CH2 Setting a new world standard in green building design

Design snap shot 14: Indoor Environment Quality

Summary

Introduction

This snap shot discusses the indoor environment quality (IEQ) initiatives integrated into CH2 and concludes with a summary of the business case provided for the IEQ initiatives.

One of the key design priorities of the CH2 project is to provide a building that is sensitive to the health and wellbeing of the employees. The City of Melbourne (CoM) aims to foster a working environment that supports staff. For CH2, this means providing comfort facilities, amenities, access to natural light and air, some control over the ventilation of immediate areas, and a bright, supportive environment.

Drivers and objectives

Council's objectives for CH2 were refined in the Charrette process (see Snap Shot 3: The Design Charrette). Through this, and separate work on Council House 1, the original priority of energy efficiency was supplemented and the buildings future occupants also became a major focus. This was articulated into the following five design objectives:

- To provide a healthy, comfortable, adaptable and stimulating working environment for the staff of City of Melbourne
- To provide cost benefits through reduced absenteeism and increased productivity, thus offsetting the investments in creating a building with high IEQ
- To minimise risks of sick building syndrome and other illnesses, and associated health effects and litigation
- To provide a place that is welcoming, accessible and easy to navigate for all visitors
- To provide a positive social environmental space.

Costs and benefits

Although energy cost savings will be substantial, the greatest economic benefit is expected to be in increased effectiveness, reduced absenteeism and lower staff turnover rates. These factors cost employers millions of dollars each year.

Studies have shown that air conditioning that delivers improved air quality could achieve an overall 4.9% increase in productivity, mainly through reduced sick leave and improved effectiveness at work. It is predicted this will save Melbourne City Council up to $1.12 million a year.

Outcomes

Some people see 'increased productivity' as equating to people 'doing more with less'. However this is not the intention of CH2 or the City of Melbourne. Through a well-designed working environment, fresh air, natural light, greenery, and use of materials that emit low amounts of Volatile Organic Compounds (VOCs), the City of Melbourne hopes to create a healthy place to work. The result will be fewer sick days, less headaches and better wellbeing while staff are at work.

Figure 1. Sharing sunlight and window spaces

Fresh air in CH2 is increased from the conventional 10l/s/person (AS 1668.2) to 22.5l/s/person. This directly increases the quality of the internal environment.

Also, by giving occupants more control of the system it is expected that they will be more satisfied with their thermal environment. This hypothesis will be tested through the maintenance and monitoring period after the building is completed. The net result will be a balance of control and automation, allowing the systems and the staff to work to their optimum.

Lessons

In evaluating the IEQ strategies the most cost effective range of systems were used. This required the close working of different design team disciplines to evaluate the decisions made and how they will influence IEQ.

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

Although energy efficiency is a laudable aim on both environmental and financial grounds, neither should the cost savings of increasing IEQ be understated. Major financial benefits accrue from reduced absenteeism, lower staff turnover rates, and increased effectiveness of building occupants.

More detail

The starting point for the CH2 designers was what makes a comfortable working environment for people, such as:

- control over their environment; and
- feeling neither too warm or cold.

This latter element is the most difficult to design for, as everyone has different levels of comfort, and these vary from week to week. Having control helps with this, but how do you then design for heating and cooling?

It's all about creating a sustainable work environment … that's been the focus…. The great thing about this project and the way the City of Melbourne have done it - it is a building for the people. … it has been the prime driver through everything no matter what the idea is.

Stephen Webb, DesignInc

Heating and cooling strategy

The design team reviewed various types of heating and cooling systems, assessing them to determine which people find most comfortable. Most people find radiant heating or cooling most comfortable, that is for example, coolth that radiates from cool surfaces, as opposed to blowing chilled air onto them. With this in mind, a 100% fresh air strategy was taken up in the design with an abundance of radiative elements such as chilled ceiling and beams were designed.

