A PROTOTYPE E.S.D.[1]HOME: TOWARDS A MODEL FOR PRACTICE IN SOLAR SUSTAINABLE DESIGN

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SUMMARY

The design of an urban house located on the Gold Coast, Queensland, Australia has been completed as an exemplar of Ecologically Sustainable Design. The home is an essay in design synthesis: intended to integrate existing principles with state of the art environmental technologies and a comprehensive methodology for evaluating the performance of these technologies. The aim of this paper is to present selected results of the data gained from this evaluation to give feedback on the performance of the solar technologies used in the building. The paper argues that the project can form a Trojan horse for future practice concerning sustainability. The outcomes inform the debate on the design for wider use of solar design principles in building design in urban areas and how this confronts present approaches to provide some form of Energy Code compliance legislation.

Figure 1: Prosser House, prototype environmental home

1 INTRODUCTION

A prototype environmental house for urban areas has been constructed in the sub-tropical, coastal climate of the Gold Coast, Queensland. The house, designed by Hyde and Rajapashka was based on ‘Green design principles’ and a framework for environmental design. This framework defined sustainable design in terms of reducing environmental impacts of buildings, hence a number of design strategies and technologies were used to address this framework. The underlying design philosophy followed the Jungian notion of holism - the collective sum of the whole can greatly exceed the effect of the individual parts. Hence, the environmental benefits from designing such a house would have a significant reduction in environmental impact from the cumulative effect of its parts. This can be thought of as a silver thread that is woven through the building to effect ESD. For example, the

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[1] Environmentally Sustainable Development

strategies for ventilation were linked to fabric strategies to reduce solar heat load, which in turn was linked to the structural form to maximise openness of the building, to promote a thermal siphon, natural ventilation and avoid the need for air conditioning with is negative impact. Rainwater collection and recycling represent a further layer in the environmental system.

It is hypothesised that these inter-linked strategies effect greater efficiency in building design while producing a reduction in environmental impacts. Yet, such inter-linking of strategies has to date been largely ignored. For example, recent attempts to integrate sustainable principles into the Building Code of Australia are based on only a partial model of building design. This model is focussed only on the envelope and air conditioning strategies for reducing greenhouse gas emissions. This leaves the model open to criticism of imbalance, reductionism and lack of sensitivity. The use of a more comprehensive model, rather than the selective approach to sustainable practice to date, could have far reaching effects in terms of the collective, dominant social paradigm towards sustainability in buildings .

Yet to be of impact in this wider arena, sustainable building features require performance evaluation and development into a model for wider use by the design disciplines. Thus, just as one swallow does not make a summer, one building will not transform the design and construction industry to sustainability. It can be argued that through evaluation, a model of a sustainable building approach, such as the prototype house presented here, could act as a catalyst to such a shift.

Furthermore, analysis of similar directions in housing reveal a lack of evaluation of the ability of such buildings to deliver a sustainable outcome. These other buildings are largely ‘show casing’ sustainability for marketing and image purposes, without substantiating the claims for sustainability. It is argued here that this reduces these buildings to mere political statements that support a design direction similar to a manifesto. Such buildings, like many political statements can be marginalised and even ignored, and through this, devalue the significance of sustainable design.

It therefore seemed appropriate to soundly evaluate the prototype to substantiate claims through an unequivocal research methodology. To this end the house has been fitted with a range of in-use monitoring equipment to allow a longitudinal study of its behaviour. Also, a number of spot measurement protocols have been developed to examine selectively, aspects of the building that are not amenable to continuous on-site measurement. Findings from this work are proving useful in the debate on legislation to introduce energy measures into the Building Code of Australia. This change is driven by statistics on Australian greenhouse gas emissions (AGO, 1999(a), AGO, 1999(b)). There is evidence to show that Australia is the second largest polluter of greenhouse gas emissions in the world per head of population. Legislators are now faced with an onerous task of devising rules, which are simple and effective for controlling energy use through the building design.

There are two strategies that are presently advocated; an elemental approach which prescribes performance standards for elements of the buildings e.g. R values for walls, shading for windows; and a systems approach which examines more holistically a range of strategies in the building. The former is assessed qualitatively based on a checklist, the latter quantitatively, through computer simulation.

