# THE INFLUENCE OF PASSIVE COOLING ON ENERGY SAVING

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## Summary

The increase in energy consumption in summer season is very often caused by the design of buildings with transparent façades and light-weight envelopes with the low thermal storage capacity. The energy consumption depends on the efficiency of air-conditioning systems that are used for provision of thermal comfort. The design and use of building structures with phase change materials can increase thermal storage capacity of the envelope and reduce the energy consumption for operating of a building.

The paper deals with the results of practical monitoring of the influence of building structures with integrated phase change materials on the thermal comfort. The storage medium, e.g. in the walls and ceiling, absorbs thermal energy during the day. But for the repeated use on the next day it is necessary to provide discharging of stored energy. Paper shows the results from measurement with different air change rates in the special testing room. It seems to be necessary to use mechanical night ventilation for activation of latent heat storage medium during the off-peak time.

**Keywords:** thermal comfort, building structures, phase change materials, passive cooling

## 1 Introduction

In sensible heat storage, thermal energy is stored by changing the temperature of the storage medium (Lane 1985). A sensible heat storage system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging heat (Sharma *et al.* 2009). The amount of stored heat depends on the specific heat of storage material, the temperature difference and the amount of storage material. In case of heavy-weight building structures (clay blocks walls, concrete slab floors, etc.) building structures themselves can be used as thermal storage mass. But thermal storage by common building structures with utilization of sensible heat storage has its limits.

Latent heat storage can be use in many energy storage applications. 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 (Sharma *et al.* 2009). The phase change materials (PCMs) use chemical bonds to store and release the heat (Tyagi *et al.* 2007). Advances in chemical engineering and material science have enabled development of new phase change materials (PCMs) with the possibility to tailor their properties for a specific use (e.g. by blending of various PCMs or addition of nucleating agents). The PCMs have successfully been used as a heat storage medium in solar energy systems and other applications. The PCMs are attracting more and more as a possible cold storage medium. Ice harvesting as a way of application of phase change for cooling purpose had been quite widespread before the invention of mechanical refrigeration. Ice cold storage is still being used in some air-conditioning and refrigeration systems in order to take advantage of the off-peak electricity prices or to reduce the necessary cooling capacity of chillers. A number of PCMs with the phase change temperature close to the indoor air temperature in buildings are already available and these PCMs can be employed in both passive and mechanical cooling in built environments.

The latent heat cold storage in the PCMs seems to be quite promising since it offers high thermal storage capacity in a narrow temperature interval.

## 2 PCMs integrated in building structures

Modern building structures generally provide rather small thermal mass and that mass is very often not directly exposed to the ambient air (e.g. sound attenuated concrete slab floors, suspended ceiling covering concrete slab ceilings, etc.). A solution to increase the thermal capacity is to incorporate phase change materials into the light-weight envelope, which is of large energy storage density and nearly isothermal nature during the phase change process compared with the sensible heat storage (Xiao et al. 2009). Every application of latent heat thermal energy storage requires a suitable PCM for the use in particular kind of operating conditions (Shukla et al. 2008).

The 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 (Zhang et al. 2007).

The PCMs in the building light-weight structures allow to reduce the overheating during summer time. Materials with PCMs could be incorporated in building structures such as vertical walls, horizontal floor structures, on the top of suspended ceilings or in the composition of floor finishing

First 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 second advantage is the elimination of energy consumption for ventilation because the PCMs are directly in contact with internal environment. The nighttime cooling storage can be achieved by natural ventilation.

Two testing room were built at Faculty of Civil Engineering for the evaluation of the influence of PCMs on the indoor environment. The external and internal structures of the testing rooms were made of light-weight materials only. The floor area of each testing attic room is 14.9 m$^2$. The rooms are positioned side by side. There is a skylight in each of the rooms. Orientation of skylights and external envelope is south-west. The test rooms consist of galvanized steel frame structures insulated with mineral wool with the thickness of 200 mm. Fig. 1 shows the scheme of testing rooms. One room is without the PCMs and it is referred to as the referential room, the second room has integrated PCMs and it is referred to as the experimental room. Outdoor air is supplied to the rooms by an air-handling unit.

Totally 240 panels filled with the DELTA®-COOL24 from Dörken GmbH & Co. KG were installed in the experimental room in order to study the influence of latent heat thermal storage on indoor thermal comfort. The panels were installed on the internal surface of three walls, on the horizontal suspended ceiling and sloped ceiling of the roof structure.

