Sustainable housing competition case study
House 17.5 S. Broome, Australia

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ABSTRACT: This paper sets off with the intention to explore Passive Design strategies towards environmental conscious Architecture with the analysis of a single dwelling submitted for the Broome Sustainable Housing Design Competition in Australia. The project is based on the study of the azimuth, latitude, and longitude angles at 17.5 latitude and 122.1 longitudes for the building’s envelope generation and the analysis of micro-climatic conditions and material properties to improve the passive strategies. The outcome is the generation of design geometries as guidelines for the projects creative and scientific process.

The building envelope is designed to be shaded and prevent annual increments between 25.6 – 29 C due to direct solar radiation absorbance. The building materials have specific low embodied energy properties that allow thermal comfort, low maintenance, recycling and reuse. A 70% reduction in energy demand and 75% of water consumption is attained by water recycling and harvesting, PV tracking and solar heating, achieving comfort levels and reductions in operational costs.

The 17.5 house consequently was awarded with the third place in the International Design Competition. Substantial research has been previously done in regard of sustainable design methodologies and further research is undergoing in the field of sustainable geometries and its applicability to low cost responses.

Conference Topic : Design Strategies
Keywords: Solar Geometry

1. GEOMETRICAL CONSTRUCT

The design principles for the development of the project were based on the study of solar and wind patterns of the competition’s site. Based on the analysis of solar geometries by Azimuth angles (Plan) Latitude angles (N-S Section) and Longitude angles (E-W Section) at -17.5 latitude and -122.1 longitude to construct a 3D Structural Model.

This is the principal Design strategy for this project given that at any moment of the day or night there is some spot in the earth’s surface that is directly underneath the sun. and a continuous elliptic movement that prevents the earth from being static in relation to this celestial body as the Sun’s declination moves from 23.5N in midsummer when its geographical position reaches the tropic of cancer, to 23.5 S when it reaches the tropic of Capricorn. In spring and autumn the declination is 0 as the sun crosses the equator.
Therefore the meridian of longitude determinates the hour angle of the sun in relation to a specific place. The sun moves in azimuth throughout the year and in altitude throughout the day. These solar components should be recorded, both data of coordinates in regards to the location and solar radiation to be therefore utilized in the design process. The result for – 17.5 latitude –122.1 longitude is as follows. A 3D Model created for this specific location determining a X Y Z matrix that intertwines with a series of unique structures that will achieve typological architectural form for the conceptual environmentally responsive envelope generation.

Figure 2: Geometric Construct Section

2. ARCHITECTURAL LAYOUT

The single dwelling submitted for the Broome Sustainable Housing Design Competition in Australia has a specific program. The competition aimed to create a Sustainable housing prototype in north western Australia with a significant environmental footing. An internal temperature range was set between the thermal comfort levels for broome, a reduction in energy and water consumption of 50 %, and the understanding and preservation of Western Australia housing typology. Our aim was to design a self sufficient dwelling with an innovative solution that could fulfill the competitions program encouraging the use of passive design solutions via the exploration of solar geometries.

The building envelope was designed to be shaded all year round to prevent increments of more than 25.6 – 28 C due to direct solar radiation absorbance and encourage natural ventilation to achieve thermal comfort throughout the year. Given Brooms mean daily temperature in summer 28 - 31 C and winter 26.2 C and our desire to design a low cost, self sufficient dwelling, there is no direct solar gain on the building fabric facades at noon time to prevent overheating and manual shading devices permit the control of direct solar gains at other times. There is a wind cooling body “ service area ” that divides the building “ private N and social S ” and cools the internal fabrics preventing temperature gains and encouraging differential pressures to permit natural ventilation with adaptive qualities.

The building fabric and structure materials have specific low embodied energy properties that allow thermal comfort both in winter and summer, low long maintenance and potential use for recycling and reuse. This architectural layout develops a geometrical scheme that creates a innovative encounter towards passive design principles such as Orientation, Shading, Thermal Mass, Natural Ventilation, Solar Power, Water Harvest, Thermal Comfort (Tn) and Waste Management creating an infinite combination of matrices that may intertwine with the architects creative process.

