A green building for the roaring forties

A. Barbour
Beca - Consulting Engineers, New Zealand

G. Marriage
Victoria University Wellington and Studio Pacific Architecture, New Zealand

ABSTRACT

This paper looks at the design and construction in 2006/2007 of a 'green' office building in Wellington, New Zealand.
Wellington lies at 42 degrees South of the equator, in a region known as the 'Roaring Forties' due to the constant winds, making it an ideal situation for wind farms. While the temperature range in the city is moderate, the strong wind has severe climatic effects.
Studio Pacific Architecture are the architects of the Meridian building on Site 7 at Kumutoto, on the waterfront in Wellington, which aims to be one of the greenest buildings in New Zealand upon completion in 2007. Innovative engineering has focused on designing a thoroughly modern building that is highly energy efficient and site specific.
The authors are part of the design team of this landmark New Zealand building.

1. INTRODUCTION

The Kumutoto precinct, an area at the edge of a successfully pedestrianised waterfront, which incorporates several sites for new buildings: Site 7 is the first purpose built office building in the precinct for more than 10 years. The building is nearing completion, and will be fully occupied by October 2007, from when measurements can be taken to evaluate the building's energy use against the targets.

2. DESIGN BRIEF

The initial design brief for the site stipulated a building which:
- Is sympathetic to, and related to, existing heritage buildings
- Contributes to the recreational potential, shelter, comfort and social inclusiveness of the waterfront
- Incorporates as many environmentally friendly construction and design principles into the building as possible.

The building was initiated by Wellington Waterfront Ltd, with consultants Studio Pacific Architects, Dunning Thornton structural engineers and Beca Environmental and Services Engineers. The team set out to ensure the building maximized the use of passive thermal heating and cooling, captured roof water for re-use, was naturally ventilated with minimal forced ventilation, and was a very low user of energy.
The building was taken through a thorough public consultation process lasting over a year. Once Resource Consent (ie planning permission) had been granted, Dominion Property Fund bought the development and Meridian Energy signed as the sole tenant for the commercial office space.
The tenant is a supplier of renewably generated electricity, primarily using hydro and wind generation. Keen to align the project goals with their business drivers, in addition to the above goals Meridian Energy's brief required the building design to:
- Use 60% less energy than a standard building
- Use 70% less water than a standard building
- provide a "wow" factor and invigorating, healthy and productive work environment for the occupants.

3. ENVIRONMENTAL PERFORMANCE

The building aims to be New Zealand's first purpose built, 5-star green rated, office building.
The building will be a test case for the New Zealand Green Building Council, set up in 2006 and is looking for best practice buildings on which to build a set of aims, goals, and rules.
In many areas the design exceeds Greenstar benchmarks, through the use of environmentally preferable materials and practices wherever possible. The contractor's recycling of waste associated with construction is being used as a case study by the Ministry of Environment to encourage further uptake in the Wellington region.

4. WELLINGTON CLIMATE

Wellington, the capital of New Zealand, has a temperate climate with 2.5% design condition 5°C winter and 25°C summer. The mean annual temperature is 7.8°C with mean temperature during working hours of 8am to 6pm is 13.7°C. The International Weather Year for Energy Calculations (IWEC) for Wellington was used to summarise the frequency of ambient temperatures.

4.1 Wind

Situated at the southern tip of the North Island, the city is positioned to catch both the predominant north-westerly air stream as well as the frequent icy southerly blasts straight up from the Southern Alps. As a result, Wellington has a very steady flow of often extremely strong wind at 0 or 360 degrees (up to 13 m/s).

4.2 Sunshine

Wellington receives an average of 14MJ/ m^2 solar radiation, with monthly bright sunshine hours, approx 100 hours / month in winter and 240 / month in mid summer.

4.3 Rainfall

Wellington receives an average of 1226mm rainfall annually.

5. ARCHITECTURAL CONCEPT

Studio Pacific Architecture's concept for the 4-storey office building comprises 3 distinct architectural elements: the main 'Pavilion', the 'Annex' adjacent to listed heritage buildings Shed 11 and Shed 13, and the 'Link' between. To take advantage of the exceptional site and waterfront views the architectural design features highly transparent façades. The environmental performance of each façade has been designed to acknowledge the building's orientation, and these façade treatments are also used architecturally to help define the differing forms making up the building.

Figure 1. East elevation

Figure 2. South Elevation

The building was designed with thermal floor mass, recycled or recyclable materials wherever possible, and is planned (by Meridian) to also feature photovoltaic rooftop panels, and if possible, a latest generation wind turbine. Chilled beams are being used to moderate the temperatures, one of the first times this technology has been used in New Zealand.

