ENVIRONMENT DESIGN GUIDE

BUILDING T, DEAKIN UNIVERSITY

Dr Mark B Luther and Chris Lamborn

Building T at Deakin University, Burwood in Victoria was designed by DesignInc. The development, located in Melbourne's eastern suburbs, utilises thermal mass and hybrid ventilation systems. This case study provides a detailed evaluation of the building in terms of its energy efficient design features.

1.0 PROJECT OUTLINE

1.1 Project details

Client

Deakin University, Buildings and Grounds Divisions

Consultants

Architect

DesignInc Melbourne Pty Ltd

Engineer

Meinhardt Consulting Engineers Pty Ltd

Umow, Lai & Associates Pty Ltd

Quantity Surveyor

Wilde & Woollard

ESD Concepts

Built Environment Research Group

Builders

Wycombe Constructions

Year of completion

June 2002

Building type

Office and educational facility

Floor area

2,860m² (usable floor area)

Number of storeys

Three storey building with a full height atrium running its full length.

Cost at completion

$5.85 million

Occupancy rates and number of people

Building T is multi-functional, accommodating offices, teaching spaces and laboratories. The building is used 40 hours a week by approximately 230 regular occupants on average.

1.2 Location and climate

Building T is located at Deakin University's, Burwood Campus in the eastern suburbs of Melbourne, Victoria. On a predominately flat site with a minor slope from east to west the building is situated on the eastern side of the campus. It is set in amongst existing university buildings and it specifically ties into a neighbouring

Figure 1. The east facade of Building T (source: Deakin University)

building via a covered walkway. Landscaping and pedestrian access ways have also been incorporated. A garden bed surrounds the perimeter of the building and a surrounding footpath caters for pedestrian traffic and links the building to other areas of the university. A temporary ground level carpark (approximately 100 car spaces) is located to the north of the building, but does not infringe on the building.

The temperature of the eastern suburbs of Melbourne is characterised as temperate with warm to hot summers and cool to cold winters. It has a diurnal temperature range in summer of approximately 12°C, whilst in winter it is approximately 11°C. The suburb of Burwood also experiences extreme hot days during summer that reach 30°C plus, whilst in winter cold days below 10°C are also experienced.

The average annual rainfall in Melbourne is 656mm, whilst the wind predominately comes from the south-west although in summer the wind can commonly shift to the north.

1.3 Background

Building T is a Science and Technology Building at Deakin University. It has been designed to specifically incorporate energy efficient strategies responding to Deakin University's ecologically sustainable design (ESD) policy.

The design brief was for a three storey, flexible office building that incorporated office, teaching and laboratory spaces. The architect's response was to design a three storey naturally ventilated building, split into two wings divided by a central atrium (see Figure 2). An external concrete lift shaft provides a focal point and a link to a neighbouring building. High levels of exposed thermal mass are a feature of the building in order to promote its thermal qualities and provide an aesthetically pleasing finish.

The building was the recipient of a commendation for sustainable design in 2003 by the Property Council of Australia.

2.0 DESIGN PHILOSOPHY

2.1 Sustainable objectives

The building was designed with the intention to conserve energy in everyday use and to achieve energy usage rates well below that of a conventional building of a similar nature. Specifically, it was designed to achieve an energy consumption level of around one-third of an equivalent university building (360MJ/m²) with a comfort range operating temperature of 18°C to 28°C (Fuller and Luther, 2003).

The building was also designed to promote passive ventilation and provide maximum natural daylight. However, in areas such as the computer laboratory where environmental control is crucial to the function of the space, mechanical air conditioning was incorporated.

2.2 Design process

Building T was designed through detailed drawings using AutoCAD. Three-dimensional (3D) models were also established in order to understand the massing of the building. These 3D models became the vehicle to refine the design and inform the various consultants. They were subsequently used to carry out thermal, structural and lighting models.

