SUSTAINABILITY CASE STUDY

Passive design strategies

This is the third article in a series describing the design, construction and monitoring of a more sustainable urban house in Hamilton.

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At the heart of any more environmentally sustainable house is a robust approach to passive solar design, which involves using the surrounding environment to ensure a comfortable indoor climate all year round. Passive solar design minimises the requirement for on-going heating and cooling costs, as well as having low operating and maintenance costs. This article focuses on the process and strategies used in the Hamilton house.

Comfort the aim

The aim was to have a completed building that is comfortable thermally all year round, with minimal external purchased energy. 'Comfort' can be measured by many methods, but the most common is using air temperature. For the majority of people, the preferred temperature is around 18–25°C, which is also good for human health. Thus, the goal was to keep the indoor temperature within this range. More details on this performance aim are shown in Table 1.

Selecting insulation

It was decided that meeting the 'Best' insulation category in SNZ/PAS 4244: 2003 *Insulation of lightweight-framed and solid-timber house* for the house's climate zone would be an appropriate starting point. SNZ/PAS 4244 outlines the benefits of higher insulation levels for each of the three climate zones in an easy-to-follow way, all underpinned by thermal modelling. For more design flexibility, these insulation (R-value) figures were translated into equivalent whole house heat loss figures (see Table 2), just like the modelling method does in NZS 4218: 2004 *Energy efficiency – Small building envelope*.

Mostly passive, with some active systems

As far as possible, the aim was to achieve the performance target passively, through the usual methods of:

- positioning and orientation of the building for solar access and cooling breezes
- super-insulation of the ceiling, walls, floor, windows, the main entrance and exit doors
- thermal mass for temperature smoothing
- careful placement of shading devices and wide openings for summertime.

However, it was likely that assistance with active systems (i.e. using purchased power) during prolonged Hamilton cold spells would be needed. The systems that were chosen for this will be covered in a future article.

Approaches used for the passive measures

The approaches used for the various passive measures are outlined below, starting with the most important. It should be noted that there is a loose hierarchy of importance in passive solar design – good siting first, then high insulation, then window placement, thermal mass and so on. However, the process of integrating the various facets of passive solar design (orientation, insulation, thermal mass, window size and so on) is an iterative one.

HOUSE ORIENTATION

Starting from a newly cleared site meant that there was some flexibility in this. However, the shape of the section (like most) dictated to a large degree the house's position. In the end, the house was placed with the longer axis running east-west, which is the preferred way. Luckily, one benefit of the section's orientation is that the northern side is partially facing the road, so that it cannot be built out (and therefore shaded) in the future.

The room placement was chosen with the idea of having the living spaces (lounge, dining, bedrooms) on the northern aspect, with the utility rooms (bathroom, laundry and entranceway) south facing.

SUPER INSULATION

Specifying high insulation values within the contract documents does not necessarily result in a well-insulated building element. For its potential to be maximised, the insulation must:

- be continuous for all of the thermal envelope
- have minimal thermal breaks
- not be compromised during its lifetime
- be installed correctly.

These ideals were met on this site in a variety of ways. Firstly, the installers were briefed on good practice. This meant that the insulation was installed with a minimium of compression, gaps and folds. Prior to the building wrap being installed, any area that could not be accessed later was properly insulated beforehand (see Figure 1). This included inter-floor perimeter junctions and corners.

Also, an offset double-stud timber frame wall system was used, which meant effectively having two 90 mm wide walls running side by side. In the original design, the dwangs as well as the studs were offset to lessen the thermal bridging even further. However, this detail was lost in communication to the timber precutter, even though drawings specifying this unusual

Table 1: Overarching performance target.

Issue	Target	Specifics	Measurement
Thermal (comfort)	Overheating less than 3 hours per day, for the hottest 10 days over summer. Underheating less than 3 hours per day, for the coldest 10 days over winter.	Overheating temperature is defined as greater than 25°C. Underheating is defined as less than 18°C or 16°C, depending on the space.	Temperature loggers in key spaces, collecting data at 10 minute intervals.

layout were provided. Having a double stud system addresses several thermal bridging issues, including the recent issue encountered when butt-joining prenailed wall framing units together (see Figure 2).