These approaches lead to a number of paradoxes as follows:

- In hot humid and moderate climates there are multiple options to achieve thermal comfort and energy efficiency in buildings. Simplistic rules governing the elements of the building discriminate against certain solutions such as single skin construction.
- The systems approach, whilst being appealing in that multiple strategies can be tested and evaluated, seem to fall foul of the lack of rigour with which the software performs, e.g. some software has limitations modeling ventilation effectively.
- Some buildings are designed to be predominantly free running whilst others are largely conditioned, also some are hybrids and run on mixed mode. This plethora of user operational modes leads to further complexity in how to rate and assess buildings; the later favours thermal comfort criteria the former energy use.

The purpose of this paper is to use the Prototype House as a Trojan horse, very similar to the downfall of Troy. The data collected on the building can be used to assess the thermal performance in use. It can also be used to assess the proposed elemental approach to Building Energy Code compliance legislation and the systems approach to compliance with computer simulated rating.

To this end the paper presents three assessments. The first is based on thermal comfort criteria drawn from measured data, the second assessment uses the elemental approach to Code Compliance using the Brisbane City Council criteria (BCC, 2000) and the third assessment will follow the systems approach as found in the BERS software (Wilraith).

The Prototype home was designed prior to the introduction of Energy Codes in Queensland but uses best practice design principles for solar sustainable design. The extent to which the Code Compliance criteria recognise the use of these principles will be of particular interest.

2. THERMAL PERFORMANCE ASSESSMENT

2.1 Design Principles

The house was designed from design principles found from a number of sources. Brenda and Robert Vale, in their book on ‘Green Architecture’(Vale, 1991) set forth six principles to design this type of building as follows. All these factors are used in designing for thermal comfort.

- Conserving energy
- Conserving materials and resources
- Working with climate
- Respect for site
- Respecting for users
- Holism, relating to the wider urban environment.

2.2 Concepts

The project has become termed the ‘Healthy House’ primarily because of the client’s objectives for designing buildings that minimise impacts on the health of occupants. Apart from the physiological aspects of materials this includes tapping into a wider sense of well being through life style and environment. This concept is clearly linked to the Queensland regionalist architectural tradition, which has evolved around a lightweight aesthetic.

Yet to put this aesthetic in a current technical context new products and systems have been employed. In the prototyping process this has involved a synthesis of systems and ideas from over thirty manufacturers.

The house is of lightweight timber construction. An innovative glue-lam portal frame construction has been utilised (see figure 2). This is common in industrial and commercial buildings but is new in the design of single dwellings. The portal frame allows a great degree of flexibility in the design of the internal spaces of the house. It frees up the structure internally, allowing large volumes which promote stack ventilation, and large numbers of openings to permit cross ventilation.