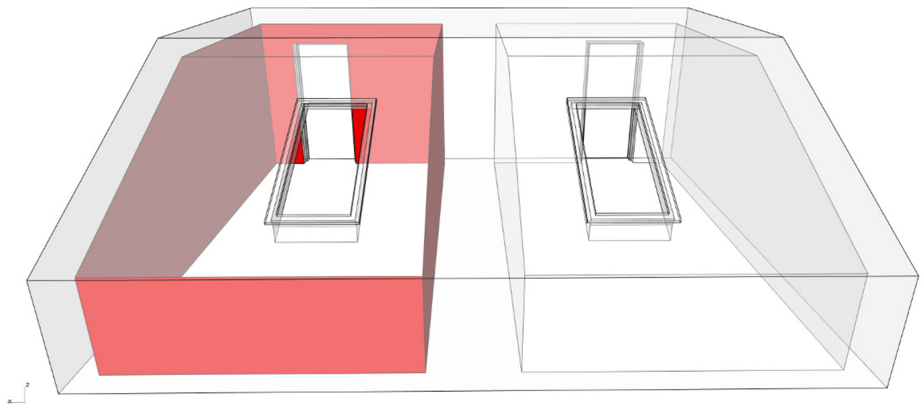

**Fig. 1** Scheme of testing room

## 3 Results and discussion

Three different scenarios were tested in 2009:

1. testing rooms with air-change only due to air leakage (air infiltration);
2. minimum air-change provided by mechanical ventilation during daytime and passive cooling (intensive mechanical ventilation) at night;
3. minimum air-change provided by mechanical ventilation during daytime and intensive ventilation with supply air mechanically cooled down by an air-handling unit (mechanical cooling at night)

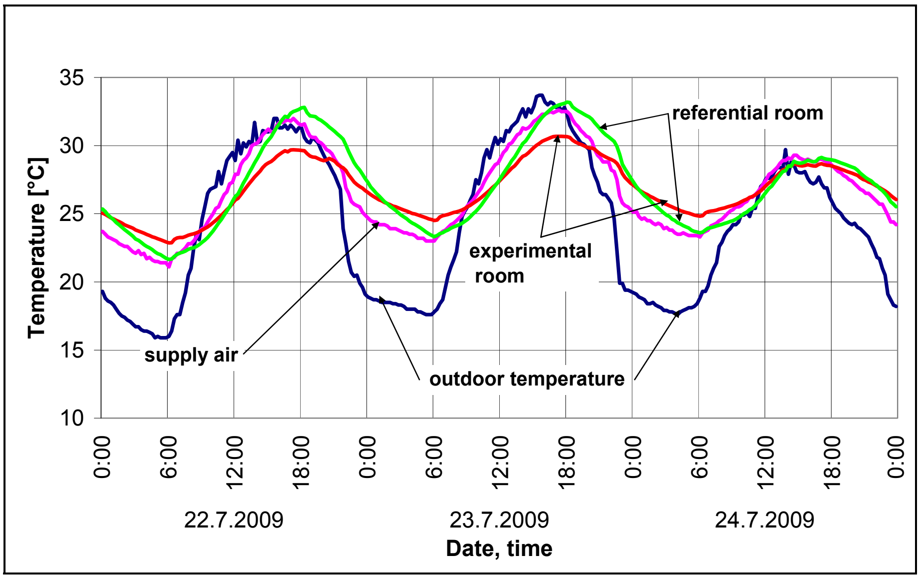


**Fig. 2** Results from measurement (scenario 2)

The chart in Fig. 2 shows results for the selected 3 days in July 2009. Mechanical ventilation was used at night in this case. Temperatures in the referential and experimental room are represented by operative temperatures measured by spherical thermometers. The curves of operative temperatures show the positive effect of thermal mass of PCMs. Daily temperatures in the experimental room were lower compared with the referential room. On the other hand the temperatures at night are higher in testing room because of the discharge of stored energy. But the temperature of supply air shows problem with night cooling. The temperature of supply air was too high for sufficient discharge of stored energy.

## 4 Conclusions

The PCMs incorporated in building structures can contribute to the decrease of indoor air temperature fluctuations and improve the level of indoor thermal comfort. The experiments showed that the discharge of heat from the thermal storage mass is the main problem of cold storage in the PCMs.

Natural ventilation can be effective only in some parts of spring or autumn with relatively high daily temperatures and low night temperatures. The outdoor air temperature can be rather high at summer nights and natural ventilation is not able to provide sufficient air change rates to compensate for smaller temperature difference. It may therefore be necessary to use mechanical ventilation for the discharge of the stored heat and in some cases even combined with mechanical cooling of supply air.

## Acknowledgement

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