Deakin University's Buildings and Grounds Department (the client and project managers) were determined to assemble the right design team to produce an energy efficient building from the outset (Luther and Fuller, 2000). The team consisted of mechanical and structural consultants, project managers, contractors and the internal Built

Figure 2. Interior of Building T (source: Deakin University)

Environment Research Group (BERG) who were the environmental and energy consultants.

Specifically, the research group carried out computer modeling to explore and determine the effects of passive solar construction materials and system strategies. It also determined the effect of the air flow modeling through the 200mm hollowcore concrete floor and ceiling panels.

During the design phase all relevant consultants were included to discuss the issues surrounding Building T. Weekly meetings were held to set goals and to discuss various simulation refinements due to the unique nature of some materials.

2.3 Procurement process

Wycombe Constructions was appointed as contractor, but difficulties were experienced during procurement when Wycombe Constructions went bankrupt two-thirds into the project.

Facing the possibility of major disruptions, Deakin University immediately employed Wycombe Constructions' employees directly, along with the relevant sub-contractors, to complete the project under a construction management contract. This enabled the project to continue with minimal delay and minor budgetary dilemmas (Deakin, 2003).

3.0 DESIGN AND CONSTRUCTION

3.1 Design features

Building T addresses a wide range of design features. It is a building of moderate size and scale that enables it to sit comfortably within its surrounding area, yet be distinct from neighbouring buildings.

Figure 3. North view of the lift shaft and louvres to the west end of Building T (source: Deakin University)

Externally, the building explores a range of concrete finishes from light grey infill panels to pigmented plinth sections. The separate lift shaft is a feature of the design that provides a focal point and an element that links the building to an adjacent University building. Large aluminium louvred profiles (see Figure 3) clearly distinguish the entrances to the building and provide a strong visual break between the concrete forms, whilst the clearly defined concrete joints add detail to the thermal mass and highlight this external design feature.

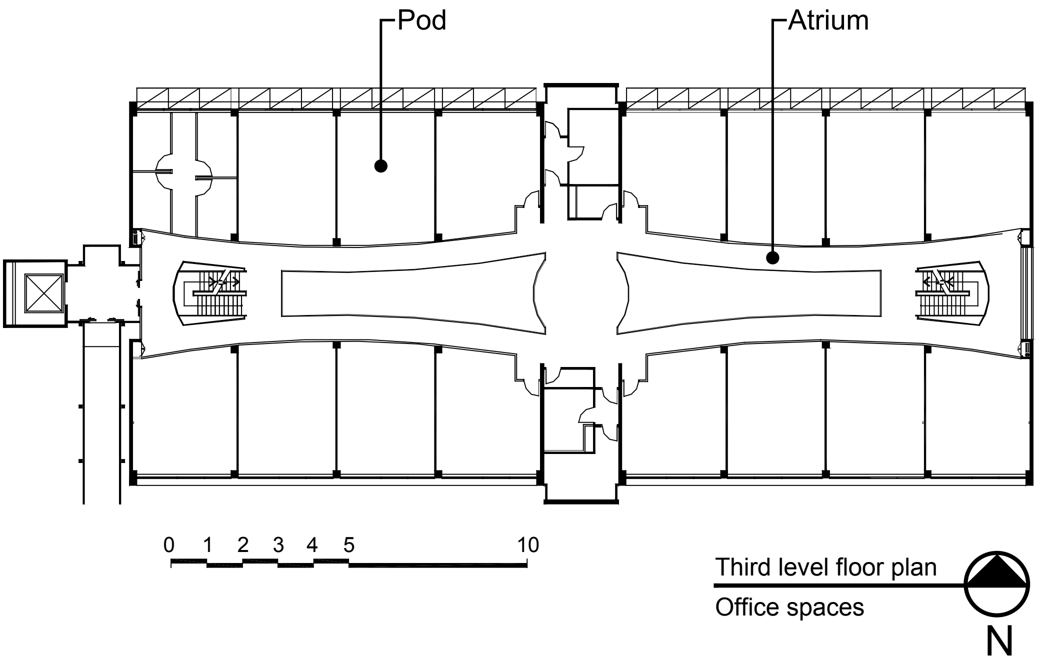

Figure 4. Typical floor plan of Building T (source: Deakin University)

The shading screens on the north elevation and an atrium clerestory, which includes a light scoop, highlight the building's energy efficient and day-lighting features. The large louvred profile sections at each entry point also continue this energy efficient theme.

