CH2 Setting a new world standard in green building design

Design snap shot 16: Chilled panels and beams

Summary

Introduction

This summary sheet discusses how CH2 is cooled using chilled panels and beams, a method that uses little energy relative to a traditional commercial office building cooling system. As water is about 200 times more efficient than air in carrying 'coolth', it has been adopted as the main temperature regulation medium. Thus, the panels and beams have chilled water running through them. The water absorbs the heat from the building and so cools it.

This is a radiant system, as opposed to a traditional air-based convective system. Figure 1 demonstrates how the technology is integrated into the building design.

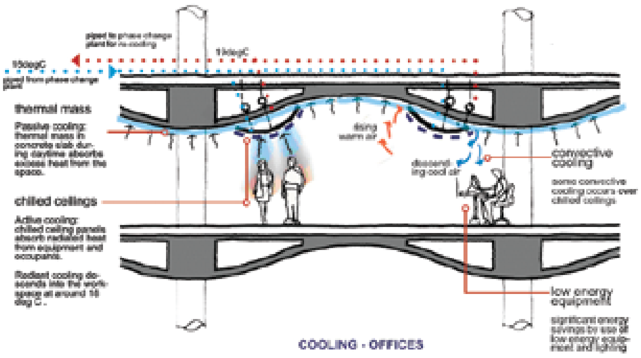

Figure 1. Integration of thermal mass, chilled ceilings and raised floors (DesignInc Melb)

Note that the cooling panels are located on the ceiling. The panels provide radiant cooling as they absorb warm air rising from people and equipment.

The transfer medium (water) of the panels is more efficient. The efficiency is derived from the fact that heat generated is not dealt with immediately by constantly re-chilling air but is absorbed by the water and taken away.

Drivers and objectives

A traditional building provides cooling by a VAV system, essentially providing heat or coolth by air injected into the office space. The main objective was to provide temperature comfort while maximising energy efficiency. It was this that led to CH2 utilising water-cooled radiant panels.

Outcomes

Prototypes were made to configure the ceiling panels with the wavy shape of the ceiling, as well as to test the acoustic performance. As a result:

- Chilled beams are provided at the perimeter of the floor plan, to combat the heat gain through the glass on summer days
- Chilled ceilings are provided in the main office space

Both systems were provided by Krantz.

Figure 2. The final panel design with a perforated acoustic backing panel

Lessons

The use of new technologies requires coordination across disciplines. This was achieved with CH2 by the Charrette process (see Fact Sheet 3: The Design Charrette), assisted by calculations and a computer model to simulate the air flows in the building.

The acoustics and aesthetics of the panel had to be considered. A full size mock-up was tested to provide realistic results for the end product.

Earlier prototypes, in the form of flat panels, and ones with smaller holes, where found to bounce too much sound around. The final solution contains a heavily perforated backing plate with thick acoustic insulation to absorb sound. The flat panel also clashed aesthetically with the wavy shape of the ceilings.

16 Chilled panels and beams

More detail

Chilled beams and ceiling panels

Many commercial office buildings use traditional Variable Air Volume (VAV) systems that use fans to blow cool air directly at occupants. The air is provided at a cool 13°C, as the VAV system relies on this air being mixed with existing air, to produce an overall temperature in a range that is considered comfortable for staff (19-22°C). However this method of cooling uses a lot of energy, both to cool the supplied air to 13°C, and to force the air through the workspace so it mixes adequately.

The CH2 building however uses an innovative radiant cooling system, that requires significantly less energy to run, delivers ‘coolth’ in a way that is more comfortable for the occupants, and assists with the desire to achieve high levels of indoor environment quality (see Snap shot 5: Energy Systems, 14: Indoor Environment Quality and 15: Phase Change Material).

There are two types of chilled systems: panels on the vaulted ceilings; and beam on the north and south walls above the windows. Water running through these panels removes heat from the air, creating a gentle radiant air cooling that descends into the workspace at around 18°C. The beams over the windows together with increased airflow through large floor mounted vents, help to minimise heat gain and loss. Both are passive systems, they do not actively pump air past the chilled water, rather letting the natural convective properties of air do the work. The use of these panels and beams is not new in Australia, although it is uncommon. The cool water is derived from the phase change materials and the cooling towers depending on the level of cooling required. Chillers are also available as back up if required.

