22. DEVELOPMENT OF THE PCM FLOOR SUPPLY AIR-CONDITIONING SYSTEM

Katsunori Nagano
Hokkaido University, Hokkaido University, Graduate School of Engineering, Division of Urban Environmental Engineering, N13-W8 Sapporo, 060-8628, Japan

Abstract. Floor supply air-conditioning system using PCM can enhance the building mass storage. In this study, diurnal cooling load is aimed to be covered by stored cold energy in PCM and building during night. Results from actual scale experiments and performance predictions are given.

Keywords: Floor supply air conditioning, granular PCM, diurnal, building mass

22.1. System Concept

A new floor supply air-conditioning system was proposed using phase change material to augment building mass thermal storage [1, 2]. Figure 209 shows conceptual diagrams of the system. In this system, latent heat is stored in PCM that is embedded just under OA floor boards in the form of granules with several millimeters in diameter. The feature of the system is that heat exchange occurs through direct contact between the packed bed of the granular PCM and air flowing as the heat medium. This allows outstanding heat exchange efficiency and little space needed for storing PCM then increase of the TES capacity in the entire system [3]. The whole diurnal cooling load aimed to be covered by stored cold energy in an embedded packed bed of the granular PCM and the building frame during night. In addition, the use of the granular PCM can lead to improvement of the indoor thermal environment in comparison with that in conventional systems due to thermal radiation from the floor surface area, which can be maintained around the phase change temperature.

22.2. Used PCM and Numerical Prediction of System Performances [4]

Figure 210 shows a flowchart of our study and development of actual system. As a result of some trials, PCM granules, which consist of microcapsules with a diameter of a several micrometers containing paraffin wax PCM, named

H. Ö. Paksoy (ed.), Thermal Energy Storage for Sustainable Energy Consumption, 367–373.

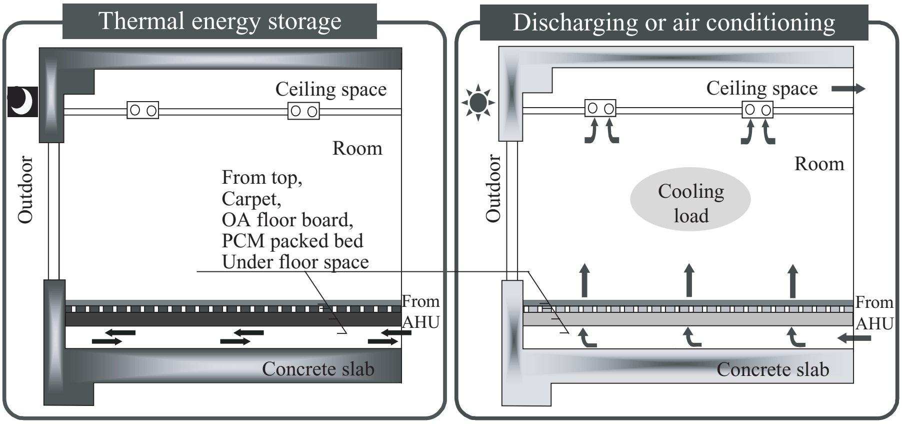


Figure 209. Conceptual diagrams of the developed system

FMC-PCM (Flocculated Microcapsules PCM) as in Figure 211 have been applied in this system. Figure 212 indicates a cross section of the FMC-PCM taken by a scanning electron microscope. Operating conditions were discussed by a developed computer simulation program, which includes not only heat balances for each component under the floor board and for the room space according to the air movement but also analyses of radiative thermal environment in the target room using the Monte-Carlo method. The values of heat transfer coefficient of each part were determined as compared with measurements. Calculation predicted that the use of a FMC-PCM, which shows phase change temperature between 20.0 °C and 22.9 °C and latent heat