Even though there were construction delays and an introduction of unfamiliar technologies, the design and construction cost of building T was kept to a moderate $1650/m^2 (not including fitout) (Deakin, 2003). This is considerably lower than buildings of a similar nature where costs are generally above $2000/m^2.

3.2 Orientation and layout

Building T is constituted of mainly office spaces (along with several teaching spaces) and is divided into two main wings that are elongated in an east-west direction. Between the two wings a full-height atrium runs the full length of the building (see Figure 4).

This arrangement has provided the building with a high degree of northern orientation to maximise solar performance and natural day-lighting opportunities. The offices and teaching spaces in the north wing, along with the atrium, experience solar gain to many of the rooms. Large windows on the south facade provide high levels of natural day-lighting to the south wing.

Internally, each wing is divided into main office areas called 'pods' and each pod area is broken down into smaller offices through floor to ceiling flexible wall partitions. This flexible approach was a part of the design brief and enables each area to accommodate a variety of staff requirements. Although the partitions can restrict the potential for solar gains to many of the rooms, commercial buildings require a greater focus on cooling measures. Theoretically, therefore, the wall partitions should not pose too much of a problem.

3.3 Building form and envelope

Robust in form, Building T is simple and rectangular in shape (see Figures 1 and 4). It offers little in terms of complexity, however it provides an efficient solution to incorporating energy efficient strategies and maximising the use of its internal space.

The east and west walls emphasise the building's use of thermal mass. They are constructed of thermomass insulated precast concrete sandwich panels, which consist of styrofoam insulation sandwiched between two layers of concrete. The north and south facades consist of high levels of glazing for maximum solar and day-lighting performance, with insulated lightweight sandwich panels in between. The shading devices to the north facade provide solar protection, whilst the clerestory glazing above the shading screens provides the opportunity for day-lighting to penetrate deep into the internal spaces (see Figure 5).

The roof continues the building's theme of thermal mass. It is constructed of precast hollowcore concrete with insulation over to provide further thermal protection and enhance ventilation to the top floor. Colorbond steel decking over the concrete ensures weather protection and water run-off. The roof to the atrium is also curved Colorbond steel decking.

3.4 Construction system

The main structure of Building T is of reinforced concrete pier and beam construction. Also, due to its simple form the end wall concrete panels and flooring system are all precast concrete panels. By precasting the concrete off-site the cost of construction and waste has been kept to a minimum.

4.0 ENVIRONMENTAL CONTROL METHODS

4.1 Energy efficient strategies

The energy efficient strategies included in the building are:

- lighting/day-lighting control
- facade systems – thermal mass and insulated lightweight spandrel panels
- hollowcore ceiling/floor systems
- passive-active hybrid systems
- night ventilation.

These design strategies are intended to reduce energy consumption and provide a comfortable working and teaching environment.

4.2 Lighting and day-lighting

One of the main energy efficient goals of the design was to provide the building with maximum natural day-lighting. As previously mentioned, high levels of glazing on the north and south facades provide the building with an abundance of natural light. A clerestory window with a laser cut panel running along the north facade promotes natural light penetration along the ceiling plane (see Figure 5). This has the benefit of not only allowing light deep into the space, but also reduces glare. The atrium clerestory with light scoop and glazing to the building foyers also provides adequate natural day-lighting down to ground level so that the building is bright and inviting.

