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Numerical Analysis of an innovative PCM Storage System based on climatic data and experimental measurements

Energy and Environment

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1. Introduction

Despite their very promising building energy storage capabilities, Phase Change Material (PCM) are still in the investigating phase before a large potential deployment. This is due to several challenges [1] such as high storage capacity, efficient heat extraction [2] and a lack of simulation tools and data analysis [3]. If the storage capacity can be adapted by implementing the right amount of PCM, the heat extraction efficiency is difficult to optimize and the simulation of its impact on a building remains a challenge. It depends on the PCM thermal conductivity, its ventilation, the building thermal insulation, the external temperature, the wind factor, the direct heating from the sun, the building occupancy and its equipment.

2. Experimental Concept and Simulations

An experimental set-up has been developed (Figure 1a) with an insulated PCM wall charged by a hot water circuit and discharged by an internal ventilation. Despite the low PCM fusion temperature, T_c, of 23°C, high discharge efficiencies were achieved with a room temperature increase of +5°C in less than 40 minutes.

To understand the achieved high efficiency despite the low fusion temperature, we performed daily cycle simulations with PCM charge, storage and discharge phases for two different fusion temperatures of 23° and 26°. The PCM was integrated into a two-floor building, shown in Figure 1b, with an external wall heat loss of 0.15 $W/(m^2 \cdot K)$.

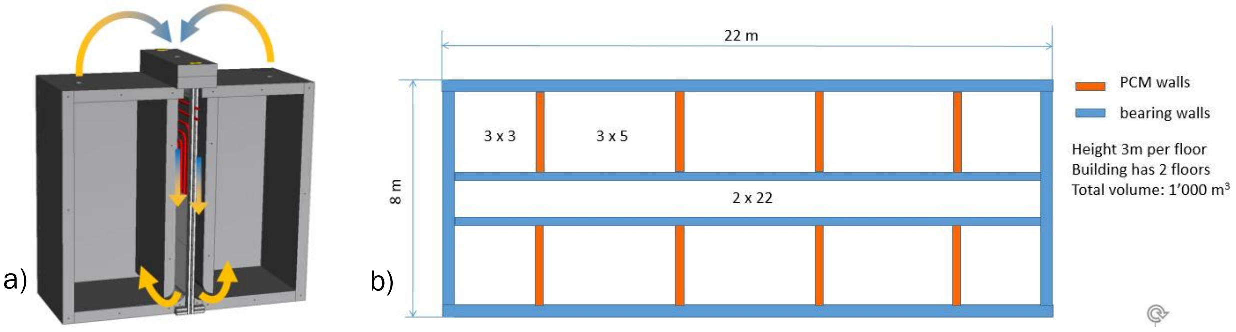

Figure 1: a) Measurement concept with PCM and heating circuit, b) Reference building used for the simulation.

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. Two different daily cycles were used for buildings without and with renewable energy. In the first simulation, the PCM was loaded overnight due to cheaper energy prices. The second simulation, shown in Figure 3, used a midday PCM loading at peak solar energy production time.

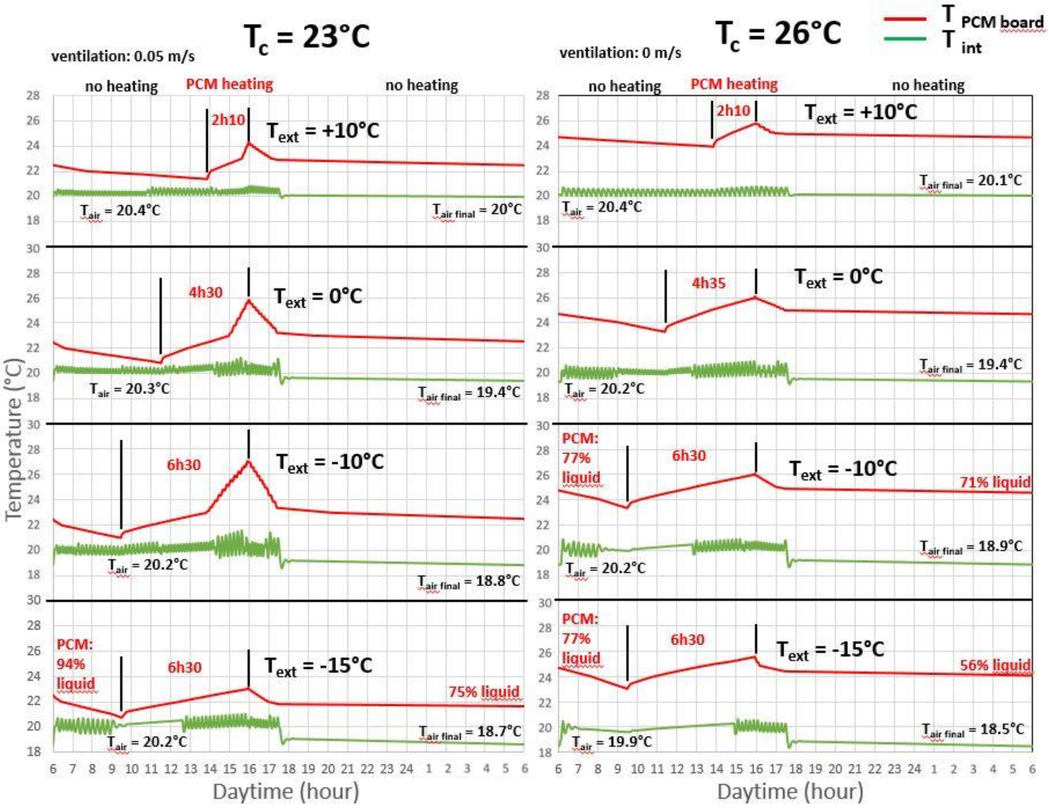

Figure 3: Indoor air and PCM temperatures with PCM loading at midday and discharge taking place between 6:00 and 17:30. The fluctuation of T_{int} is due to the controlled PCM discharge.

In the second simulation, 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 23°C. On the other hand, the PCM of 26°C could only maintain the comfort temperature until -5°C. Even if a larger efficiency for lower fusion temperatures could appear to be contradictory, it can be easily explained. The overnight storage is less efficient for PCMs with higher T_c due to their higher overnight temperature leading to a larger discharge. In that respect, the bottom graphs of Figure 3 (T_{ext}= -15°C) show a daily loss of the PCM liquid phase of 9% for T_c=23°C and of 21% for T_c=26°C.

The results show that the overnight PCM thermal storage drastically increases the energy independency of buildings equipped with solar energy. The larger efficiency for lower fusion temperature has another advantage: the 23°C PCM could also be used to store cold in the summer. This opens the door to new PCM all-seasons thermal storage perspectives, especially interesting in the context of global warming.

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[3] I. Plüss, Ph. Kräuchi, D. Bionda, M. Schröcker, S. Felsenstein and G. Zweifel, *Fifth German-Austrian IBPSA Conference, RWTH Aachen University* (2014)