A main principle of the design was to permit the elevations to respond to the local environmental context. The southern elevation was therefore designed with only a relatively small amount of glazing, to reduce heat loss, while the eastern façade was fully glazed to maximise the harbour views. The north elevation of the Pavilion faces directly into the midday sun, although will have some shading from nearby office towers in the mid afternoon.

The proposed building comprises 4 levels:

- Ground Floor - retail, lobby, loading bay and plant uses, along with cyclists facilities
- Level 1 – Office Space
- Level 2 – Office Space
- Level 3 – Office Space

Office floors are open plan with a feature circulation stair in the centre of the pavilion building, to facilitate circulation between floors reducing the requirement to use the lifts. Wind driven turbine ventilators are incorporated at the roof of the feature stair to enhance ventilation when operating in natural ventilation mode. The ground floor is being leased to separate retail and hospitality tenants, and is set back from the upper floors to allow public shelter under the 6m wide cantilever over the seaward deck. This raises issues of how much control over tenants is possible, if they have not signed up to equal ESD protocols and restrictions. The head lease of the ground floor retail is still held by Wellington Waterfront, so that some control is retained over tenant choice. The building floor areas are summarised below (ref Table 1).

Table 1: Building Floor Areas

Level	Gross Floor Area	Net Lettable (Commercial)
Ground	1,123 m^2	
Mezzanine	30 m^2	
Level 1	1,634 m^2	1,443 m^2
Level 2	1,634 m^2	1,443 m^2
Level 3	1,490 m^2	1,077 m^2
Total	5,911 m^2	3,963 m^2

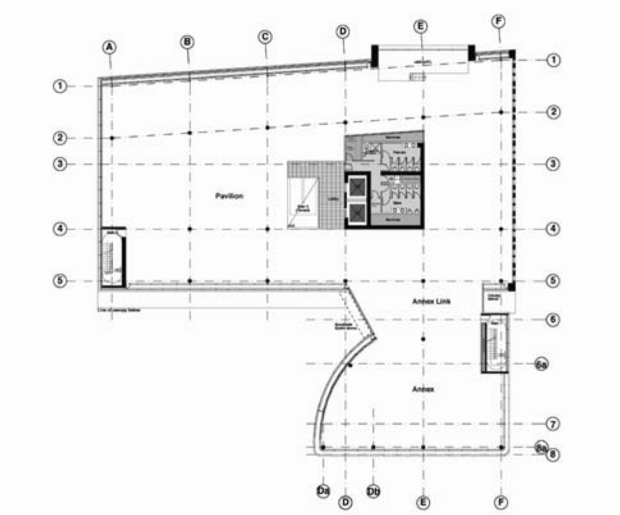

Figure 3. Floor plan – level 1 and 2

6. COMPUTER MODELLING

As part of adopting an ESD approach, Beca's ESD team developed a number of computer models to inform the design and specifications, including:

- 3D dynamic thermal simulation
- Energy consumption benchmarking
- Thermal comfort modelling
- Water use analysis
- Daylight Availability
- Greenstar pre-assessments using the Australian and pilot New Zealand rating tools.

While the initial project was for speculative commercial office space, Meridian had already engaged consultants and thus fitout has been undertaken by another architectural practice, Warren and Mahoney. One of the first acts they undertook for the tenant Meridian was to request a new access stair to rise up through the building, leaving the two existing stairs to function only as emergency escape stairs. While this was a welcome move, using lettable space to create a more dynamic spatial volume, it had the side effect of making the initial ventilation design modelling somewhat redundant.

Beca had spent some time calculating the airflow patterns within the building, and the introduction of a new stair was to prove a challenge: the possibility of smoke spilling from floor to floor in fire load conditions via the new stair meant that a rooftop housing had to be added, both to control natural ventilation and also to form a smoke plenum and emergency fan extract point above the new stair. It would have been very useful for the services engineers to have had only one set of architectural plans to work to, even though both architects are closely aligned in terms of design methodologies.

6.1 Lifts / Elevators

Usage of the lifts has been assumed below typical office average with the provision of the feature circulation stair.

7. BUILDING ENVELOPE

The design of the building envelope is a key element in achieving the project objectives and aims of high quality design as well as a healthy work environment for the occupants. The building design incorporates active facades with a high provision of solar shading (automated and fixed external louvres, plus automated venetian blinds). Automated windows are also provided for natural ventilation, automatically controlled to adapt to best suit the prevailing weather conditions. These systems are more common in the richer economies of Europe but are very rare in the more stringent financial atmosphere of New Zealand.

Extensive glazing is used on all facades, the sole exception being the south faces of levels 1 and 2 of the Pavilion where vertical slot windows are employed to limit heat loss. The facades are double glazed: an unusual move in New Zealand's moderate climate and lax energy control laws for commercial buildings.