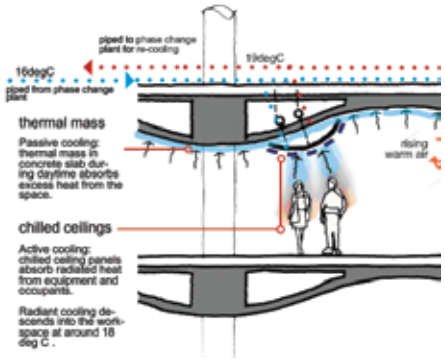

Figure 2. Use of radiant systems such as chilled ceilings to provide 'coolth' (DesignInc Melb)

The importance of comfort - design for user philosophy

The physiology of the building users and how they would experience the space was paramount in each design decision. To test this thermal modelling using Thermal Analysis Software (TAS) was used extensively throughout the design of CH2 to influence decision making with regards to those aspects which affect thermal comfort. In addition, computational fluid dynamic modelling (CFD), using Phoenics software, was utilised for discrete elements to quantify and optimise their performance.

Through the use of TAS and the international thermal comfort standard (ISO 7730-Ergonomics of the thermal environment), all building and services elements that affect thermal comfort have been designed to achieve a Predicted Mean Vote (PMV) level between -0.5 and 0.5. This has been achieved by addressing all of the factors that affect thermal comfort, such as radiation, convection and conduction.

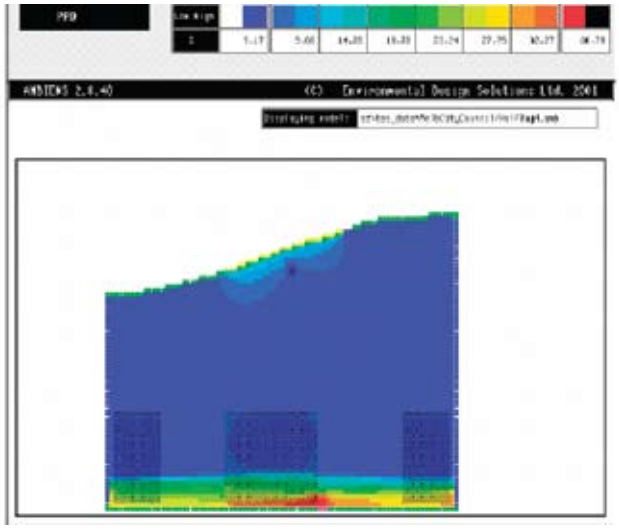

Figure 3. CH2 cross-section view showing occupant comfort levels (Predicted Percentage Dissatisfied [PPD]) study done for the placement of chilled ceiling elements (AEC)

This study demonstrated that the option used at CH2 shows a consistently low PPD across the whole floor – that is people are in generally satisfied with their environment in relation to temperature.

Ventilation strategy for CH2

Displacement ventilation is a method used in ventilating and air conditioning buildings. Most office buildings are ventilated in order to control the temperature of the workspace, and to maintain an acceptable quality of the air (air is contaminated in the workplace by various activities and other sources). Most office buildings typically force new air down into the space from vents in the ceiling. It is commonly referred to as VAV (Variable Air Velocity) or a 'mixing system'. The new air mixes (dilutes) with the existing air in the space, resulting in the desired uniform temperature and air quality.

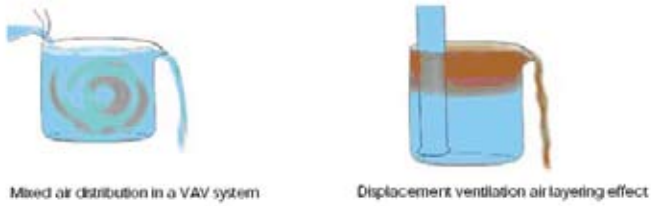

Figure 4. Representation of two air introduction systems (AEC)

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.

Displacement ventilation however aims to 'displace' old (warm and stale) air with new (cooler and fresher) air, as opposed to mixing with the old air. Air is supplied through the floor at a low velocity. The air in the office space rises as it is heated (from the heat generated by office equipment, and people), and a 'layering' of the air in the workspace develops, with the cooler and fresher air occupying the lower area that people inhabit. The old air is exhausted through ceiling vents. This means that the air follows a 'one-way path' in the office space, with very little mixing or recirculation occurring. In general office buildings need to be cooled rather than heated due to the heat load generated by the people, the equipment and the lighting, for CH2 the fresh air introduced is pre-cooled or heated to 18ºCelsius.