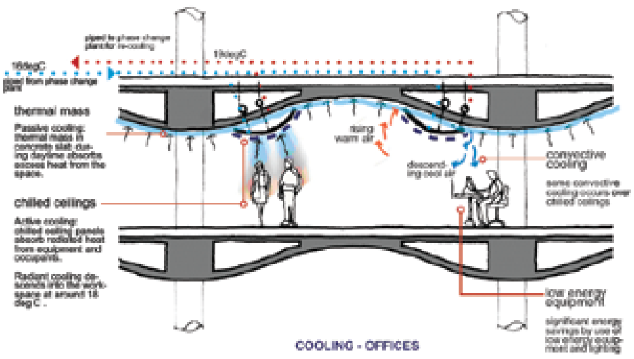

Figure 3. Depiction of how the ceilings and chilled panels work (DesignInc Melb)z

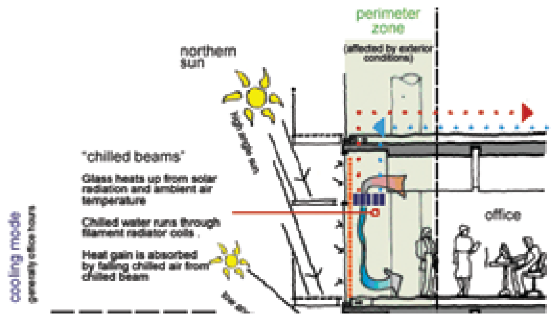

Figure 4. Depiction of how the chilled beam works (DesignInc Melb)

Applying this technology proved challenging, especially with how the beams and ceiling panels were integrated into the ceiling design. Three main issues were of concern:

- How to ‘fit’ the panels with the wavy roof shape, so it worked ‘aesthetically’ and technically
- How to position the panels to get the best cooling result
- How to deal with acoustic issues created by the panels

These are outlined in this fact sheet.

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 5-8 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 5. Version 1

Version 2 – This mock up fitted better with the organic shape of the ceiling. It worked much better aesthetically but still created acoustic disturbance as there was still a large surface of metal.

Figure 6. Version 2

Version 3 – This mock up was more rounded with the chilled water pipes (normally covered by the metal surface) somewhat exposed. This worked much better acoustically, by avoiding flat and solid surfaces. However, the modelling showed that a flatter shape was needed to improve the performance of the panel.

Figure 7. Version 3 – three versions developed at different levels of curvature, middle one is the final system

Version 4 – This mock up integrates the aesthetic, functional and acoustic concerns. The perforated metal rounded panel minimises acoustic disruption while the rounded shape works with the look of the wavy ceiling, while providing maximum 'coolth'.

Figure 8. Version 4.

The acoustic treatment is made up of a thick layer of dense acoustic insulation on the back side of the panel (Figure 9).

Figure 9. Insulation material behind the chilled ceiling panels

Figure 10. shows the chilled beams in the prototype space. Chilled air falls, dragging warm air through the chilled beam, cooling it and producing a curtain of cool air over the window.

Figure 10. Chilled beam as detailed in prototype office

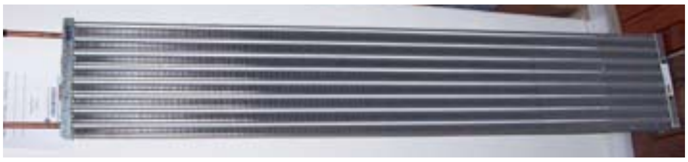

Figure 11. Chilled beam with its cover removed

The prototypes were displayed in the 'prototype space', a place where the project team works and holds its meetings.

Positioning the panels to get the most efficient cooling effect

Having mounted the panels, the ceiling systems were integrated with the ventilation, heating and cooling systems. However the team was unsure about how best to position the panels on each 'wave' of the ceiling. The two options were considered and modelled to determine their effect on air movement and air temperature, this found that the placement of the panels half way up was most effective. Occupant comfort levels were also calculated, using software which models 'percentage persons dissatisfied' (PPD) in the workspace. PPD is a measure of the expected percentage of that will be unhappy with the conditions modelled.

Option 1

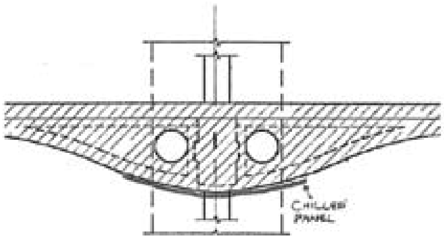

Figure 12. Option one; chilled ceiling panel placed at the bottom of the curve (AEC)

Option one was to place the panel at the bottom of each wave on the ceiling. However, as the diagrams below shows, this option created a cool air column directly below the panel (a), causing an uncomfortable downdraught in the office space (c) and delivered an uneven air temperature distribution.

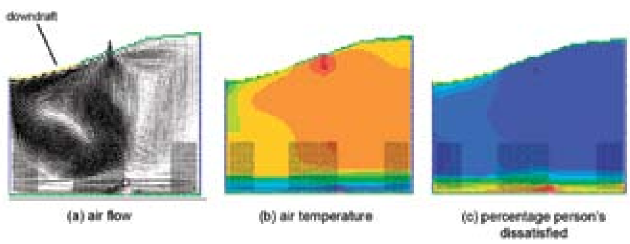

Figure 13. Office space modelling results for panel placed at the bottom of the wave (panel in yellow): Cross sections of office space, giving (a) air flow results, (b) air temperature and (c) comfort levels. (AEC)