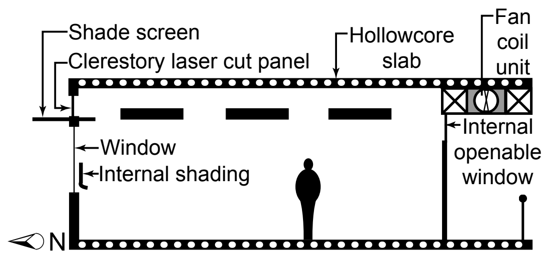

Figure 5. Section through a north wing pod (source: Deakin University)

There is also a range of artificial fluorescent lighting within the building that includes both direct and indirect lighting distribution. The main fluorescent luminaires in the offices have been designed to work in conjunction with user presence and daylight dimming control. Dimming sensors are mounted directly onto each lighting fixture to maintain a 320 lux workplane illuminance.

Energy savings are dependent on the successful operation of this system, since the installed power (lighting) density is around 17 W/m² (an unacceptable amount by today's environmental standards).

The building was designed in order to monitor light usage and keep artificial lighting as low as possible. It was also designed to provide bright, uniformly lit internal spaces together with operable shading devices to reduce glare. In hindsight, there is too much light provided to the space on most days of the year, resulting in glare issues. Less glazing openings and darker glass tints would provide a solution to this problem.

4.3 Facade System

The extensive use of thermal mass on the east and west walls provides the building with protection from the low level morning and harsh afternoon sun.

Thermomass insulated concrete sandwich wall panels (see Figure 6) in particular provide a high level of protection to the offices and teaching spaces by reducing heat transfer into the building and ultimately minimising the internal heat loads, as well as maintaining a stable internal environment through the interior concrete portion of the wall. Internally, this abundance of concrete has been exposed to visually promote the thermal mass within the building.

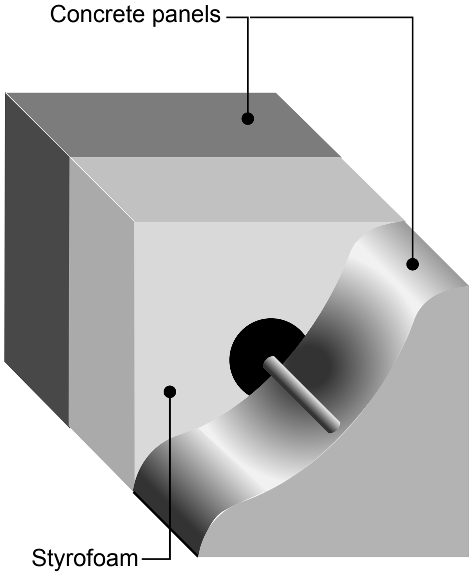

Figure 6. A typical cross section of thermomass insulated concrete wall panel, R-value = 3–3.5 (source: Thermomass Building Systems)

The north and south walls are constructed of floor to ceiling aluminium framed curtain-walls with glazed or solid insulated infill spandrel panels. Certain components of the glazing are openable to provide adjustable ventilation to the internal rooms. On the north facade steel framed horizontal shading screens (Figure 7) provide protection from the summer sun, whilst allowing the winter sun to penetrate into the spaces. The large louvred profiles provide protection to the entry spaces in the same way.

Figure 7. The north facade of Building T (source: Deakin University)

4.4 Hollow core flooring system

The use of a 'Termodeck' hollow core ceiling system provides the building with an adaptive mixed mode ventilation system. The ceiling/floor or hypocaust system works by allowing passive air to run through holes in the thermal mass provided by the concrete structure. The ceiling system consists of hollow concrete planks (200mm thick with 150mm diameter holes) with interconnecting channels (air inlet and outlet holes) to allow ventilation air to pass through at the rate of 2 changes per hour as shown in Figure 8. This air ventilation rate, which exceeds minimum BCA standards, is channeled through the hollowcore slab prior to entering the offices, providing the slab with a cooling or heating radiative effect.