VAV systems typically have to introduce new air at 7 degrees lower than the desired workspace temperatures, to overcome the diluting (mixing) with the older air (which is warmer than the desired temperature). With displacement ventilation, as the fresh air is not diluted by the old air already in the space, it can be introduced at a temperature a lot closer to the desired workplace temperature. It is energy efficient, because the air does not have to be forced as strongly into the workspace, and the new air does not need to be pre-cooled as much as with a mixing system.

Displacement ventilation is a lot more efficient in providing high quality fresh air, and removing contaminants that are created in the indoor environment. The VAV 'mixing' system creates a lot of air turbulence, distributing contaminants throughout the space. A good illustration of this point is how a sneeze containing flu germs is dealt with. In a mixing system, there is much more chance of the germs from the sneeze being distributed throughout the office space, to be breathed in by other occupants. With the displacement ventilation system, there is much more chance of the contaminant being contained and exhausted from the workplace (Figure 4.).

1. 'ISO 7730:2005 presents methods for predicting the general thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments. It enables the analytical determination and interpretation of thermal comfort using calculation of PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) and local thermal comfort, giving the environmental conditions considered acceptable for general thermal comfort as well as those representing local discomfort.' www.iso.org

In summary, the advantages of displacement ventilation systems over conventional air conditioning and mixed flow systems are:

- Increased cost effectiveness in operation
- Improved air quality within the occupied zone
- Greater operational efficiency
- Can be concealed behind architecturally designed fascias
- Extremely quiet in operation
- Generally greater compatibility with architectural requirements
- Greater flexibility

A major part of designing a ventilation system is the minimum fresh air requirement. CH2 has set its minimum fresh air requirement at 22.5 litres/second/person. The Australian Standard requires 10 l/s/person (AS 1668.2), the USA standard is 10 l/s/person (ASHRAE Standard 62 2001) and European standards range from 10–20 l/s/person. An increasing amount of research shows that low fresh air requirements can be directly linked to low productivity and sickness, including colds and flu.

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.

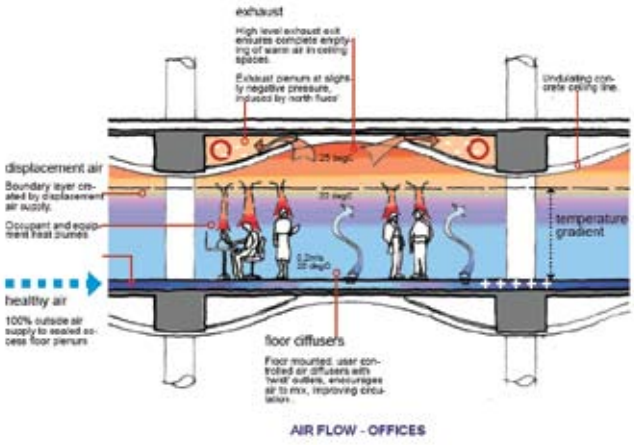

Figure 5. The CH2 system: Natural air diffused at low rates from the subfloor (DesignInc Melb)

The ventilation systems designed for CH2 deliver outside air into the space without mixing or recirculating air back at the central air handling plant.

Figure 6. 100% fresh air ventilation system

Natural light and views

Natural light and access to views from windows impact on productivity and IEQ. Studies were carried out to optimise natural lighting in CH2 and to provide access to views. The result was the wavy ceiling, use of light shelves, large windows at the bottom of the building and smaller windows at the top, use of colours to accentuate the natural light and the concepts that windowed areas were shared by all not owned by individuals. Further, to give people the ability to manage their own environment, while saving on over-lighting, each desk has been designed to include a task light.

Plants - anternal

To further improve the indoor environment of CH2 indoor plants were used. Research at the University of Technology, Sydney, has shown how indoor pot plants improve air quality (The Nursery papers). There are several species of plants, which aid in the filtration of toxins from the air. As a result, clear claims can now be made, and development of varieties with an even better capacity for cleaning indoor air can begin.

Our findings support the view that the potted-plant system represents a potentially more selfsustaining (provided the plants are well maintained), flexible and attractive biofiltration system for the future, that can be used in any indoor space.