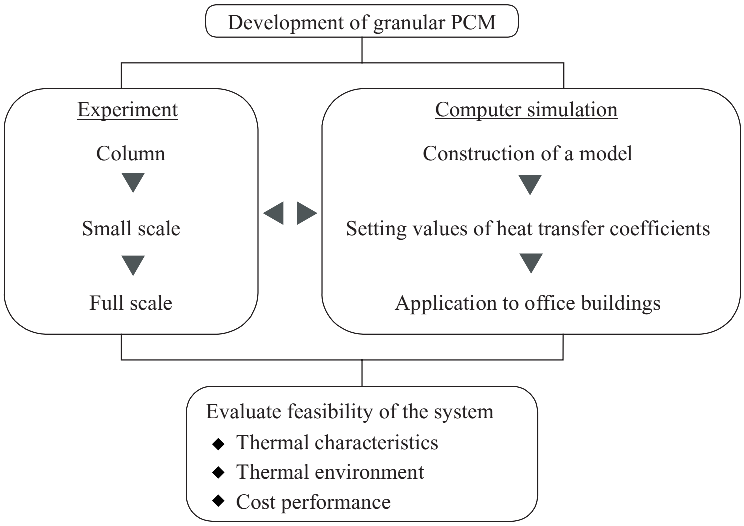


Figure 210. A flowchart of the development

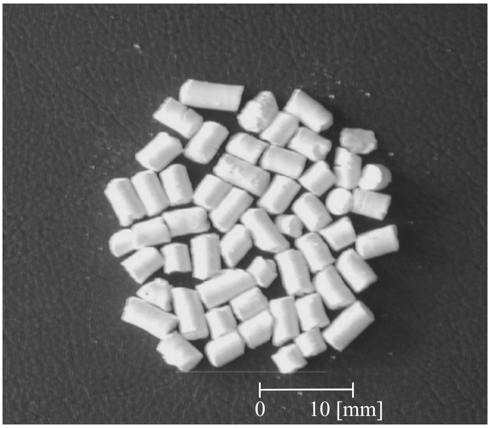


Figure 211. Appearance of FMC-PCM

of 130 kJ/kg, led to a load shifting ratio η_s of 100% in the case of the packed bed with a thickness of 25 mm and a weight of 12.5 kg/m^2. Additionally heat radiation from the floor face resulted in comfortable thermal environment even at a room temperature of 28 °C in office hours.

22.3. Results of Actual Scale Experiment and Discussions

On the basis of calculation results, full scale experiments were conducted in a test room with a floor area of 9.2 m^2 shown in Figure 213. In this experiment, packed beds of FMC-PCM, which shows phase change temperature between

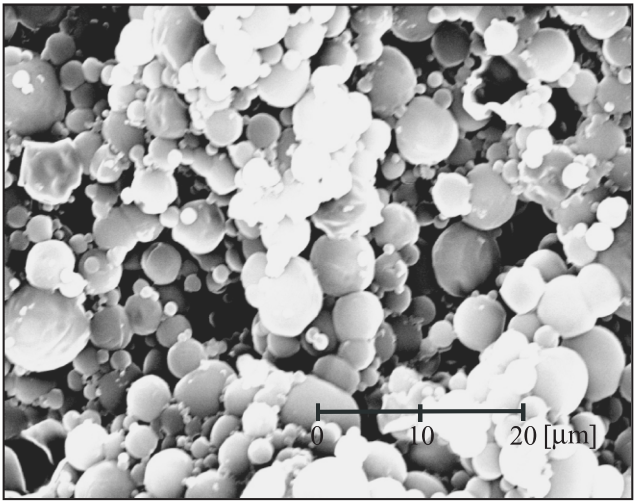
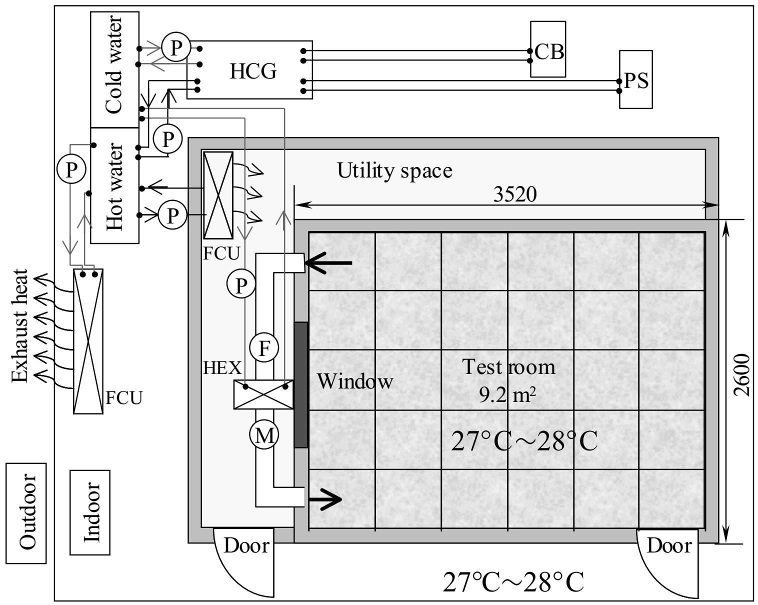


