PRODUCT APPLICATION NOTE

PCM as thermal mass in building envelope

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PCM as thermal mass in building envelope

Increasingly, building designers are turning to help deliver sustainable outcomes. Thermal energy system can be applied in various methods; from storage of chilled water (Sensible energy) to ice/phase change materials (PCM) at a designed temperature (Latent energy) delivering results in a range of applications.

In an area that experiences a large diurnal temperature range, PCMs have the potential to be used to store substantial amounts of thermal energy due to high energy density to volume ratio. The peak daily temperature occurs in the afternoon and similarly, the minimum daily temperature occurs substantially after midnight.

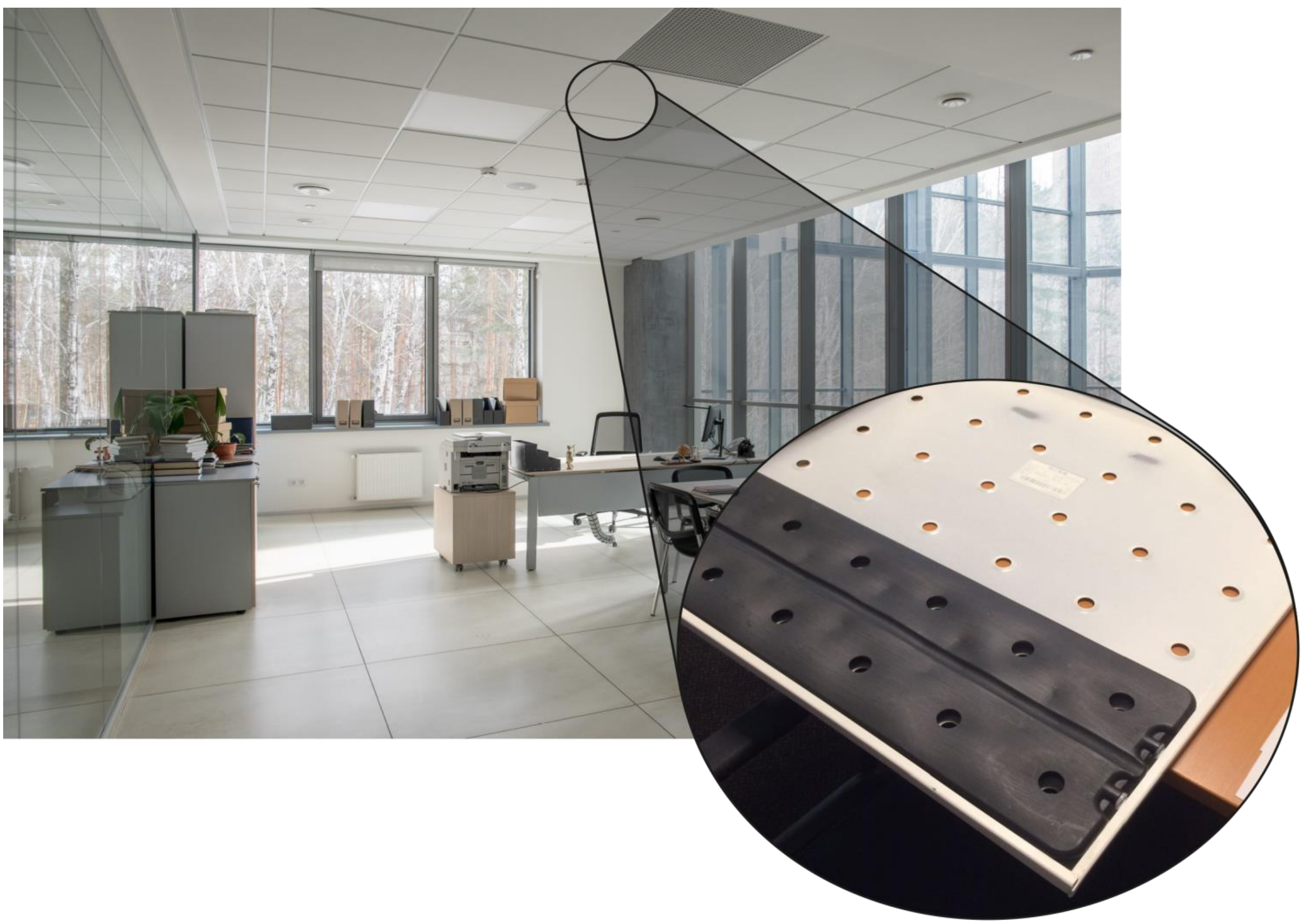
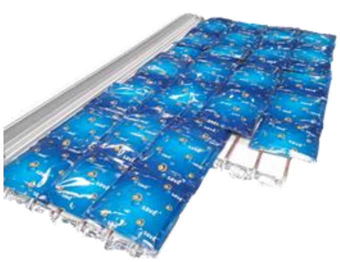