In addition, the front and back timber doors – which are usually uninsulated – were made with an 80 mm thick polystyrene core.

WINDOW SPECIFICATION

Double glazing is now almost a requirement, as a result of recent changes to the energy efficiency requirements. A window's thermal property is made up of a combination of its glazing performance and its frame performance. Thermally broken aluminium was selected for the framing. Although alternative framing materials perform better thermally, other considerations – such as cost, maintenance and structural rigidity – dictated the decision.

The wider (12 mm) spacing between insulated glazing units was chosen for its better thermal performance. A low-E (emissivity) coating was applied to the outside surface of the inner pane to further reduce the transfer of radiant heat.

THERMAL MASS

The placement, surface treatment and amount of thermal mass is critical in moderating daily ambient temperature swings. Ideally, an existing heavyweight element should be used to reduce costs, which is:

- well placed for solar access in the winter, but well shaded in the summer
- mid-dark in colour, to absorb more solar radiation
- uncovered by furnishings or floor coverings
- well insulated from the outside
- sized correctly for the thermal area it is influencing.

The house's 100 mm thick concrete floor slab was used as the thermal mass. Its features include:

- good placement through careful site selection and overall house orientation, ensuring good winter sun from the northern aspect
- a darker colour, through concrete colouring
- a highly polished concrete surface, so that it looks good enough not to need covering
- high insulation levels, by incorporating an 80 mm deep high density expanded polystyrene underbase, with a perimeter timber thermal break detail, as outlined in the *BRANZ Insulation Guide* (3rd edition).

The result is well moderated indoor temperatures, according to the comprehensive thermal modelling carried out.

Figure 1: Insulation needs to be installed beforehand in all areas that cannot be accessed after the building wrap is installed. In this case, the insulation is grey.

Figure 2: The stud to stud butt joint (thermal bridge) common on most sites today, where framing is constructed off-site.

OTHER WINTERTIME DESIGN FEATURES

The house has a simple form (a rectangular box), necessitating the minimum number of corners, greatly reducing a known thermal weak point.

There is also a wind-sheltered entranceway. Even better would be to have a lobby, to minimise the majority of the heat losses when entering and leaving the building.

Heat losses (resulting from draughts) have been minimised by maintaining the integrity of the building wrap and having fully sealed external doors and service ducts.

SUMMERTIME DESIGN FEATURES

There is a moveable external roller-blind shading system in the north and eastern windows. The semi-transparent shading is horizontal for the northern openings and vertical for the eastern openings. By making them movable, they can be adjusted for the seasons. There is also a combination of passive cooling strategies, which makes use of both the wind effect (i.e. the air movement by wind-induced pressure differences) and the stack effect (i.e. the air movement from the natural buoyancy due to indoor-outdoor temperature differences). Having a 2-storey house helps to cater for both of these cooling strategies.

COMPUTER MODELLING

Ideally, to really fine-tune the thermal aspects of a house and to determine the best cost/performance trade-offs, a comprehensive thermal modelling program should be used. Until recently, this was beyond the grasp of all but keen technologists, but with the introduction of EECA's Home Energy Rating Scheme (HERS) – see www.energywise.govt.nz (click on 'Your home') – this option is now well within the realms of the average homeowner. For a fee, a HERS assessment provides an accurate overview of a home's year-round performance. BRANZ's updated ALF program also gives a good idea of a house's wintertime thermal and moisture performance, free of charge.

The next issue will look at the blackwater and greywater systems.

Table 2: Performance target translated into practical design characteristics.

Issue	Target	Specifics	Source
1a. Thermal (insulation values)	Elemental (construction) R-values to be equal to or better than the 'Best' category of NZS 4244.	This equates to: $R_{Ceiling} = 3.3$ $R_{Walls} = 2.6$ $R_{Window} = 0.43$ $R_{Floor} = 3.1$ m²°C/W.	*BRANZ Insulation Guide* (3rd edition), product literature and NZS 4244.
1b. Thermal (heat loss)	As above.	Having an equivalent whole building heat loss that equates to 188 W/m² or less.	Insulation product literature, ALF modelling and NZS 4244.