Figure 212. Cross section of the FMC-PCM



CB: Control board, F: Fan, FCU: fan coil unit, HCG: Hot and cold water generator, HEX: Heat exchanger, M: Flow rate meter, P: Pump, PS: Power supply

Figure 213. Plane of the full scale experimental room and air-conditioning units

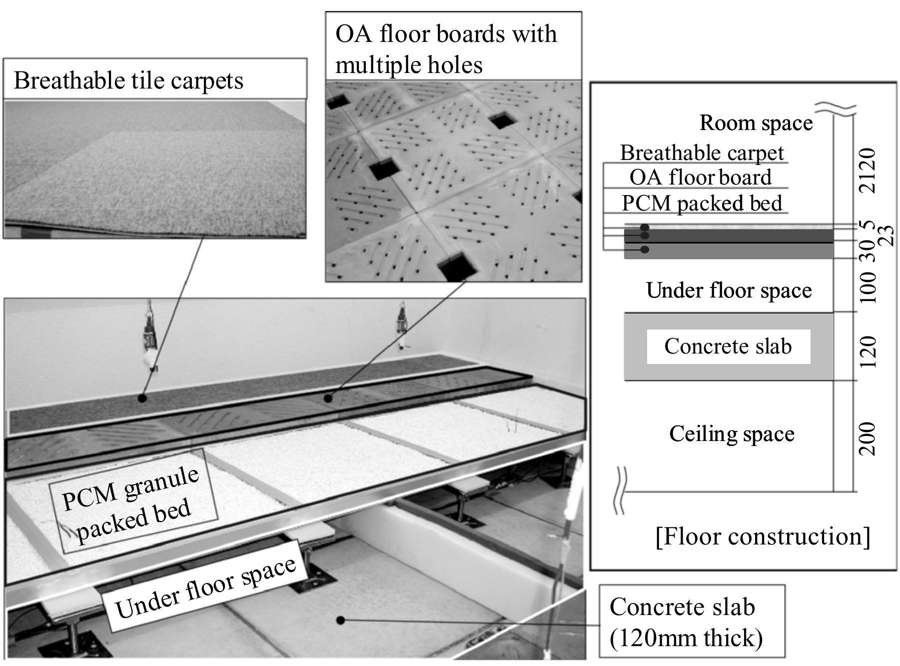


Figure 214. Detail construction of under floor ventilation system

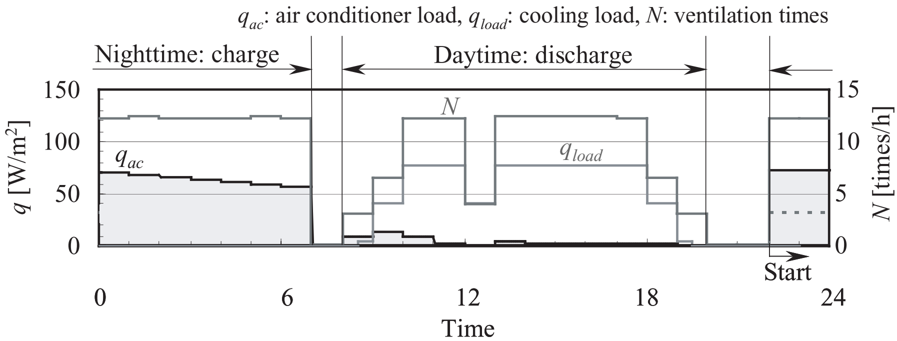


Figure 215. Variation of air conditioner load indicates that almost all diurnal cooling load can be covered by stored cold energy in the nighttime

18.2 °C and 21.4 °C and latent heat of 136 kJ/kg, were installed under the OA floor board with a thickness of 25 mm in 12.5 kg/m^2 (Figure 214). The authors made some experiments under different conditions and explain one successful example.

Cool air at 12 °C was flowed into the under floor space between OA floor boards and concrete slab in order to store thermal energy during night. On the other hand, room air circulated through the PCM packed bed at the air change rate of 12 times per hour during office hours. The air change rate was decreased before 10:00 in the morning, during the lunch time and after 18:00 according to the cooling loads. An air conditioner was operated when the room air temperature exceeds 27.5 °C. Stored cold energy was estimated 2.1 MJ/m^2 during night and the air conditioner supplied only 0.2 MJ/m^2 during daytime. Consequently, this system could achieve a load shifting ratio η_s of 92% as shown in Figure 215, whereas another condition with conventional thermal mass storage, that is, without PCM, shows the η_s of 50%.

22.4. Indoor Thermal Environment