Figure 1

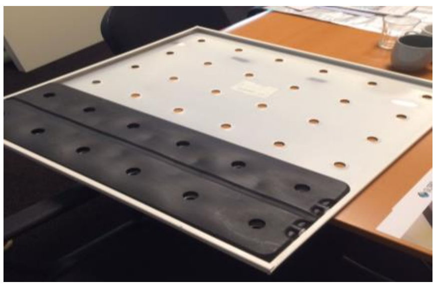
A small change of temperature difference can charge or in other words activate the PCM. For instance, a PCM which has phase change point at +22°C would require exposure to an air temperature of +17°C. As the human comfort range is from 24 - 26°C, the PCM to be used should be in melting range of 22-24°C. For instance, PCMs sav*E*® HS22 or sav*E*® HS24 are salt which can change phase between 22°C and 24°C respectively. By comparison with the same temperature limitations, a conventional sensible heat storage system such as water or concrete would occupy a volume several times greater than latent heat storage.

PCM systems can be developed using a wide range of encapsulations, including flexible pouches, HDPE containers as shown in Table 1.

Table 1: Types of encapsulations

Sr. No	Type of Encapsulation	Material	Dimensions	Energy Storage/ Sq. m
1.		HDPE	570mm×285mm×15mm	1965.95 kJ/ sq. m
2.		Nylon multi-layered film (3 celled) Pouch	570mm×157mm×17mm	1902.26 kJ/ sq. m
3.		125-micron Metallized Aluminium foil film (8 celled) Pouch	570mm×270mm×14mm	1811.76 kJ/ sq. m

To keep a space cold or avoid the temperature increase beyond a certain limit, there are three ways i.e., reduction of heat gain inside the room, reduction in temperature fluctuations and improvement of heat rejection. Implementations of PCMs are the best way to reduce the temperature fluctuations and these can be applied in buildings in either of the two ways: active or passive or a combination of both. The passive way of cooling is easier to implement and use as there is no requirement of mechanical equipment and additional energy. Only natural ventilation helps in charging the PCM by bringing the cold inside the room during the night.



thermoTab in ceiling tiles

Pouches in ceiling tiles

Figure 2

Selection of the right Phase Change Material

The selection of the right Phase Change Materials (PCM) may vary depending on the average minimum temperature of the region.

Three commonly used PCM temperatures are:
SavE® HS 22 - Requires minimum air temperature of +17°C.
SavE® HS 24 - Requires minimum air temperature of +19°C.
SavE® HS 29 - Requires minimum air temperature of +24°C.

Case Study for Indian sub-continent

India being a tropical country and having different climatic zones it experiences large diurnal temperature range in some geography. We selected cities based on their climatic condition (cities exposed to 25 ^{0}C for 95% of the year) and having a large diurnal mean temperature (15 ^{0}C to 17^{0}C for at least 4 months in a year).

Commercial application (Institutions/Office/Shopping centres) –

<u>Sample calculation of PCM required for a space having floor size of 50mtrs x 200 metres.</u>

Input Criteria / parameters

- Floor area: 10,000 sq. m.
- PCM: HS22.
- Density: 1540 kg/m^3.

- Latent heat: 167.6 kJ/kg.
- PCM module, Dimension, PCM weight and encapsulation type – 570mm x 270 mm x 14mm, 2Kg, 8-celled pouches using 125-micron Metallized Aluminium foil film.

