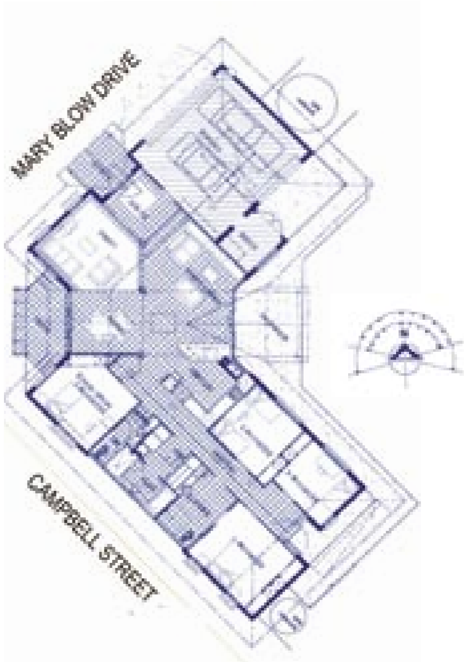
House – subtropical
Rockhampton

BUILDING TYPE: New house, Masonry construction	
CLIMATE: Subtropical - Rockhampton, Queensland	
Topics covered	Success Level
Passive design	good
Daylighting	very good
Reducing water use	very good
Rainwater	very good
Reducing embodied energy	excellent
Greenhouse gas reductions	excellent
Sustainable materials use	excellent
Renewable energy generation	very good
Indoor air quality	excellent
Adaptability	excellent
BERS rating	★★★★★

Waste flyash is used in the innovative wall construction of this passive solar house. Designed to show community and industry that sustainable development and commercial marketability can be successfully combined, this house presents an attractive and familiar appearance whilst reducing embodied and operational energy use. Indoor thermal comfort is achieved without supplementary heating or cooling.



DESCRIPTION

Brief

'Triple bottom line' requirements of social, economic and environmental sustainability were set by the client (see the 'Smart Housing' triangle illustration) and the house had to be fully accessible for the widest possible range of users with varying abilities whilst providing a safe, secure and cost-efficient environment. Within the habitable area of 180 sq.m. one of the four bedrooms had to be usable as a home office.

Site

The site is on the corner of a main road, Campbell Street, running northwest-southeast and a minor street (see plan). Access was allowed only from the minor street and this determined the position of the garage.

The corner of the house presents the glazed doors of the dining room and projecting patio roof towards the road junction. The inherent difficulties of the site were accepted as part of the strategy of demonstrating the flexibility of a sustainable design approach. [See: Choosing a Site, Orientation]

During the hottest months the prevailing wind is easterly and in January there are north-easterly winds for about 30% of the time. This suggested an 'L'-shaped plan to funnel the breezes through the house for natural cross-ventilation, primarily through the verandah, family room, dining room and patio but also through all other rooms.

Climatic design strategy

The mean temperature of the coldest month of July is 16°C and almost every day the daytime temperature reaches 22°C so winter comfort conditions are relatively easy to achieve. Summer overheating is controlled by reducing solar gain, maximising natural ventilation and using thermal mass to even out temperature extremes. Because the daily range of temperatures is quite high (mean maximum to mean minimum is around 10 – 14°C) thermal mass is beneficial. The concrete slab-on-ground floor serves this purpose assisted by the medium-mass masonry walls. [See: Design for Climate]

Entrance, facing N/W, well shaded

At Rockhampton's latitude of 23.5o the roof is the element most exposed to solar radiation. An off-white 'Colorbond' surface has been chosen to minimise solar heat input. This lightweight roof is heavily insulated with a layer of foil-faced glass fibre batts under the roof skin (face downwards) giving R1.5 and another layer of R2.5 on top of the plasterboard ceiling giving an overall resistance over R4.5.

Ceiling fans are installed in all rooms as well as over the verandah. Safety is assisted by having 2.7 m room heights that also assist cross-ventilation.

The attic space is ventilated through the two gambrel ends at the front patio and slotted sheeting to the eaves soffit.

Walls

The external load-bearing masonry walls of hollow blocks (400 x 200 x 200mm) contribute to the sustainability of the house by being made by Ultimate Masonry from waste fly-ash from a nearby power station with the addition of some cement. The wall is externally rendered with an off-white finish to reduce solar heat input and internally lined with foil-backed plasterboard on battens. The overall R-value of the wall is 0.88.