The environmental performance of the façades is a key element in the architectural design, and in the ESD approach. Extensive use of 3D thermal and visual computer simulation analysis was employed to develop the transparent façade concept to integrate the environmental performance aspects required to achieve a comfortable and low energy workplace (Baird, 2001).

7.1 Double Skin Facades

However it is the eastern elevation, facing the stunning view of the harbour, that is working the hardest. Here, to avoid any interruption of views, the façade has been twin skinned – the internal skin is double glazed, and the external skin is single glazed and takes the brunt of the wind. However the wind directions being predominantly north and south, this leaves the east and west facades able to utilize the twin skin façade to permit opening windows, linked via computer. The east and west sides of the pavilion building incorporate a ventilated 'double skin' façade, with blinds located in the cavity (Barbour, 2007).

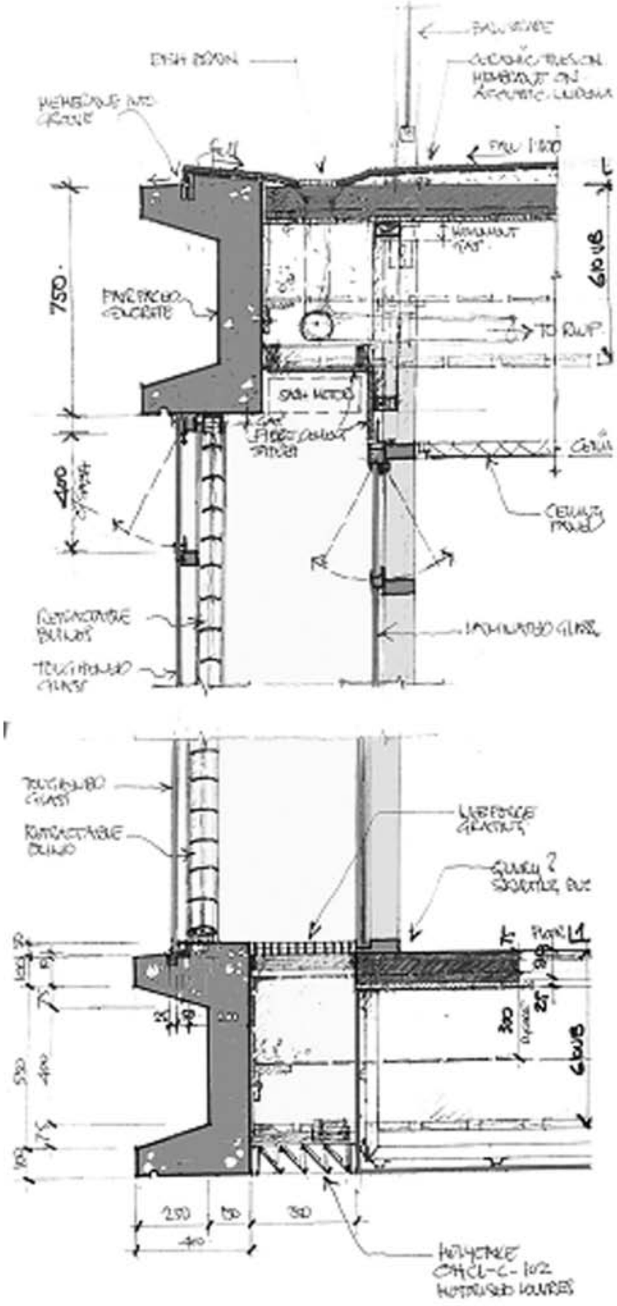

Figure 4. Section through Double Skin facade

The single glazed outer skin protects the venetian blinds from salty air and the high winds, while an automatic solar sensor control controls the motorised venetian blind. The blinds are retractable to allow uninterrupted views to the harbour when they are not required to limit glare or solar gain. The performance of the double skin is automatically adjusted to assist with project environmental performance, with operating modes:

- Winter – the cavity of the double façade is sealed to capture solar gains and limit heat loss
- Mid-Season – the cavity is ventilated, and the operable windows to the offices are opened to provide natural ventilation to the office space, and the wind-driven rotating turbine ventilators located on the top of the central circulation stair operates to enhance the natural ventilation performance.
- Summer – the façade cavity is ventilated to reduce heat build-up.

7.2 Level 3 Interstitial Blinds

The Level 3 windows use 'low e' double glazing with an interstitial venetian blinds between the panes.

7.3 External Solar Louvres

To restrict the heat input and glare problem, horizontal external louvers have been installed across the north façade to the Pavilion and the annex building. The motorised sun louvres are automatically controlled by sun sensors to control solar heat gain.

7.4 Automated Solar Control

Controls are included for the automated blinds which are controlled to close when incident solar radiation onto the outer surface of the glass is 150W/m^2 or greater. Table 2 below summarises the hours per year when the model predicts the blinds will be closed to limit solar gain.