In a single 60 x 60 cm false ceiling 2 units of such PCM pouches can fit. Hence, the amount of PCM coverage in one false ceiling will be 2 kg x 2 modules = 4 kg/false ceiling. The surface area of a single false ceiling is 0.37 sq. m. Therefore, the amount of PCM required per sq. m will be 10.81 kg.

- Incorporable weight of PCM in a 10,000 sq. m space - 10000 sq. m x 10.81 kg/sq. m = **1,08,100 kg**
- The total energy storage (PCM) capacity - 1,08,100 x 167.6 = 1,81,17,560 kJ = 5,036.68 Kw-h = **1432.17 TRH**

Reference to data from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) we have assumed the average HVAC load per sq. m as **0.038 TR/sq. m (135 Watt/sq. m).**

Hence, a building of 10,000 sq. m would have an average heat load of 380 TR. Assuming 12 operational hours per day the cumulative cooling capacity would be **4560 TRH.**

Based on the above scenario the PCM offers opportunity to shift up to **31%** of the HVAC load towards free cooling for an average of 4 to 5 months in a year. If accounted for in the beginning of the project the capital equipment such as chillers, AHUs, ducts, pumping system can be downsized.

Case Study for Europe

In Europe, diurnal temperatures are more common and hence the PCM ceiling pouches are an excellent application for office spaces and commercial buildings there. To demonstrate the same, a simulation case study was carried out for a ventilated (Rated at 20 to 40 dm^3/s) office with 2 workers working from 8AM to 12:30PM and 1PM to 5PM:

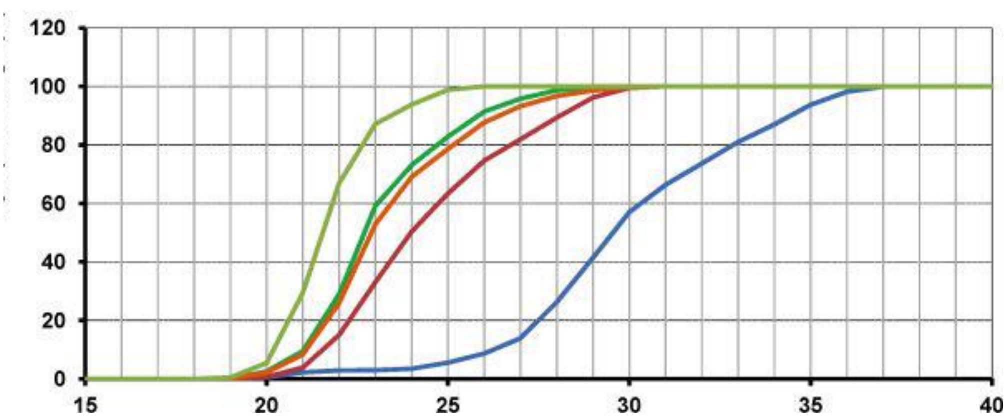
- Office dimensions (L x W x H): 5.4m x 3.6m x 3.5m. Total surface area is 12.6 m^2 and 4.6m^2 is that of glass.
- Surface area of a PCM pouch is 0.5m x 0.5m per 0.6m x 0.6m of ceiling space (70% coverage). Thickness of the pouch is 8mm.
- Specific heat of the PCM is 4kJ/kg-K. Latent heat is 120kJ/kg. PCM weighs 1560kg/m^3.

Based on above factors, it has been simulated that 14m^2 of PCM pouches would be required to maintain comfortable temperatures 21-25^{o}C which translates to (14 x 0.008 x 1560) = 175kg of PCM. **That is 2.57kg of PCM per cubic meter of room space.**