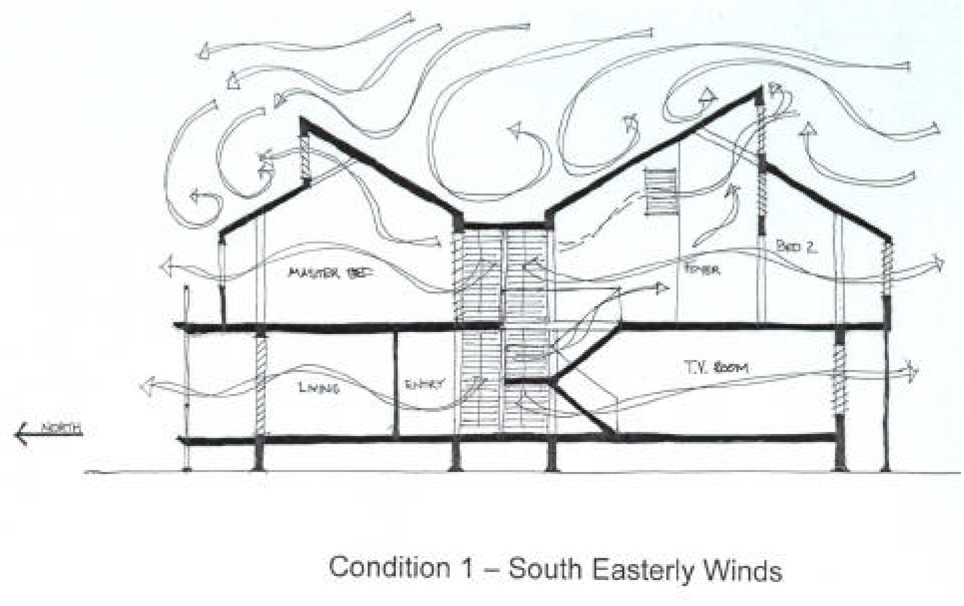


Figure 2: Section through the home showing stack ventilation

2.3 Climate Responsive Design Strategies

The building is situated two hundred metres from the pacific ocean. The microclimate is such that the site is a heat sink due to the ‘shelter belt effect’ of surrounding buildings which reduce prevailing sea breezes and reflect solar radiation. This creates a distinct ‘urban microclimate,’ which precipitates the use of specific strategies for the building to respond to that climate (Hyde, 2000). These are summarised as follows:

Summer Strategies	***Winter Strategies***
Orientation	Orientation
Ventilation	Solar Gain
Solar Defence	Fast Response

The site has almost unobstructed solar access throughout the year. However, to the east and south east there are two, large two storey dwellings, and a large jacaranda tree. These objects cause the winds at a low level to be redirected.

2.4 Climatic Context

The climatic conditions of the area are sub-topical, with warm, humid summers and cool, dry winters. Macroclimate analysis of the heating requirements reveals that there is a greater problem with winter under heating than with summer overheating.

Yet the location of the house so close to the pacific coast, with the Australian continent to the west and the ocean to the east determines a distinctive weather pattern. In summer the site experiences westerlies in the early morning, the wind swings around through the south during the day to be easterly in the afternoon and evening. It then swings back through the south to the west overnight. This is a land breeze/sea breeze combination typical of a coastal location. In winter the conditions are dominated by prevailing winds from the south and west.

2.5 Thermal Assessment Methodology

A detailed description of the thermal performance assessment methodology is contained in previous work by the authors.(Watson and Hyde, 2000) The thermal monitoring has taken place over a 2 year period. There are nine temperature readings being taken in a vertical stack through the middle of the house. Humidity is being taken internally and externally. Meteorological conditions are also being monitored. All of these readings are taken at half hour intervals, logged on site and then download at the UQ Department of Architecture. Assessment is conducted using two basic measures. Firstly the comfort of the occupants is assessed using standard comfort zones (Auliciems and Szokolay, 1997) Secondly the household energy budget is used as a means of assessing the success of the design to passively condition the internal environment.

2.6 Thermal Assessment

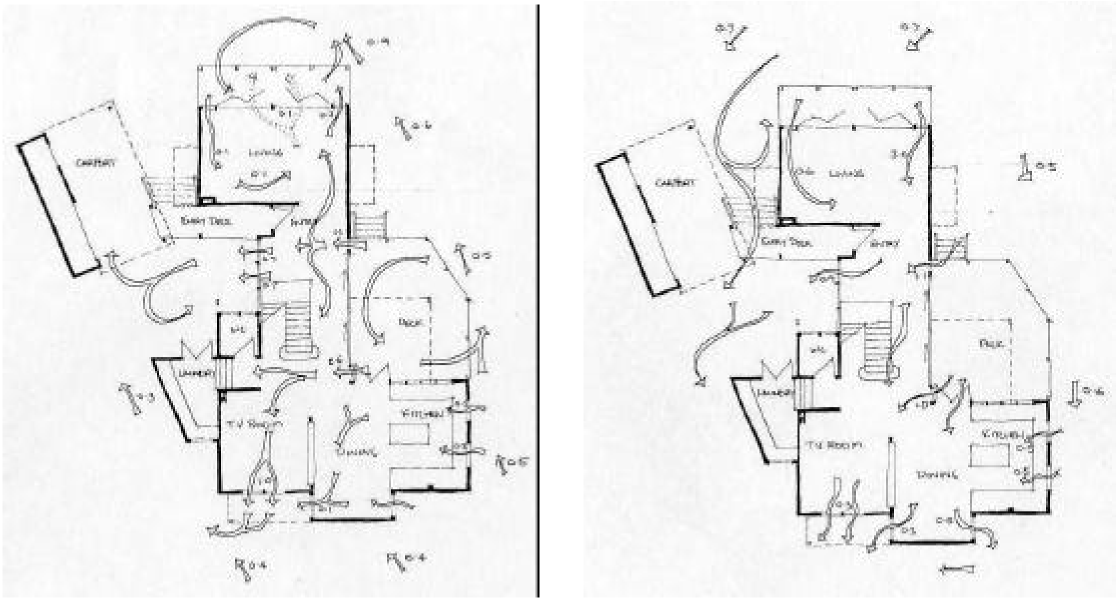
The main indicator of thermal performance for the purpose of this assessment is the internal temperature during the summer (see Table I). Ventilation is designed to be the main means of summer cooling. The plan form uses a pavilion design to increase pressure differential across the house promoting increased air movement. The roof form also creates pressure differentials, which drives ventilation vertically through an internal open section (refer figure 2). This forms an atrium, which links the ground floor spaces to clerestory windows in the roof.

