city of Melbourne

CH_2 Setting a new world standard in green building design

Design snap shot 15: Phase change material

Summary

Introduction

This summary sheet discusses the use of Phase Change Materials (PCMs) in CH2 as a ‘coolth’ storage mechanism.

A phase change material changes from a solid to a liquid state when sufficient energy is applied to it. For instance upon heating, water changes from solid (ice) to liquid (water) at 0°C.

In traditional buildings cooling is wholly provided by a chiller unit working like a refrigerator, converting electricity into cooling for the building.

In CH2 for some of the cooling load, chilled water is supplied to the phase change material ‘battery’ where the ‘coolth’ is stored to be used when required.

Drivers and objectives

The main objective of the use of PCM is to minimise energy consumption by storing the free coolth provided by the night time air and using it to cool the building during the day. A secondary driver is the demonstration of this technology in Australia under Melbourne weather conditions.

Costs and benefits

Using PCMs in a commercial building for the first time in Australia demonstrates the benefits of the application of entropy (in this case freezing and thawing) to store coolth generated by conventional efficient chillers at the coolest points of the day.

The system comprises a cooling capacity of 1200kW. This coolth is provided by electric chillers, in combination with the shower towers and cooling towers. Of these systems the majority of heat rejection will be performed by the cooling towers.

Outcomes

The PCM used in CH2 changes to a solid at 15°C. The material is stored in 100mm diameter metallic balls in three tanks. Various designs were proposed for the storage mechanism. The three tanks hold a total of 30,000 balls.

Figure 1. Final PCM storage vessel

Lessons

A backup system is required when using innovative technologies. If the PCM system fails, a standard chiller can be connected in its place for cooling. Although this will increase energy cost, the building’s thermal performance will not be degraded.

The PCM system works efficiently in the non-summer months and is not that effective with summer heat loads.

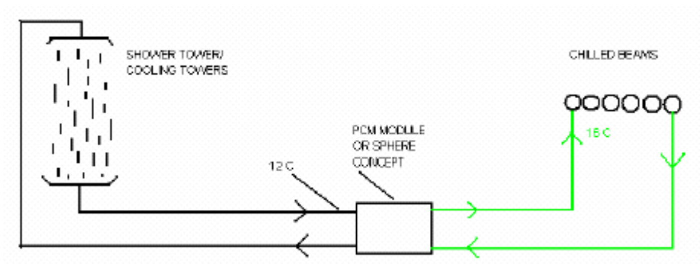

Figure 2. Summary of system (AEC)

Snap shot compiled by Dominique Hes, dhes@unimelb.edu.au from input by the entire design and construction team.

15 Phase change material

More detail

Phase Change Material Theory

Phase Change Materials (PCMs) are proposed to be used as the main supply of thermal energy to the chilled panel/ beams in CH2. PCMs work on the principle that when a material undergoes a phase change (solid to liquid, liquid to gas or vice versa) the material absorbs/releases energy, for no change in temperature, until the phase change is complete. The heat energy absorbed/released is called the latent heat of the material, and it varies for different materials.

The PCMs proposed for CH2 comprise of mixtures of non-toxic salts and organic compounds known as Eutectic Salts, which have freezing temperatures above 0°C. The freezing/melting points can be modified by adjusting the percentages of the mixing compounds.

The PCMs will 'charge' during the night time. The lower ambient temperatures at night will enable "free cooling" during certain times of the year. "Free cooling" refers to heat rejection without operating a chiller, i.e. by utilizing cooling towers or shower towers.

The system works in the following way:

- Daytime: cooling mode where water to the chilled beams is cooled by the PCM
- Night-time: PCM's charging mode where the cooling towers feed coolth to the PCMs for storage and use the next day, the shower towers pre-cool the water from the chilled panels before going through the PCMs.

The system

CH2's PCM tank is much like a battery that stores coolness, or 'coolth'. Essentially, the battery comprises a series of 3 tanks filled with balls containing the PCMs. The PCMs in the CH2 system will freeze at 15°C. Water cooled by the cooling towers and chillers will travel through the tank and add coolth to the whole system. A separate sealed water system will pass through the tank to be chilled, travel through the chilled ceiling panels and chilled beams to cool the building, and then run back into the tank, passed a heat exchanger with shower tower cooled water, to begin the cycle again.

It is expected that the cooling tower charging of the PCMs will occur 63% of the year. At other times, the chillers will be used. This charging will occur at night to ensure that the chillers are operating as efficiently as possible (AEC report EKA30504).

PCMs are a new technology that has not been used extensively in Australia. To minimise any risk, the heating and cooling system in CH2 has been designed so that, should the PCM system not function as it should, a conventional chiller will be able to perform in its place.