Almost half of the block cavities are reinforced and core-filled at corners, window and door-jambs with a bond-beam along the top. Overall average thermal properties have been calculated as providing an R-value of 0.85 m2K/W and a time-lag of 5.3 hours.

A side-benefit of the lightweight blocks is in handling, which is much easier than for heavy conventional concrete blocks.
[See: Construction Systems]

Solar control

All roof and wall surfaces are an off-white colour with a low solar absorbance. All eaves are 900 mm wide to exclude high-angle sun. Projecting roofs over the verandah, entry porch and corner patio provide full shading to the glazed doors. Vegetation and other obstructions provide shading from early morning and late afternoon sun. Bedrooms 1 and 2 have been strategically placed to utilise the shading effect of the existing large Poinciana tree. Because the windows of the living room may be exposed to the sun after 3:30 p.m. at mid-summer, some solar control 3-star 'OptLight' low-e glass is being used for comparative testing of its effect.
[See: Passive Cooling]

Water

Dual flush (3/6 litre) toilet cisterns and flow control taps with an AAA rating are used, except for the kitchen sink and laundry tub where AA rating is appropriate. The washbasin in the 'powder room' is fitted with an automatic, infrared controlled tap. The washing machine and the dishwasher are AAA-rated.

The 'Hydrotap' unit installed in the kitchen provides instant boiling or chilled water and is claimed to result in significant water savings.

The 5 kL rainwater tank

Roof rainwater collection is into two tanks of 2 and 5 kilolitres respectively, and is used for garden watering. There are plans to introduce a dual plumbing system to allow use of rainwater and grey water for other purposes.

The 2 kL rainwater tank at the S/E corner
[See: Rainwater]

Energy

Two photovoltaic arrays of twelve BP/Solarex 82Wp polycrystalline silicon modules are installed on the roof facing northeast. These are grid-connected through a Sunrise inverter with two-way metering. A Clipsal 'C-bus' energy management system is integrated with the power supply. [See: Photovoltaic Systems]

Two arrays of PV cells and the solar H/W unit

As part of the project three water heating systems are being compared. The system originally installed was a Quantum heat pump unit and then this was replaced by a Solahart solar panel system with an integral hot water cylinder. After one year of operation this will be replaced by a Bosch instantaneous gas heater.
[See: Solar Hot Water]

Passive controls

Site conditions dictated a sub-optimal solar orientation but associated problems are resolved by making good use of the prevailing breezes. On summer afternoons the east-facing verandah provides a good, well covered outdoor living space useable even during rain.

The 'thermal flywheel' effect of building mass is well utilised. The tiled concrete slab-on-ground is thermally well coupled to room air (only the bedrooms have carpet). The masonry walls provide useful thermal capacity. [See: Thermal Mass]

One of the best features of the house is the roof insulation with its overall R-value more than double the recent BCA requirement of 2.2 m^2K/W.

Insulation of the masonry wall is not quite as good but the average R-value of 0.85 is almost twice as good as current practice (brick-veneer walls provide an R-value of 0.46). It is well shaded with a time-lag of 5.3 hours and its performance is quite good. [See: Insulation]

Cross-ventilation is excellent through the central part of the house across the family living/dining room. Provisions for capturing the breezes from the dominantly northeast and easterly directions are excellent although different window patterns and openings might have helped and the fanlight openings with drop-in hopper type sashes are obstructed by the eaves and direct the air flow up to the ceiling. Metal louvres down to floor level (in bedrooms 3 and 4) provide some additional openings.

View from verandah through the house to the patio

Embodied energy

The embodied energy content of materials used is low and their sustainability rating is high. Wall blocks incorporate a waste material and the roof framing is made of plantation timber. Windows and door frames are made of aluminium, which is a high energy material but long lasting and fully recyclable. [See: Embodied Energy]

Roof framing: plantation softwood. Note the skylight shaft to the family room

Maintenance requirements are minimised, materials selection has been based on LCA (life-cycle cost analysis). Only materials with nil or very low VOC (volatile organic compounds) content were selected. The bedrooms are carpeted with wool. All other rooms have ceramic tile floors which are not only easy to maintain, but also thermally advantageous. All paints used internally are water-based. [See: Indoor Air Quality]

Lighting and daylighting

The fenestration (windows and window fittings) is adequate for all rooms, except the quite deep family living/dining room where a large roof light ('SkyDome') has been installed with a rectangular shaft through the attic space and a large ceiling diffuser panel.

Two small domed skylights are installed over the corridor. One of these, as well as the main skylight is fitted with laser-cut angularly selective acrylic panels to admit low angle sunbeams, but reflect high sun to reduce solar heat gain during the hottest part of summer days.