The house is analysed here in terms of its performance during the extreme seasons of winter and summer. The temperature measurements from a height of 1800 above the downstairs floor level are used in all comparisons between external and internal temperatures.

The average maximum air temperature for summer conditions was reduced internally by 2.0 degrees C. This reduction places the average maximum within the acceptable summer comfort zone (Table I). External air temperatures in the shade measured over the 92 days of summer revealed that only 15 days had a maximum within the comfort zone. Internally air temperatures on the other hand show an improvement, 53 days were measured to have a maximum within the comfort zone.

More over on extreme days with external temperatures of 37 degrees or more were measured the internal temperatures were reduced to by 7-8 degrees (see Figure 4(a)).

In addition the house is designed to increase internal airflow to improve physiological cooling. Measured airflow readings are shown in Figure 3. This natural cooling effect on hot days reduces the effective temperature by a further 2-3 degrees.

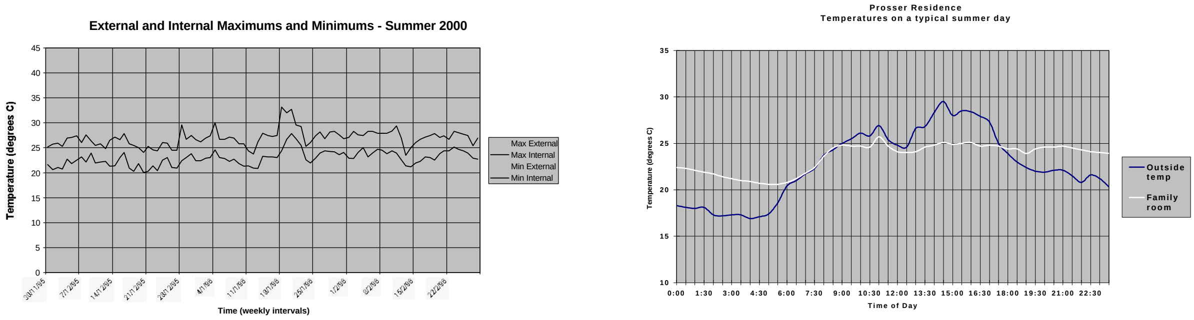


(a) (b)

Figure 3: Plans showing the ventilation measurements, north is to the top of the page. (a) summer morning, SE winds (b) summer afternoon, NE winds.

Season	Summer	
Location	External	Internal
Average maximum temperature	28.9	27.0
Upper limit of comfort zone	27.2	
Achieving of comfort zone	1.7 outside	within
Average minimum temperature	20.4	22.9
Lower limit of comfort zone	23.2	
Achieving of comfort zone	2.8 outside	0.3 outside

Table I: Assessment of comfort zones based on average maximums and minimums for summer conditions (Degrees C.)



(a) (b)

Figure 4: (a) Internal and external maximum air temperatures for the summer period and (b) internal and external temperatures on a typical summer day.

Thermal performance measurements therefore demonstrate the passive ventilation strategies are effective for urban areas. The elements and planning of the fabric of the building contribute to the reducing heat gains. These are assessed next.

3. ELEMENTAL ASSESSMENT

3.1 The Building Skin

Solar defence is achieved through the use of insulation and shading to provide solar exclusion in summer. Foil batts, which combine expandable reflective foil are used in all walls and roof elements. A combination of bulk and foil insulation is used in the roof. Light colours are used to reduce solar absorption and provide lower emissivity.

3.2 Planning

A number of planning strategies are aimed at reducing the heat gains to habitable rooms due to low angle sun from the east and west. Servant spaces, that is, bathrooms, storage, laundry and carport, are placed to the west as a buffer for the served space from westerly sun and heat gain. In addition westerly-orientated windows are avoided.