Figure 3. Plan
2.1 Envelope Performance

2.1.1 - 09:00
21/12: Shading devices optional at dining room and main bedroom during the year. North, South and West facade shaded summer autumn and spring. Bedrooms and Living no direct solar gain. Cross ventilation NW>SE through adjustable roof vents (10ach m/s) courtyard and louvers adjustable to prevent dust. No mechanical ventilation required during the year.
21/03-09: Bedrooms no direct solar gain. Cross ventilation W>E through adjustable roof vents (10ach m/s) courtyard and louvers.
21/06: N facade direct solar gain. Landscape thermal storage. S and W facade shaded all winter. Main bedroom adjustable direct solar gain. Cross ventilation SE>NW through adjustable roof vents (10ach m/s) courtyard and louvers.

2.1.2 - 12:00
21/12: Shading devices not required during the year at midday in the dwelling. Transversal tilted structure provides constant shade to West and East facades throughout the year. North and South facade shaded all year by roof cantilever. Bedrooms no direct solar gain. Cross ventilation SE,NW through adjustable roof vents (10ach m/s) courtyard and louvers. Fans to increase air movement for adaptive comfort may be used throughout the year.
21/03-09 North and South facade shaded during Autumn Spring and Winter. Bedrooms no direct solar gain S, A, W. Cross ventilation W>E through adjustable roof vents (10ach m/s) courtyard and louvers.
21/06: Cross ventilation SE>NW through adjustable roof vents (10ach m/s) courtyard and louvers.

Fans to increase air movement for adaptive comfort may be used.

21/03-09: Cross ventilation W>E through adjustable roof vents (10ach m/s) courtyard and louvers.

2.1.3 - 15:00

21/12: Shading devices optional for living and bedrooms throughout the year. N-S-E facades shaded all summer, autumn/spring. Main bedroom and dining no direct solar gain (WSSA). Cross ventilation NW>SE through adjustable roof vents courtyard and louvers.

Figure 8

3 ENVIRONMENTAL SYSTEMS

3.1 Solar System

3.1.1 Solar Water heating system

The solar water heater is installed on the service area roof. It can not be seen from the street, and is naturally cleaned with its inclination. The solar water heater is used in hot water taps for the shower, kitchen sink, bath, and washing machine. The average annual residential hot water consumption for Broome is 7.5 G/j (2,083 KWh.). The standard household requires a 200 litres Tank. We recommend a 30 gal solar tank with gas back up. This will produce an average 15 gallon per day and will have a 60 % security coverage, and an energy savings potential of 70 % in water heating using both solar and gas booster. This represents an annual reduction in carbon dioxide of 3 ton.

3.1.2 Electricity Generating Solar system

The average annual residential electrical consumption in Broome is 6154KWh, this is 17KWh daily average. The solar Power system aims towards an annual production of 2874KWh grid interactive, battery-less power system. That Combined with the household Solar Heating Strategy, will achieve a 70 % annual contribution by electricity generated from the sun. The Electricity Generating Solar Power System is Located in the Household Central Service Area, with 36 Photovoltaic Panels of 75 watts each. The system is manually operated with six independent tracking steel structure systems operated from the courtyard (L+2.2 mts) area . There are three different Set Positions that track the annual Suns Movement . Latitude angle/day: 1)21/12, 2)21/03-09 3)21/06 The PV system is designed as a Canopy as well to provide shade in the central courtyard.

3.2 Water Harvest

There is a Rain water collection system, with two down pipes, and a 15KL rainwater tank located in the service/ system area for easy maintenance and collection. The tank can store 15.000 litres, achieving a 70 % security in its autonomous water supply. Therefore, it may need water from a source other than the rainwater tank ( water recycling system and main grid) when it runs dry for 25 % of the year. Given that the annual rainfall in Broome is 595 ml and there is a potential collection roof area of 230 sqm. The Water Harvest System will therefore achieve a 60 % water requirement.

