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Thermal Storage and Discharge Efficiency as a Function of the PCM Critical Temperature – Simulations and Experimental Analysis

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Introduction

Despite their very promising building energy storage capabilities, PCM are still in the investigating phase before a large potential deployment. This is due to several challenges [1] such as high storage capacity and efficient heat extraction [2]. If the storage capacity can be adapted by implementing an appropriate quantity of PCM, the heat extraction efficiency is more delicate and difficult to optimize. It depends on the conductivity between the PCM surface and the indoor air and can be enhanced by ventilating the PCM surface.

Concept

We chose the last mentioned solution and developed the experimental set-up (see Figure 1) described in the current document. A hot water circuit was used to charge the isolated PCM wall and an internal ventilation to discharge it.

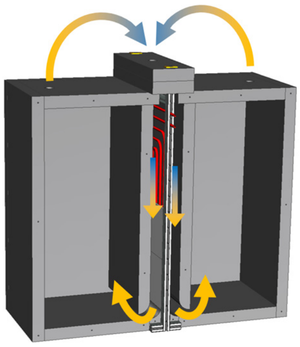

Figure 1: Measurement concept with PCM and heating circuit

Despite the low PCM critical temperature, T_c, of 23°C used in the experiments, high discharge efficiencies were achieved with a room temperature increase of +5°C in less than 40 minutes.

Simulations

To understand the high efficiency achieved despite the low critical temperature, we performed daily cycle simulations with PCM charge, storage and discharge phases for two different critical temperatures of 23°C and 26°C. The PCM was integrated into a two-floor building, shown in Figure 2, with an external wall heat loss of 0.11 W/(m²K).

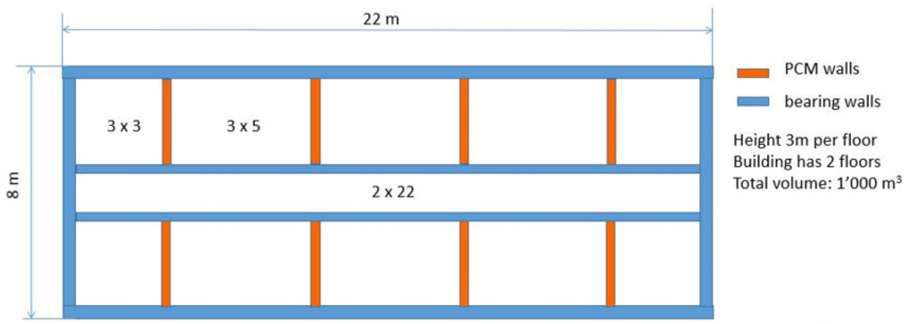

Figure 2: Reference building used for the simulations with bearing and PCM walls

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As the current analysis concerned administrative buildings, an indoor air comfort temperature of about 20.5°C was maintained between 6:00 and 17:30 with potential lower temperatures overnight.

External temperatures, T_{ext}, were simulated between -15°C and +10°C and considered constant during the entire day. Two different daily cycles were used. The first one was dedicated to buildings without renewable energy production. In that case, the PCM charge was performed overnight during periods of low energy prices. In the second simulation, with results shown in Figure 3, the PCM was loaded around midday, at the solar energy peak production time, and the comfort indoor temperature was maintained between 6:00 and 17:30.

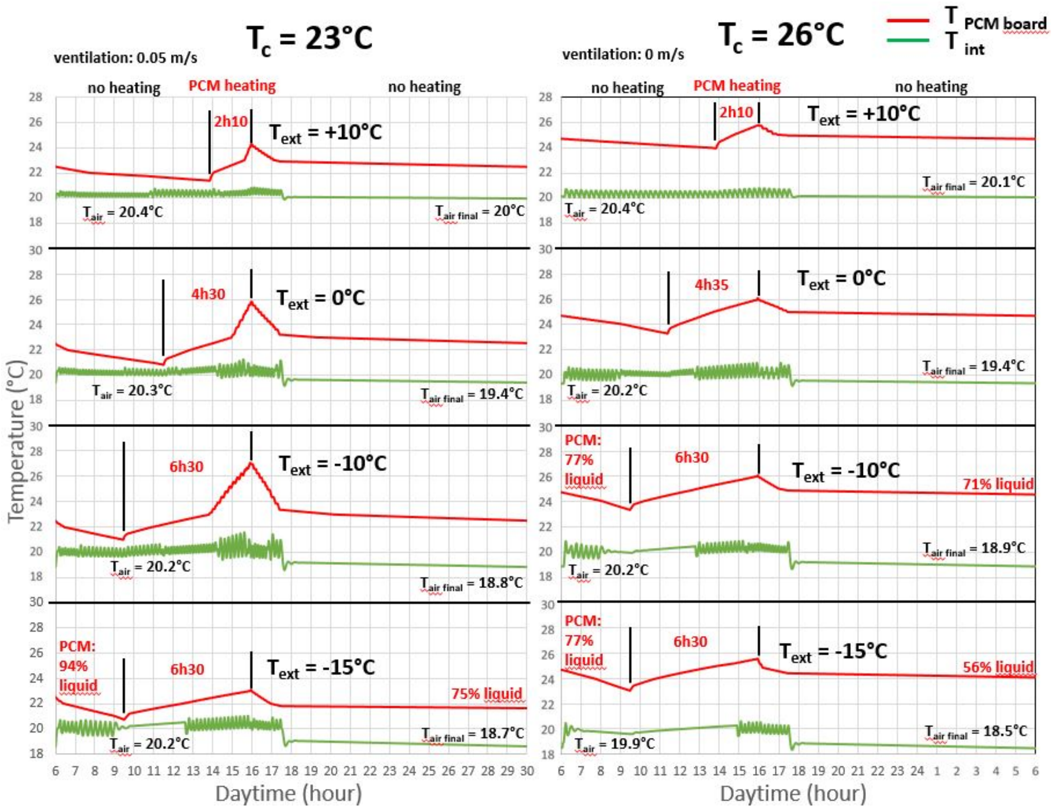

Figure 3: Indoor air and PCM temperatures with PCM loading at midday and discharge taking place between 6:00 and 17:30. The fluctuation of T_{int} is due to the controlled PCM discharge.

For the simulations as for the experiments, the indoor air temperature, T_{int}, was increased by ventilating the PCM walls. The PCM heating of 12 KW was limited to a maximal duration of 6.5 hours to simulate the peak solar power. Interestingly, T_{int} could be maintained at a comfort temperature for external temperatures down to T_{ext} = -10°C for the PCM of T_c = 23°C. On the other side, for the PCM with T_c of 26°C, the comfort temperature could only be maintained until T_{ext} = -5°C. Even if a larger efficiency for lower critical temperatures could appear to be contradictory, it can be easily explained. The overnight storage phase is less efficient for PCM with higher T_c due to their larger overnight temperature that is responsible of a larger discharge. In that respect, the bottom graphs of Figure 3 (T_{ext} = -15°C) show a daily PCM liquid phase loss of only 9 % for T_c = 23°C while a phase loss of up to 21 % is observed for T_c = 26°C.

The results show that the overnight PCM thermal storage drastically increase the energy independency of buildings equipped with solar energy. Note that the larger efficiency for lower critical temperature has one advantage: the 23°C PCM could be used to store heat in winter as well as cold in summer. This opens the door to new PCM all-seasons thermal storage perspectives especially in the context of global warming.

References

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