Previous under floor ventilation systems have indicated a disadvantage of low room temperature at the beginning of office hours, in which only sensible thermal energy storage is applied by using building frame such as concrete slab. The use of the FMC-PCM is expected to improve this drawback. Figure 216 illustrates variations of room air temperature T_a and mean radiative temperature T_r. Both T_a and T_r were kept around 24 °C even at 9:00. In addition though T_a reached 28 °C at 6 PM, the maximum T_r was 27 °C due to radiative influence from the lower floor surface temperature. PMVs, that is one of the representative indexes for thermal sensation, were −0.4 at 8:00 and

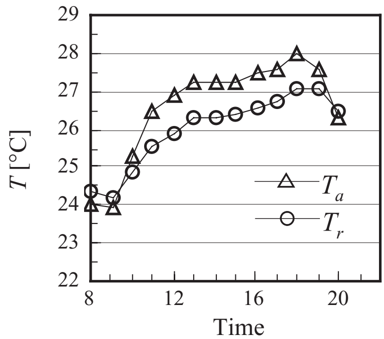


Figure 216. Hourly variations of room air temperature T_a and mean radiative temperature T_r

0.4 at 13:00 lying within the neutral zone. The thermal sensation tests using some young subjects resulted in the answers of "Comfortable" throughout the daytime. These results indicate that this system can provide the comfortable thermal environment as well as the high rate of the load shifting.

22.5. Cost Analysis and Further Challenges

At this moment, the price of the used granular PCM exceeds 10 EURO/kg due to the test production stage. Our calculation showed the cost payback time can be less than 10 years when the PCM cost would be reduced to 4 EURO/kg under the electrical utility rate condition in Japan. Further cost reduction will be needed to promote the actual system. In addition we have to care of flammability of paraffin wax as PCM in use of inside the buildings. Fortunately, PCM is placed under the OA floor board made of fireproof cement-mortal and above the concrete slab in this system. It may not have any problems under the Fire Defense Law in Japan. However, further development of noninflammable PCM granules, for example micro encapsulation of mixture of inorganic and organic PCM, is required.

References

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