3.3 Water Recycling

Given that the average Daily water Intake in the house hold may be between 500 and 700 litres per day, and 400 liters are used in showers taps and washing machines, the house will have a waste water recycling system providing an effective solution for treating and reusing the water waste from the bathroom, laundry and kitchen. The system consists of a water tank, a submersible pump, a set of floats and an electronic controller that uses solar power over the day. The stored water is then used to flush the toilet and to water the garden and general maintenance. The toilet average consumption for a 4 person household is 80 litres per day with a waste water recycling system. The water use in the laundry will have an automatic diverter system if the waste water tank is full . These systems will backup the water harvest tank, in the household need for a 25 % - 30 % external source supply. Minimizing the total external potable water need. The water recycling system will save 27000-30000 litres a year.
4. Building performance Steady State Analysis

The combination of the geometrical construct (1) and an asserted selection of materials result in an innovative design with scientific results that confirm the viability of self sufficient housing, given a site with extreme characteristics and a fulfilling result after the implementation of passive design strategies towards an environmental Architectural practice.

The house is designed with prefabricated materials, reducing costs and minimizing wastage. Modularisation is a key element for doors, louvers, shading devices, stairs, and superstructure. Recycled Steel must be used for all structure. This takes only 26 % of the amount of energy required to use raw Iron or Steel making. The structure has modular length and joints, to avoid a high percentile of waste on site and provides efficient transportation dimensions. The Timber Used in the interior of the house and deck is plantation Radiata Pine Timber which obtains 25 % more timber from a log than conventional Timber. Plantation Timber from Western Australia is considered. Materials were evaluated in terms of embodied energy, life cycle, maintenance and properties.

4.1 Material Properties

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Sloping roof and ceilings: Corrugated Iron, 50mm insulation (Fibre glass blanket), reflective foil, air space, plaster (Zincalume coated).

Walls and partition: Timber frame walls with air space 100mm, plaster board 12mm, insect screen timber frame Floor: Radiata Pine Timber 20mm 100x250. Steel framing.

Sun Control: Timber Louvers 1250mm timber frame. Synthetic Woven Fabric with reflective coating. Pv Cell tracking system, steel structure.

<table>
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<th>Wall</th>
<th>Roof</th>
<th>Ceiling</th>
<th>Floor</th>
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Calculation of Internal Temperature:

I. Mean Heat Gain Rate:
Total mean fabric gain: 5061.23W  
Total mean internal gain: 710.83W  
Total mean energy gain: 5772.02W

II Mean heat loss rate per degree:
Total mean fabric loss: 180W  
Ventilation loss: 891W  
Total mean heat loss rate: 1071W/C  
Mean Internal Temperature: 26.189C

Estimation of Temperature at 15:00 Winter

III. Transient Gains:
Total transient Internal gains: -250.833W  
Ventilation transient load: -1603.8W  
Transient Conduction gain: 23W  
Fabric transient solar gain: 1482W  
Total Transient gain at 15:00: -350.1W  
Total room admittance: 585.62W/C  
Variation about internal Temperature: -0.24W  
Internal Temperature at 15:00: 25.95C
Calculation of Internal Temperature:
Summer February Living Space.
Mean External Air Temperature:
T‘ao: 25.6~29°C  Tn: 26~28°C

I. Mean Heat Gain Rate:
Total mean fabric gain: 1776W
Total mean internal gain: 710.83W
Total mean energy gain: 2486.7W

II. Mean heat loss rate per degree:
Mean fabric loss: 216.9W
Ventilation loss: 891W
Total mean heat loss rate: 1107.9W/C Mean Internal Temperature: 27.8°C
Estimation of Temperature at 15:00 Summer

III. Transient Gains:
Total transient Internal gains: -251W
Ventilation transient load: 356.4W
Transient Conduction gain: -43.9W
Fabric transient solar gain: -440W
Total Transient gain at 15:00: -378.1W
Total room admittance: 525.5W/C
Variation about internal Temperature: -0.26W
Internal Temperature at 15:00: 27.58°C

5. Explore

All thoughts in this paper are encouraged by our interest in exploring innovative design strategies. The aim is to awaken queries in regards to the vast creative and scientific terrain to achieve a self sustaining design reduced to its basic essentials as its relationship with the environment and the exploration of geometric components and technological applications towards self sufficiency. Stressing the importance of evaluating Bio-Climatic Design Solutions and Innovative technologies in means of sustainable development and alternative sources of energy.

REFERENCES