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Published in:
Book of Abstracts. DTU's Sustain Conference 2015

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Coupling of phase change material with nighttime radiative cooling

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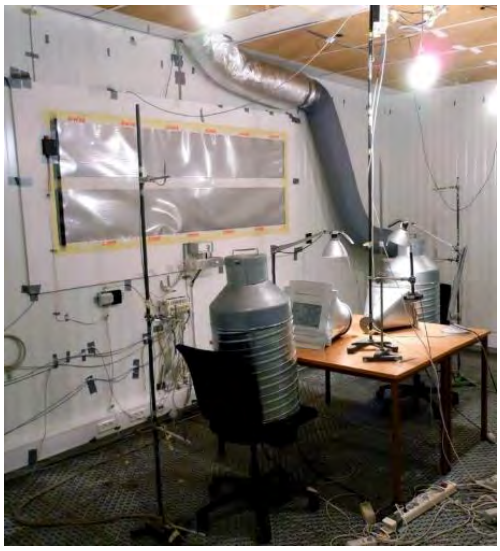
Phase change materials (PCM) can be used to reduce the peak cooling demand of a building by storing thermal energy through the phase change [1, 2]. Nighttime radiative cooling can be used to release heat by radiation towards the cold nocturnal sky, for example via solar panels [3]. Those two technologies can be combined, using the cold water produced by radiative cooling to discharge the thermal energy stored in the PCM.

The present experimental study investigates this coupling in the case of the cooling of an office room. For simulating an office room a climatic chamber in the facilities of DTU was used. In this chamber a radiant ceiling cooling system with PCM was installed. For cooling water through nighttime radiative cooling, three photovoltaic/thermal (PV/T) panels were utilized. Apart from cold water for space cooling, the installation was capable of providing domestic hot water and electricity from the PV/T panels. This system was tested for the period from 31st of August 2015 until 18th of September 2015. During this period three different combinations of water flow rate in the solar and the PCM panels were tested, each one of them for five working days. The first combination was 240 kg/h for the solar loop and 150 kg/h for the PCM loop, the second combination was 184 kg/h for the solar loop and 180 kg/h for the PCM loop and the third combination was 104 kg/h and 210 kg/h for the solar and the PCM loop, respectively.

During the first experimental case the operative temperature was within the range of Category III of EN 15251 (22 – 27^{o}C)[4] for 100% of the occupancy period, while in the second and the third case it was 95% and 87%, respectively. The average cooling power of the PCM for the three cases was 16, 15.8 and 16.7 W/m^2 of PCM surface area, respectively. Furthermore, the average cooling power per unit area provided by the PV/T panels was 18 W/m^2 of solar panel area for case I, while for case II and case III it was 31.8 W/m^2 and 8.5 W/m^2, respectively. Finally, the total electricity produced in the first case was 9.4 kWh, while for cases II and III it was 5.6 and 7.8 kWh, respectively.

It was concluded that nighttime radiative cooling can be a satisfying solution for providing space cooling to office buildings. Moreover, from the three combinations of water flow rates that were examined, the one that performed best in terms of providing the best thermal environment in the office room was the first combination. On the other hand, the one that had the highest cooling power from nighttime radiative cooling was the second one.




Figures. Experimental chamber with PCM radiant ceiling (left) and PV/T panels (right).

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