The aim of the planning strategies is to reduce the heat loads to habitable spaces, also this allows a reduction in the R values to these walls.

R value of walls for the Prototype, m2K/W	Conductivity	Thickness	Resistance
Internal surface, high emissivity			0.12
12.5 mm plasterboard	0.16	0.012	0.08
50mm cavity with low emissivity foil insulation			0.62
6 mm fibre cement	0.87	0.006	0.01
External surface, low emissivity			0.07
		Total R	0.89
Heat gain comparison through walls, W/m2	**Temperature difference**	**R value**	**W**
Prototype specification	20 deg C	0.89	22.42
Code specification	20 deg C	1	20.00
Difference			2.42

Table II: Thermal resistance of wall elements, a performance comparison between the Prototype and Code Specifications

3.3 Assessment

Comparing the specification of the walls found in the Prototype home and that of the BCC Energy Code, it can be seen that the building would not comply. An R value of not less than 1 is required whilst table II shows that the wall construction of the Prototype is only 0.89. However, further analysis reveals that the difference is not significant. If the case of the westerly walls is considered which are most exposed to solar radiation the difference in heat gain is not significant. If a temperature difference of 20 degrees C is assumed then the higher R value in the Code would only deliver a 2.42W reduction in heat gain. In addition the planning of the house is such that most walls that receive excessive solar radiation and are service spaces.

The conclusions drawn from this are that Code Compliance such as those proposed need to provide a variety of options for meeting performance standards that allow for a diversity of design options and construction types. Furthermore, a closer examination of the assumptions behind the Code are needed and the implicit building models that result. For example, the performance specification for ventilation is minimal allowing highly obstructed pathways of air movement to comply.

To this end a systems approach seems to be favoured since the interrelation of elements can be assessed in an more holistic manner. In this case the lower R values of the walls can be balanced with other aspects of the house. This assessment is considered next.

4. SYSTEMS ASSESSMENT

The house form and specification were analysed using the BERS computer simulation software.

Profile data			
File name	: health01.en	Latitude	: -27.5
Date	: 01-04-2001	Longitude	: 153.0
Location	: Brisbane	Climate file QLD	: climat10

Annual heating load : 61.3 MJ/sq m of conditioned area

Annual cooling load : 15.5 MJ/sq m of conditioned area

Annual total load : 76.8 MJ/sq m of conditioned area

Standard default values of conditions of use were specified for this simulation.

The STAR RATING is 4.0

The star bands are as follows :

0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	355	290	225	160	140	120	105	90	75	60

(MJ/sqm/year)

3 Conditioned zones	Heating	Cooling
Floor area		
Liv 1 : 108.8	7-24 21.0	7-24 27.0
Liv 2 : 54.5	7-24 21.0	7-24 27.0
Bed 1: 9.5	7-24 21.0	7-24 27.0
	Time Temp	Time Temp

Conditioned area : 182.8(sq m)

2 Unconditioned zones

Floor area

Bed 2 : 28.5

Ser 2 : 15.5

Unconditioned area : 56.4(sq m)

Total floor area : 239.3

Ser 1 : 12.5

Table III: Output from the energy report from the BERS computer simulation of the Prototype home. The building was modeled using active systems for climate control.

The BERS program is used for assessing buildings for BCC Code Compliance purposes. It forms an alternative to the elemental approach.

The results of this assessment, shown in Table III, reveal that the building achieves a 4 star rating from a possible 5 stars. Although not designed to be air conditioned the strategies for passive design also assist with reducing energy consumption. As the code compliance level is set at 3.5 stars, the house would be deemed to comply.

The more holistic assessment allows more innovative building types to achieve Code compliance and this demonstrates the value of the system approach.

5. CONCLUSIONS

The case study of the Prototype ESD home provides a model for practice of Solar Sustainable Design through the use of passive strategies to achieve thermal comfort. Proposed Energy Code regulations need to reflect this approach to avoid a reduction in design options and building solutions. Systems assessment provides a solution to this approach through computer simulation. Elemental assessment is likely to be problematic unless careful understanding of the assumptions and cumulative performance effects are fully understood. In this way innovative developments can be promoted rather than limited by Code Compliance procedures.

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