Table 2: Automated Blinds Control

	North blinds closed	East blinds closed	South blinds closed	West blinds closed
No. of hours (weekdays 8am to 6pm)	913	176	12	700

8. WATER EFFICIENCY

Along with energy use, water efficiency is a key performance indicator for the tenant and considerable research has been undertaken to incorporate water efficiency measures. Water efficiency measures incorporated in the base design include water efficient fixtures and fittings, waterless urinals, sensor controlled taps, timer-controlled showers for staff use, and a rainwater collection and recycling system for toilet flushing.

8.1 Domestic Hot Water

Solar water preheating is included, designed to provide 70% of hot water heating requirements.

9. BUILDING MANAGEMENT SYSTEM

The 'brain' of the building is the Building Management System (BMS), which automatically controls the various systems to balance comfort and energy efficiency. A weather station is incorporated on the roof to help the BMS determine the prevailing weather conditions, and the BMS is able to adjust the systems to suit forecast weather. Integrated with both the security system and the lighting control system the BMS controls and monitors:
- Solar blinds and sun louvres
- Windows for natural ventilation
- Building Services plant and systems
- Energy and water use metering.

10. HVAC SYSTEM

The building HVAC system comprises active chilled beams, controlled in zones with each beam served by heating and cooling pipework. Zone temperature is regulated by modulating 2-port control valves.
Outdoor air is reticulated to supply each chilled beam by a roof mounted air handling unit comprising filters, heating and cooling coils, energy wheel heat recovery section, supply and extract fans (with frequency inverter drive speed control facility).
Heating source comprises two packaged air source heat pumps located in the rooftop plant enclosure. Chilled water is provided by two packaged air cooled chillers located in the rooftop plant enclosure.
Primary and secondary heating and chilled water pumps are employed, all featuring inverter drive speed control to match the demand.
A dedicated toilet extract system is provided to serve the main toilets, with speed control setback linked to occupant sensors to reduce energy use when toilet areas are not occupied. For the purposes of this model, the WC extract fan has been modelled as constant volume.
A dedicated shower extract system is provided to serve the Mezzanine Level shower areas, with speed control setback linked to occupant sensors to reduce energy use when shower areas are not occupied. A dedicated tenant kitchenette extract system is provided to serve the tenant requirements.
For improved indoor air quality (IEQ) the building HVAC system uses 100 percent outdoor air with an energy recovery wheel to reduce heating and cooling energy. The ventilation system supplies filtered primary air to the ceiling-mounted active chilled beam terminal units. Heat entering through the fabric of the building and generated by occupants, office equipment and lights is absorbed into the exposed building structure around the perimeter (CCANZ 2007). An air-cooled chiller supplies chilled water to the beams at 15C. The façade performance and ventilation heat recovery reduce heating requirements – a reverse-cycle heat pump provides the remaining heating needs.
Night purging adds to the overall cooling system for the building. Windows automatically open at night to allow cool air in, flushing warm air out and cooling the exposed structural soffits.

10.1 HVAC Plant Settings

Outdoor Air Supply Rate : 1.5 litres/m^2
Heat Pump COP : 2 heat pumps with COP 3.0, 95% heating distribution efficiency
Chiller COP : 2 chillers with COP 4.0, 95% chilled water distribution efficiency
Outdoor Air Supply Temperature Set-Point 15°C
Energy Wheel Thermal Efficiency75%
Power Factor Correction 0.95

11. DAYLIGHT COMPENSATION CONTROL

Daylight modelling indicated that over 60% of the office areas achieve a daylight factor of 2.5% or greater. The glazing selection is designed to reduce glare, while allowing high levels of daylight into the offices. The lighting controls automatically reduce artificial lighting requirements when daylight is available. The automatic lighting control system is integrated with the HVAC and security system to provide energy savings and flexibility The predicted energy saving for perimeter zones, based on weekday operation during office hours (8am to 6pm) only, shows a predicted saving in annual lighting energy use of 29% of the lighting energy use equating to 26,885kWh per year (>4,000kg CO2).

12. CONCLUSIONS

The Site 7 project has identified that building with strong ESD initiatives is a viable way forward for the New Zealand construction industry. Initial fears that the extra cost this may occur would be off-putting to the investor and tenant market have proved unfounded – indeed, similar standards are now being proposed for other, nearby developments.

REFERENCES

Baird, George (2001). *The Architectural expression of Environmental Control systems.* New York: Spon Press.
Barbour, Alan (2007). Smart Building for Wellington Waterfront. *Build*. 100 (June / July 2007). Wellington: BRANZ Ltd : pp 56-58
CCANZ (2007). Sustainable building design on Wellington Waterfront. *Concrete*. Vol 51, Issue 1 (March 2007). Wellington: CCANZ Ltd : pp 1-2