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Potential of passive cooling for office buildings

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Abstract **The main task for the designers of offices and multi-dwelling buildings is to provide thermal comfort for the occupants during the whole year. Thermal comfort in winter is maintained by sophisticated heating systems. Energy consumption in winter depends on the heat loses that can be minimized by means of well insulated envelopes and heat recovery system. At present the main problems with provision of thermal comfort shift from winter to summer. Many buildings have insufficient thermal storage capacity due to the low weight of external and internal structures. It is usually necessary to install air-conditioning systems in light-weight buildings with glazed façade orientated to the south or west in order to provide thermal comfort for the occupants. This fact influences the energy consumption of such buildings. From this point of view it is very important to find a solution for these types of buildings that can help the owners to increase energy efficiency. Passive cooling with thermal storage in phase change materials is a very effective way to improve thermal comfort in light-weight buildings.**

Keywords – **Passive cooling; Sensible heat storage; Latent heat storage; Thermal comfort.**

I. INTRODUCTION

Buildings represent an essential element of built environment created for preserving quality of human life. Buildings in highly developed countries are responsible for about 40 % of total production of CO_2 emissions, waste and other pollutants. The increase in demand of thermal comfort corresponds with the increase in energy consumption. The built environment consumes substantial financial and natural resources, and generates considerable waste streams [1].

The technical approaches to provide a good indoor climate in office buildings are very often accompanied by complaints of office workers about many types of discomfort, dissatisfaction and health problems that are summarised as the "Sick Building Syndrome" [2]. Thermal stability of indoor environment in summer mostly depends on the solar heat gains through the glazed part of the external envelope and thermal storage capacity of the building structures.

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Various kinds of sun protection, e.g. sun-blinds, ledges, vertical shutters and special galvanized glazing can be employed to reduce the solar heat loads to a building. Of course, broadleaved trees planted around the low-rise buildings have a potential to reduce solar gains in summer.

II. PRINCIPLE OF PASSIVE COOLING

For any building that is located in given region the natural room temperature is the function of the following factors [3]:

$$t_{in} = f(k(t), \rho c_p(t), ACH(\tau)) \qquad (1)$$

where:

- k thermal conductivity ($W\ m^{-1}\ K^{-1}$)
- t temperature (K)
- ρ density ($kg\ m^{-3}$)
- c_p specific heat ($J\ kg^{-1}\ K^{-1}$)
- ACH air change per hour (h^{-1})
- τ time (h)

Building cooling strategies can be divided into passive and active. The goal of passive cooling is to minimize, or, if possible, eliminate the use of mechanical air-conditioning systems to decrease energy consumption [4]. The urban environment is a major factor in operational performance of passive cooling technologies in office buildings [5]. Passive cooling cannot be applied without reduction of cooling loads and internal heat gains. Building envelopes should be designed with low U-value for reduction of heat transfer through walls and windows. The design of windows and their solar shading has a significant effect on thermal stability of indoor environment. There cooling loads cannot be avoided because of the requirements on daylighting. The requirements for daylighting determine the size and orientation of windows.

A typical technique of passive cooling is based on the nigh intensive ventilation of the interior. Thermal comfort during the day is provided by cold storage. The thermal storage structures are cooled down over the night that results in heat absorption by these structures during the day. Heavy-weight structures are commonly used in passive cooling. . Thermal energy in this case is stored by the sensible heat storage principle. The reinforced concrete slabs can be employed for this purpose in modern office buildings. The slabs must be in direct contact with indoor environment. Activation of concrete slabs is often provided by the circuits with water cooled at night.

In the light-weight buildings with wooden or framed structures the weight is reduced to minimum and it has a negative influence on the sensible heat storage potential. For provision of sufficient thermal mass in light-weight buildings it is better to design systems based on the latent heat storage technology. This technology utilizes latent heat of phase changes of storage medium for cool and heat storage. The advantage is in high heat storage capacity per volume or mass unit.

The efficiency of the system depends on the possibility to integrate latent heat storage medium in the envelope of the room. There are several methods of the integration of latent heat storage medium in building structures:

- direct impregnation of storage medium into porous building material;
- microcapsules with storage medium that are dispersed into the gypsum or any other matrix;
- shape-stabilized storage medium with high-density polyethylene and styrene-butadiene-styrene as supporting material;
- macroencapsulated storage medium in panels or containers made of aluminum or plastics.

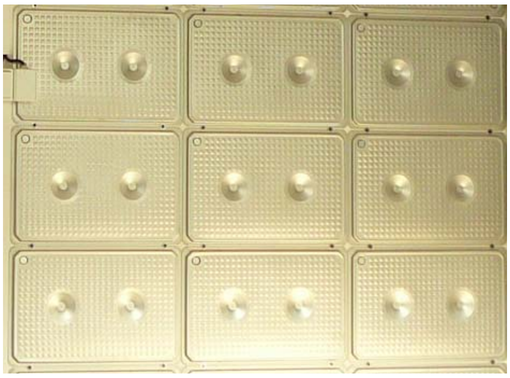

Fig. 1. Macro encapsulated storage medium

Microencapsulated storage medium can be combined with other building materials, e.g. gypsum plaster or gypsum wallboard. Figure 1. shows example of installation of macroencapsulated latent heat storage medium on the walls of experimental room at Brno University of Technology. Storage medium is encapsulated in coated aluminum panel that were fixed on the walls and suspended ceiling. This system is very easy to install and shows good heat transfer. A common problem in many applications is regeneration of heat storage medium during night, i.e. discharge of stored heat. The charging and discharging of heat into and out of thermal storage is naturally reversible in the Czech Republic from autumn to spring. The heat stored in the medium can be discharged by night ventilation. The amount of removed heat depends on [2]:

- the air change rate;
- temperature difference between indoor air and supply air;
- the duration of ventilation.

Two approaches can be used for discharge of heat stored in the medium or the building structures:

- intensive mechanical ventilation of the room during night;
- direct cooling of medium by a special circut of air or water.

The first approach has the advantage in simplicity and does not need additional equipment especially in rooms with controlled ventilation. Air-conditioning can be employed to cool down supply air with the advantage of off-peak electricity rates. The disadvantage of this approach is the discomfort caused by high air velocities. The second approach utilizes special circuit of air or water for discharge of stored energy. This system needs a special air cavity or system of pipes for cool water. The water circuit can be used for activation of heat storage medium with heat from solar collector in heating season.

III. CONCLUSION

Use of passive cooling in office buildings can contribute to the lower energy consumption of the buildings. Passive cooling depends on the possibility to store heat during the day and release it at night. This possibility is influenced by the weather conditions and ventilation system. Several systems that utilize latent heat storage were developed for practical application. Latent heat thermal storage has a better performance in comparison with the sensible heat storage in building structures. The future use of passive cooling will depend on the development of non-expensive and stable capsulated latent heat storage mediums.

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