooling during the day. Moreover system coupled with heat pump is suitable for active heating in winter season.

Acknowledgement

This work was supported by the Czech Grant Agency under project No.P104/12/1838"Utilization of latent heat storage in phase change materials to reduce primary energy consumption in buildings".

References

[1] TIAN, Z.; LOVE, J.A. A field study of occupant thermal comfort and thermal environments with radiant cooling. *Building and Environment,* 2008, vol. 43, no. 10, pp. 1658–1670. ISSN 0360-1323.

[2] KOSCHENZ, M.; LEHMANN, B. Development of a thermally activated ceiling panel with PCM for application in lightweight and retrofitted buildings. *Energy and Buildings*, 2004, vol. 36, no. 6, pp. 567–578. ISSN 0378-7788.

[3] BREESCH, H.; BOSSAER, A.; JANSSENS, A. Passive cooling in a low-energy office building. *Solar Energy*, 2005, vol.79, no. 6, pp. 682–696. ISSN 0038-092X.

[4] KLIMES, L., CHARVAT, P., OSTRY, M. Challenges in computer modelling of phase change materials. *Materiali in tehnologije*, 2012, vol.46, no.4, pp. 335–338. ISSN 1580-2949.

[5] KLIMES, L., CHARVAT, P., STETINA, J. Mathematical model of multi-layer wall with phase change material and its use in optimal design. *Advanced Materials Research*, 2012, vol.649, no.1, pp. 295–298. ISSN 1022-6680.

[6] CHARVAT, P., MAUDER, T., OSTRY, M. Simulation of latent heat thermal storage integrated with the room structures. *Materiali in tehnologije*, 2012, vol. 46, no. 3, pp. 239–242. ISSN 1580-2949.