"…we asked ourselves… if this building fails, what is the worst that could happen? And the worst that could happen is we'd need one more chiller … and just cool some more water. Otherwise the rest of the building works as a conventional building, so you're not that far out of the norm and that's interesting because people think "you must have done something really extraordinary to deliver it." It's not that extraordinary, we have used existing technologies and bringing them together in a smarter way…"

Professor Rob Adams, Director,
Design and Urban Environment

System design

The relative newness of PCM technology to the market required a team of experts to carry out a series of design-feasibility workshops in order to determine the best method of transferring the 'coolth' from the phase change material to the water for cooling of the building. Some of the designs considered are shown below:

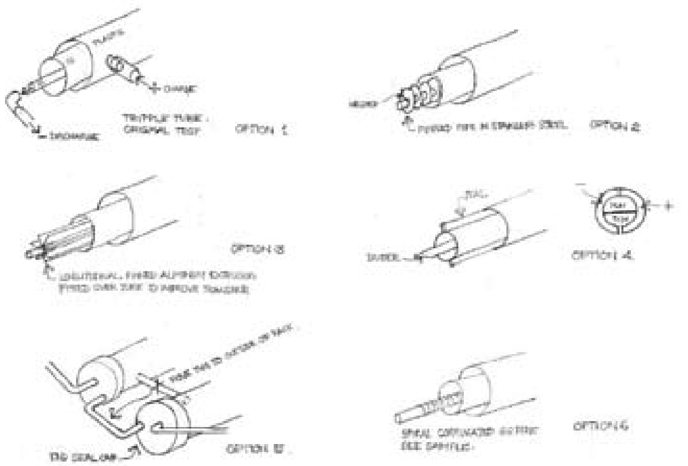

Figure 3. Six options considered for housing the phase change material (Diagrams by Mick Pearce)

Figure 4. Option 6 prototype

In the Figure 4 prototype, the design team thought that if the water or refrigerant could be in an inner tube surrounded by the phase change material, the heat transfer would be at its most efficient. The stacking and technology differences to the globe system (Figure 5) illustrated below, meant that this was eventually rejected as an option.

The final option which was decided on was a sphere, as shown below, with two halves filled with the salt blend. This will sit in a tank surrounded by passing cool water.

Figure 5. Final option for housing the phase change material

Prototyping the ceiling panels to fine tune form and function

The chilled ceiling panels went through a prototype stage to determine the most effective function and aesthetic for the panel. Figures 3-6 are a series of images showing how the prototype evolved.

Version 1 - This mock up was a flat metal panel which, although elegant and minimalist, conflicted with the organic (wavy) shape of the roof. Also, as it was a large solid metal panel, it bounced noise causing acoustic disruption.

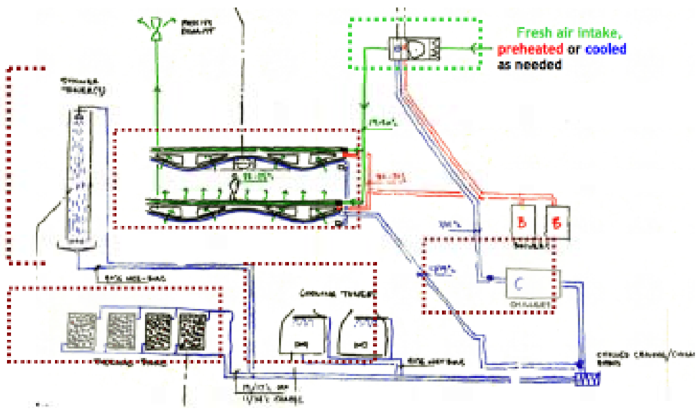

Figure 6. Proposed system for ball use – early version of system (AEC)

Figure 6 shows the proposed method for using the 'coolth' from the PCM. The chilled ceiling panels and beams are shown in section A. The cool water running through these absorbs the heat out of the air, providing radiant cooling. The warmer water is then pumped through the PCM chamber where it is first cooled by the shower tower water through heat exchange and then the PCMs as they change phase. The PCM balls in the tank (B) are charged by the cooling towers and chillers (C). Charging is the term used to change the PCMs from one phase to another. A closed loop system is used, so the water charging the PCM is separate from the water going through the chilled panels, cooling towers and shower towers.

The maintenance required for the PCM modules is limited. Initially there may be a little variation in the PCM freezing/ melting performance due to chemical reactions and settling, but this will stabilize quickly.

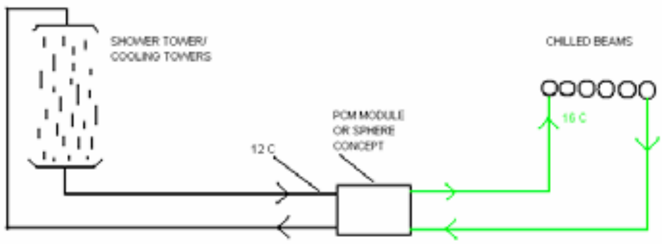

Figure 7. Use of the PCM with the shower towers (AEC)