Table 2: Overview of simulations

code	ventilation	blinds	oriëntation
var9	20 $dm^3/s^{(1>}$		south
var9N			north
var8	20 $dm^3/s^{(1)}$ 40 $dm^3/s^{(1,2)}$		south
varll	20 $dm^3/s^{(1>}$	0,45 t/m 0,9 @ sun load 300 t/m 500 W/m^2	south
varlO	20 $dm^3/s^{(1)}$ 40 $dm^3/s^{(1,2)}$	0,45 t/m 0,9 @ sun load 300 t/m 500 W/m^2	south
pcm7	20 $dm^3/s^{(1>}$ 40 $dm^3/s^{<13)}$ 40 $dm^3/s^{(4)}$		south
pcm7N	JJ		north
pcm7vent	(5)		south
pcm8	20 $dm^3/s^{(1>}$ 40 $dm^3/s^{<13)}$ 80 $dm^3/s^{(4)}$		south
pcm9	20 $dm^3/s^{(1)}$ 80 $dm^3/s^{<13)}$ 80 $dm^3/s^{<4>}$		south

"var" stands for variants without PCM ceiling and "pcm" for variants with PCM ceiling.



Left to right- var9 varlO pcm7 pcm7vent pcm7N. **(X-axis is the temperature in °C)**

Figure 3: Percentage of time that the temperature is less than the indicated for various configurations.

Configurations used in the study:

- Normal situation (Office with previously described specifications) without PCM (var9)
- Situation without PCM with ventilation of 40 dm^3/s during office hours with outdoor sun protection (varlO)
- Normal situation with PCM (pcm7)
- Normal situation with PCM with north orientation (pcm7N)

- Situation with ventilation, but no PCM material (pcm7vent)

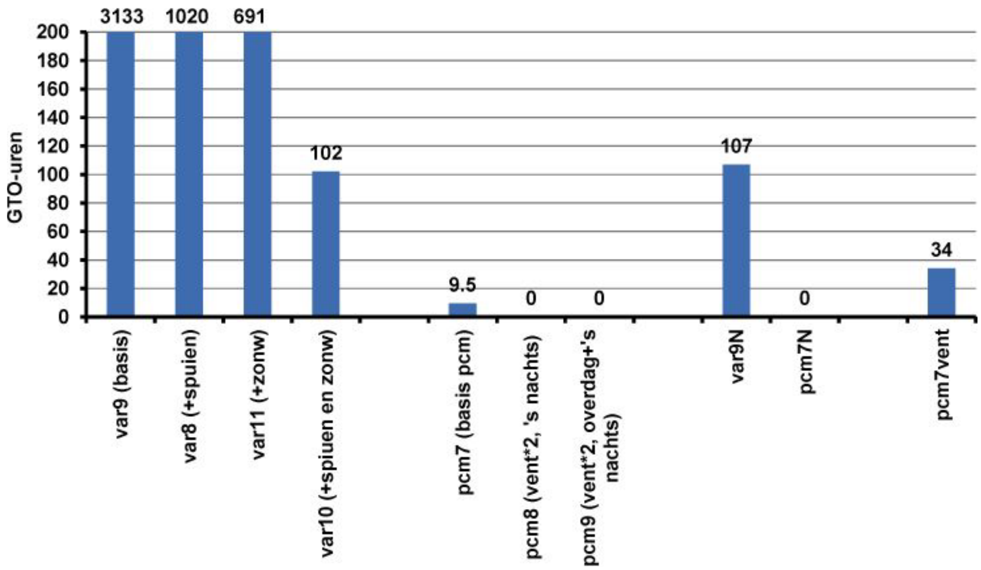


Figure 4: GTO-hours for various configurations with and without PCM-ceiling.

GTO hours or weighted excess temperature hours are the total number of hours where the office temperature exceeds the limit for comfortable temperature during work hours. 25°C is considered the maximum comfortable temperature.

As seen in figures 3 and 4, configuration, with PCM ceiling maintain desirable temperatures for longer time and have lesser number of uncomfortable temperature hours. From figure 4, it is evident that pcm7 has only 9.5 GTO hours and pcm7N has zero GTO hours. When pcm7N compared with var8 simulation results (1020 GTO hours), it is observed that PCM reduces uncomfortable hours (GTO hours) by **99.06%.**

Due to PCM incorporation in the building, the temperature maintained inside the office building is more stable as PCM absorbs the heat which is getting inside the building through walls and infiltration.