Depending on conditions, air is drawn through the hollow core from the most acceptable source into the spaces. It either enters from the outside via the mechanical system or from the internal atrium space. In summer, the hollow core system will be provided conditioned (cooler) air from the centralised plant and recharged at night by making use of cooler night time air. In winter heating will be achieved by way of fan coil units that will heat the ventilation air, distributing it through the hollow core floor slabs. This will heat the slab in a similar way to hydronic or electric coil type slab heating.

In addition to displaying environmental awareness, the client's objective was to show a certain level of innovation in its new building, therefore this hypocaust or hollowcore system is a way of meeting this objective. Although used extensively in Europe and Scandinavia hollowcore systems are relatively rare in Australian construction.

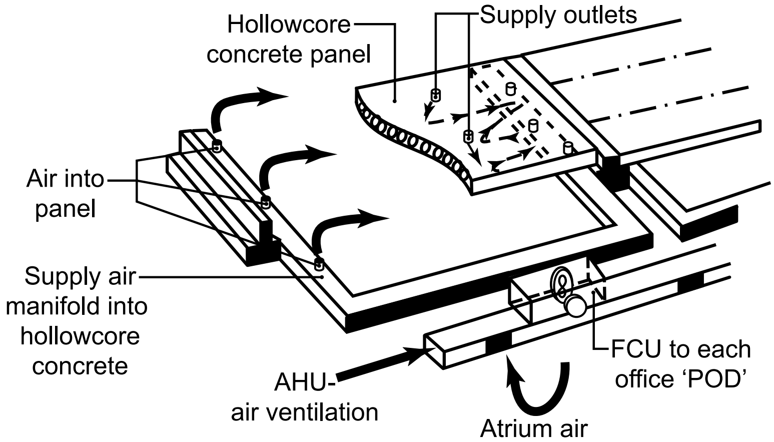

Figure 8. A schematic representation of the hypocaust system in Building T

4.5 Passive-active hybrid systems

Building T was designed around a system that makes use of both active and passive conditioning. Mechanical (active) ventilation can often be very expensive due to the need for consistent operation, whilst natural (passive) ventilation relies on the weather.

The internal planning of building T was divided into 'pods' (approximately 70m²), with each pod being self served by individual fan coils. These fan coils can be mechanically isolated from the rest of the floor, and provide a high level of control as spaces can be isolated and conditioned individually. On extremely hot days the active system is used by conditioning 100 per cent outside ventilation air (by the centralised plant), which is then ducted under the atrium corridors to individual rooms. This cooler, conditioned air is further distributed to the hypocaust by using the fans (only) of the fan coil system. In winter, air is drawn to the fan coil units from a bank of warm air in the atrium whereby a central boiler provides hot water to the fan coil units. If additional heating is required the centralised plant is put into operation. In both heating and cooling mode, user operated ceiling sweep fans assist in circulating the air within the office spaces.

This active system works in conjunction with the passive measures of the thermal mass (including the hollowcore floor system) which creates a thermal lag and acts as a stabiliser to limit abrupt temperature changes. The active system then switches on and off when required to create a stable internal environment (within a comfort band of 18°C–28°C). During certain periods blue flashing lights (in the atrium) signal the acceptance of fresh outside air, whereby occupants are encouraged to open the windows.