- The pot-plant system really does reduce or eliminate VOCs (Volatile Organic Compounds) from indoor air within 24 hours.
- The system gets better on exposure to VOCs and maintains performance with repeated doses.
- From 3 to 10 times the maximum permitted Australian occupational indoor air concentrations of each compound can be removed within about 24 hours, under light or dark conditions without saturating the system.
- The pot plant system can also remove very low residual concentrations as well,
- Work at the same rates day and night, and over weekends (when air-conditioning may be turned off).

Ron Wood

2. 'http://www.tropicalplantrentals.com.au/Pot_plants_really_do_clean_indoor_air.pdf last accessed 5 October 2004

Examples of plants which work effectively from Ron Woods study mentioned above:

- Kentia Palm (Howea forsteriana)
- Peace Lily (Spathiphyllum 'Petite')
- 'Janet Craig' (Dracaena deremensis)

Further plants give a green aesthetic to the workspace that links it to the external environment and aids in feeling good within the workspace.

Figure 7. Indoor palm
(http://www.lordhoweisland.info/environ/kentia.html)

Figure 8. Indoor Janet Craig and Peace Lily
(http://www.greendesign.com.au/plants_index.htm)

Material selection for IEQ – OW VOC material

The detailed selection and specification of internal materials and finishes has ensured that indoor air pollutants are kept to minimum. In addition, to prevent mould growth, the ventilation and air conditioning systems ensure that relative humidity is no more than 60% in the office space and no more than 80% within the ductwork and distribution system.

The materials for which credits are claimed under the green star office system are as follows:

- Low VOC paints
- Low VOC carpets
- Low VOC adhesives and sealants
- Low emission formaldehyde composite wood product

Acoustics

Acoustics consultants were employed to ensure that internal noise levels remain within suitable limits for an office space. This has been achieved through the installation of acoustic insulation above the perforated chilled ceiling panels, use of timber, carpet and soft furnishings as well as the use of background white noise.

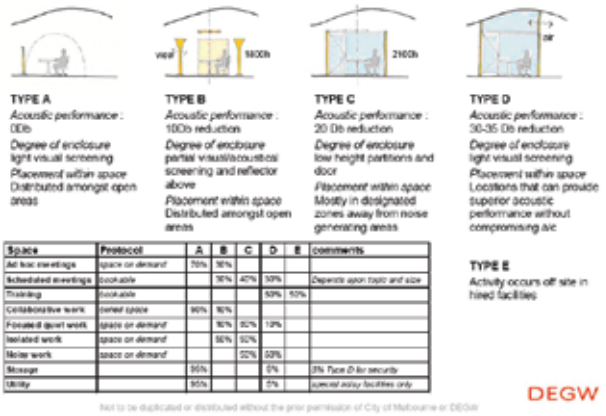

Figure 9. Functions and acoustic performance (From DEGW/MCC)

The business case for the IEQ strategies

The table below shows the potential financial savings reported on by AEC's research. It shows that there is a potential $351,340 annual saving based on a worst case scenario and $1,121,653 in a more reasonable case, mainly arising from increased productivity and reduced illness days.

3. Improving the indoor environment for health, well-being and productivity http://www.tropicalplantrentals.com.au/ron_wood.pdf last accessed 5 October 2004

		Conservative		Reasonable	
Possible area of savings for MCC	Annual cost attributed to factor	Estimated % improvement IE at CH_2	Predicted saving	Estimated % improvement IE at CH_2	Predicted saving
Illness caused by office environment	$153,142	90%	$137,827	95%	$145,485
Illness caused by home environment	$61.256	0%	$0	0%	$0
Injury caused by office environment	$30,628	5%	$1,531	10%	$3,063
Injury caused by non-office environment	$61,256	0%	$0	0%	$0
Stress related to work	$122,513	10%	$12,251	15%	$18,377
Non-work related stress	$122,513	5%	$6,175	10%	$12,251
Reduced staff turnover due to dissatisfaction with IE (5% of total turnover)	$66,055	10%	$6,606	40%	$26,422
Improved productivity (gain for each 1% improvement)	$186,950	1%	$186,950	4.9%	$916,055
Total			$351,340		$1,121,653

Table 1. Summary of potential benefits (AEC)