The house mostly uses fluorescent, or compact fluorescent lamps. [See: Lighting]

Accessibility

All of the elements of the house had to be useable for people with a range of abilities including people temporarily or permanently on crutches or with walking sticks, parents with prams, older and younger people who cannot lift their feet high when they walk. It also had to be able to be cheaply and easily modified to accommodate people's changing needs.

There are no steps or thresholds and doorways and corridors are of appropriate width. Bathrooms and the kitchen provide full access, complying with AS 4299. All handles, taps and electrical switches have been selected and located for easy use by people with varying abilities.

The kitchen roll-out bench is the lowest of three benches set at different heights to accommodate a wider range of users and is an excellent example of 'universal design'. [See: The Adaptable House]

EVALUATION

People in the tropics and sub-tropics prefer an open-air life style most of the year, with open doors and windows and no sharp boundaries between indoors and outdoors. The house facilitates this very well, obviating the need for mechanical air conditioning.

The mean temperature of the hottest month, January, is 26.9°C and the comfort range with still air is 23.4 to 28.4°C. With air movement of 1.5 metres per second this upper limit would extend to 33.4°C. The highest recorded indoor temperature is only slightly above this limit at 35°C. In bedroom 1 on Dec.1, 2002, whilst the outside temperature varied between 24 and 39°C the inside remained between 29 and 34°C.

Annual operational energy use has been measured at 9748 kWh, of which 2813 kWh was contributed by the PV system, thus the net use of 6935 kWh is 28% less than that of the average Queensland household. This is a comparative saving of 2900 kg of CO_2 emissions. The recently installed solar hot water system is expected to give a further reduction of 1800 kg CO_2.

Although they face northeast and not due north and the inverter is undersized the photovoltaic arrays contribute about 29% of the total electricity use.

Water consumption was measured at 1150 litres of water per day average compared with average Queensland use of 1455 litres. Even with rainwater collection over half of this was due to the sprinkler system and with improved management this could be substantially reduced.

Interior spaces are well lit and a light, airy atmosphere is created. Good indoor air quality is achieved by a combination of excellent ventilation and only using materials with low VOC content.

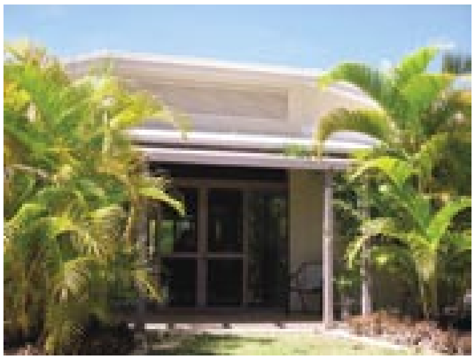
Residents were initially worried that the tiled floors may be slippery, but the non-slip tiles proved to be satisfactory.

Adaptability is well demonstrated. It can be a major headache and cost to remove a section of fixed cupboards and find matching floor tiles to create a section of bench to sit under. In this house it is already done, at minimal cost and effort.

A two year case study was carried out based on in-depth interviewing of occupants that found the residents had no difficulty in adapting to life in a 'smart' house and that it was socially sustainable, ie. designed to minimise energy consumption but also to maximise living comfort. Initially there was some worry about leaving the doors and windows open overnight but a trust in the security screens soon developed and the benefit of night ventilation was realised. An initial perception of lack of privacy has disappeared as the vegetation has grown.

An exceptionally high rate of satisfaction with the building and its equipment was reported with the residents saying that they would use many of the design features in their next house.

Patio at the dining room (W) with through-view to the verandah (E). Note the ventilation louvres above, to the attic space



PROJECT DETAILS	
Design:	Queensland Government Department of Public Works and Department of Housing
Client:	Queensland Department of Housing
Project director:	Qld Dept. of Public Works, Building Division, Built Environment Research Unit
Monitoring:	Assoc. Professor Peter Wolfs, Central Queensland University
Laser-cut acrylic panels:	Dr Ian Edmonds, QUT

ADDITIONAL KEY REFERENCES

Szokolay, S.V. 1987 Thermal Design of Buildings RAIA Education Division, Red Hill.

Further information and a virtual tour of the house are available at the web-sites:

www.build.qld.gov.au/research

www.housing.qld.gov.au/researchhouse

Principal author:
Assoc Prof Steven Szokolay

Photos courtesy of: Assoc Prof Steven Szokolay & Queensland Dept of Public Works