Option 2

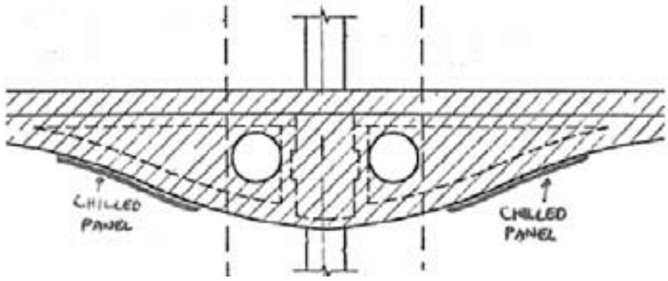

Figure 14. Option two; panel placed half way up the curve (AEC)

Option two had the panels placed half way up the side of the ceiling's wave. It shows a consistent air distribution and velocity demonstrating that good mixing has occurred.

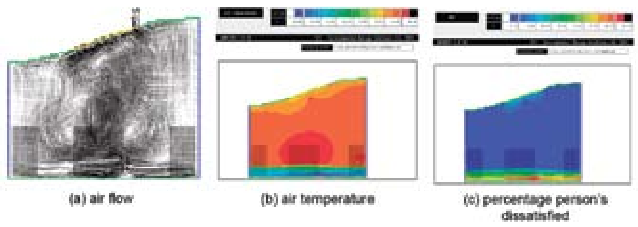

Figure 15. Office space modelling results for panel placed on the side of the wave (panel in yellow): Cross sections of office space, giving (a) air flow results, (b) air temperature and (c) comfort levels. (AEC)

Overall, option two gives an even distribution of air and temperature with better occupant comfort. Thus, it was decided to use option two in CH_2.

Working out how to fix the panels to the ceiling

Figure 16. shows the CH_2 team working on various issues related to how it needed to be fixed to the vaulted ceiling. Firstly, the chilled ceiling panels needed to be slightly off-set to allow for the configuration of the air and lighting systems. Requiring different fixing points to be designed into the pre-cast ceiling sections. Further, adjustments in three dimensions needed to be possible to take into account the curve of the ceiling.

This added a layer of complexity for the building contractor. The sub-contractors installing the panels were brought into the prototype space to look at the waved ceilings and panels. They produced a simple solution, which meant all the panels could be made the same with systematic placement of fixings by making the fixings adjustable through the use of a ferrule (a type of clamp). This idea was then developed into a bolt and two adjustable plates.

Figure 16. The prototype office with plumbers, installing contractors, architects and City of Melbourne representatives

Access to the pipes of the chilled ceiling system is achieved at the edge of each of the precast units. In the case of leakage an access panel was allowed for in the floor above each vaulted panel.

Modelling to determine effective cooling and plant size

One of the main tasks for the environmental engineers in modelling the chilled ceiling panels and beams was ensuring that adequate cooling was provided while minimising the amount of plant and ceiling space required. By this means the chilled water panels were sized, as were the chillers and the phase change material plant. Below is an example of the analysis and its implications on cooling load for one section of CH_2 – this was repeated to optimise the entire building:

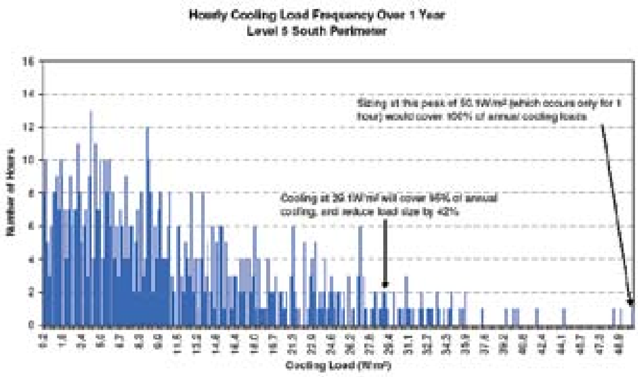

Figure 17. Research to determine acceptable cooling system load (AEC)

The result of this analysis showed that designing for 95% coverage of cooling loads would reduce load requirements by 42%, saving around $600,000 in plant.

Acoustics

In an open office, hard surfaces could cause echoing and disruptive acoustic performance. To solve this, the acoustic consultants specified treatments to the panels and beams. In their opinion, these treatments, in addition to the use of good quality carpets, would allow the space to be very pleasant acoustically. If, on the other hand, a hard floor surface had been chosen treatment to the concrete ceilings would have been required.

Integrated system results

The combination of the chilled ceiling panels and beams, and the air being supplied from beneath the floor, provide an integrated system which delivers on the key comfort and sustainability objectives for CH_2:

1. From the sub floor a 'displacement flow' of tempered fresh air is provided with appropriate diffusers.
2. With the chilled panels used, a well-mixed environment is established regardless of the manner in which the sub floor supply is introduced into the space. This means air can be supplied to the space with less energy (lower velocity) and no need for a diffuser.
3. The system is very energy efficient while providing the most comfortable environmental conditioning.
4. The system supports the achievement of the 6 star Green Star rating which the CH_2 team was aiming for.