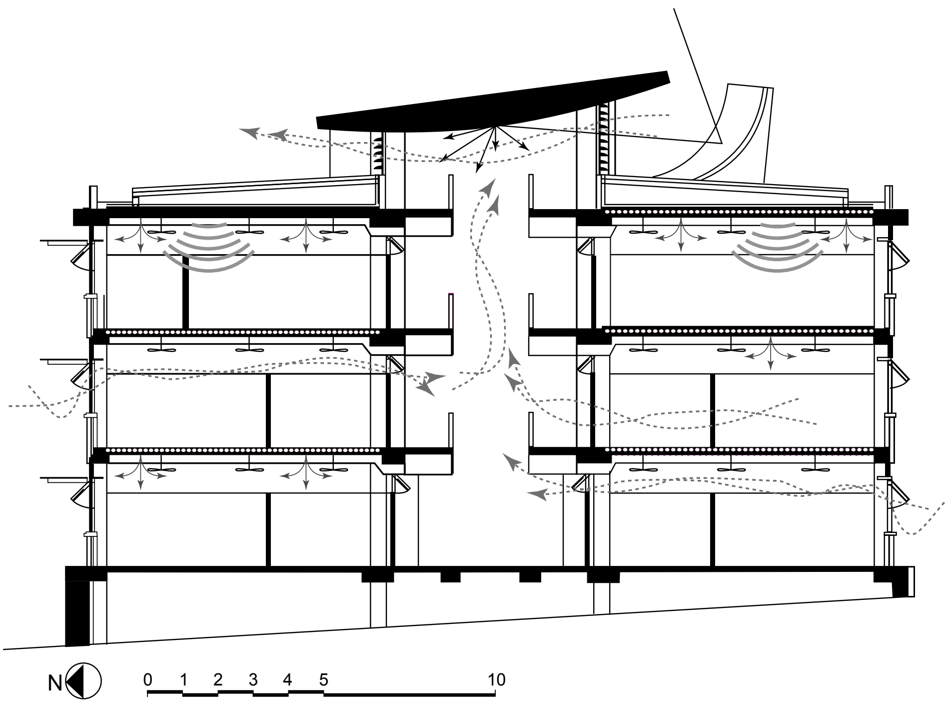

Figure 9. Cross section of Building T showing natural ventilation flow

This approach provides the building with a high level of user control. Multiple fan coil units, individual ceiling fans, shading devices and openable windows allow individuals to have more control of their environment. However, it is a system that is not immediately responsive, where it's very difficult to flick a switch to get instant results. The sequence requires slow responses that enable the system to adapt to the desired environment instead of triggering urgent demands.

4.6 Night ventilation

One of the major features of the building is the overnight ventilation system or night purging. Using the internal atrium, air can be extracted through the building either by the active or passive systems, to cool the building overnight.

During the hot summer months the active system (via ducts and windows) removes or purges the hot air in the atrium by smoke extraction fans and dampers located at the base of the atrium. This system creates an adequate air exchange by pulling air through the offices, allowing it to pass through the building fabric before extracting it.

The thermal mass of the building is recharged by the coolth of the night. Cool night air can either come from the atrium or directly from openable windows to the individual spaces (see Figure 9).

5.0 POST OCCUPANCY EVALUATION

The post occupancy evaluation (POE) has shown that although there are certain problems with Building T, generally the energy efficient component of the building showed benefits.

The calculated energy consumption of Building T is:

- 667MJ/m² per annum (measured electricity consumption).
- There is no gas or water consumption data recorded due to the lack of metering.

Although the building consumes more energy than was expected (energy consumption predicted 360MJ/m² per annum), it is much lower than a conventional building of a similar nature.

Excluding the atrium, it has been calculated that there is approximately 27 per cent reduction in energy consumption (for electricity) by this building in comparison with the Victorian Government benchmark set for 2001 (Umow Lai and Associates, 2003).

The difference between the predicted data and the actual energy consumption has resulted from several problems. It was discovered that the night time purge mode was not in operation, therefore the building required extra use of the mechanical system to cool the building each morning. Also the artificial lighting levels could be reduced by as much as 50 per cent. Faults in the lighting controls caused them to over supply the required lighting levels. These lighting discrepancies have resulted in extra energy consumption. Finally, the building's Building Management System (BMS) modes of operation are currently being investigated, and with some clearly not in operation, there is room for further improvement. Therefore, due to these factors the authors believe that the original energy consumption target of 360MJ/m² per annum is still achievable.

Further performance indicators revealed by the post occupancy evaluation include:

- Stuffiness and smells are a problem. Twenty-nine building occupants were surveyed and none of the 19 comments received about air quality were favourable.
- Many spaces have been subject to glare.
- Poor acoustic levels due to the hard, exposed surfaces in the atrium and offices.

These factors indicate that Building T hasn't performed all that well during its 'early life'. Although a concern, like any new building, Building T requires a process of fine tuning and 'ironing-out' to optimise its performance. The air quality for instance has shown improvement since the POE study. Without a quick, responsive mechanical system the building relies on the night purge mode, and the initial lack of night purging again proved to be the major problem. This deficiency of overnight fresh air causes the building to become hot and stuffy from the start of each day.

The issue of glare has caused problems for building occupants due to excessive glass areas and the need for darker tinted glazing. It was also noticed that the transmittance of the blinds at 20 per cent could be reduced even further to 8 or 10 per cent.

Due to the hard and specular internal surfaces throughout the building interior, background noise levels can be quite high. This obviously makes it difficult for staff and students, especially when wanting to open their atrium facing windows for ventilation. From the outset this was a concern for the design team, however due to financial constraints there was very little acoustic assessment carried out. A study into this issue would be valuable in order to identify solutions and rectify this problem.

The response from users has been varied. The negative responses have focused on comfort levels within the building and some occupants complained that there were too many parameters to control. Conversely, there have been several positive responses to the high level of user control over the conditioning of air in private offices.

The response to the level of user control raises the issue of responsibility of building users. Many issues could be rectified through user education and training. To deal with the blinds, to understand what the blue flashing lights mean, being able to open and adjust windows, turn on and off ceiling fans, are things some building users are not used to. Therefore, educating users about these features and what their responsibilities are, would promote and create an understanding of how the building works. Also a change in mindset and accepting responsibility for our work environment would enhance the potential to gain the full benefits of a building.

It has been stated that 'proto-type ESD' buildings (such as this one) require 2–3 years of refinement and fine tuning of the operational systems to fully optimise their potential. This building is undergoing constant monitoring and the commissioning process is being reviewed to refine and maximise its performance.

6.0 LESSONS LEARNT

Although the building has received a mixed response, the process of incorporating these energy efficient strategies has provided some valuable lessons. Notably:

- It is essential that with the inclusion of new technologies an iterative and consultative integrated design approach is adopted. Although Building T had the aim of an integrated approach and showed signs of achieving that early in the process, follow up consultation of various participants was neglected at times.
- That manufacturers and suppliers provide a high level of service and support when supplying a product. Especially when the design team and builder have limited experience in relation to the products and their installation.
- A high level of collaboration with the building users along with a willing and adaptable client is required to establish a comfortable working environment.
- Ongoing building monitoring is essential after design and construction to 'iron-out' any problems and ensure the building is functioning to its full potential.

7.0 CONCLUSION

Trying to implement new design technologies is always going to cause difficulties. Even though Building T has experienced its fair share of challenges it is an example of what can be achieved through collaboration, a willing client and an adaptable builder.

Building T has delivered on several accounts. It is:

- An environmentally sensitive building developed within an extremely tight budget and under difficult circumstances.
- A building that is cost effective in comparison to others of a similar nature.
- A demonstration of several new technologies into a building of this size and trials increased user control.
- An adaptable building in terms of its function that can be altered to suit various requirements.

Overall, Building T is a fine addition to Deakin University's Burwood Campus. It has set a new standard for buildings within the University in environmental terms. The energy efficiency features certainly provide benefits (with further improvements achievable); however there are associated problems with this type of building and it takes time, training and refinement to fully optimise the potential. During its early life Building T has received mixed responses, nevertheless it is a building that has created an interesting working and teaching environment for the University which will only improve with further refinement.

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BIOGRAPHY

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