SUSTAINABILITY AND EDUCATION – DEVELOPING AN INTERNATIONAL PERSPECTIVE.

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Abstract

This paper discuses the education, research, community, industry and international outcomes that have arisen from implementing sustainable education, construction techniques, and systems into the Project Management program at the University of Technology, Sydney (UTS).

This paper focuses on some sustainable features developed in the Australian context for their environmental and economic sustainability / buildability features and assesses their potential application to a vastly different environment- In this case a project in Tamil Nadu, a state in southern India.

Potential building designs and novel patented research such as the wind directional skylight vent are elaborated on in this paper. As well as elaborating and analysing past and present designs and projects it is hoped that this paper will stimulate an international perspective to sustainable education and research, which is an area that the author feels increased awareness and emphasis is required.

The important issues of embodied energy, construction and consumption costs coupled with functional cost/m^2 are evaluated and scrutinized. Agreement is sought to apply a more useful rating of and definition of sustainability, making a clear differentiation between energy efficient and sustainable designs. This is a very pressing concern for developing nations with large populations and limited funding, which is often overlooked by high technology / high construction cost advocates of energy efficient buildings.

Keywords: Sustainability, international sustainability, design and construct, environmental, economic sustainability, wind directional skylight ventilation.

Introduction

The Construction practical subject at UTS (an actual design and construct project initiated for full time Construction students to gain onsite exposure) has developed an enviable record of sustainably designed and built projects, which have provided some unique challenges for an educational institution.

Project managing major construction projects through a university, utilising full time students in what is usually their first building project is a very demanding and complex task.

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The client liaison may involve community groups who have little understanding of design requirements, which again presents a hurdle as usually the university provides all in house design and engineering.

Overcoming timetabling, insurance and other associated project management constraints, UTS via its Construction Practical projects has achieved considerable success, such as the 2002 project i.e. completing the 450m^2 Ethnic Child Care Community Co-Operative building at Addison Rd, Marrickville.

This building was completed on time and under budget using plantation pine timber frame and lightweight concrete panel technique (refer to figure.1). Using only second and third year students the aerated concrete panels were completed to lock up stage in 20 days - a remarkable effort!

Fig 1. Ethnic Child Care Community Co-Op, Addison Rd, Marrickville. 2002

This building contained many features that were evaluated to improve its buildability and energy efficiency. The north facing “low E” tinted windows to the clerestory provided a daylighting and ventilation capability while a 1.5m eaves hood excluded the summer sun. The building is particularly well insulated, with insulated sarking backed aerated concrete wall panels achieving in excess of R3 rating, insulated acousticon ceiling and insulated reflective metal deck roof.

The light coloured reflective metal deck roof is insulated and the roof is fitted with a ridge vent to expel hot air. Cooler air is brought in via meshed eave vents to drive the hot air from the attic space (refer to figure 2). The building ventilation is designed to operate as a hybrid (natural / mechanical) with a ratio of 75% natural to 25% mechanical. The mechanical air conditioning is provided by very efficient Daikin inverter heat pumps.

The meshed eaves vent concept was applied to an earlier student project at Addison Rd, the Greening Australia building (1998). [1]

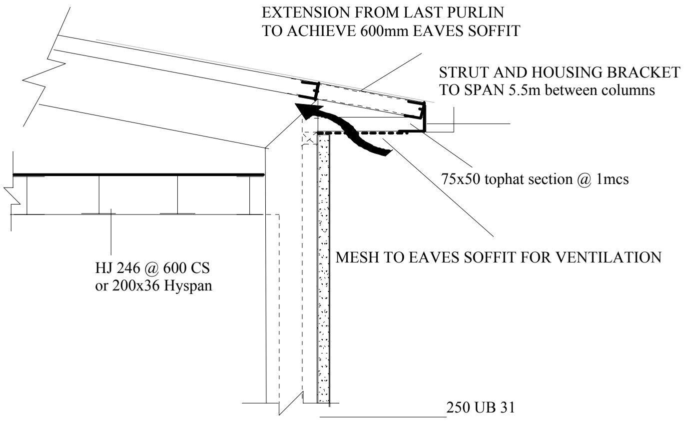


Fig 2. Vented attic space, meshed eaves vent and ridge vent

The Greening Australia buildings attic space temperature performance was computer monitored for two years. This building contained three 400mm diameter throat turbine ventilators and the difference in attic space temperature was monitored with the vents opened and closed and temperature differential noted.

By supplementing the internal lighting levels with daylight, reducing the internal heat load by shading windows to direct radiation and the utilisation of natural ventilation and air conditioning to provide hybrid ventilation, significant energy savings were achievable with all projects undertaken at the Addison Rd Centre.

By way of example of past student projects which have stimulated debate regarding acceptable sustainability criteria- the 1999 Community Child Care building project contained many unique features such as the use of student made mud bricks to sill height and the use of polystyrene sheets above sill height

The ecological versus economic sustainability and choice of hand made mud bricks and polystyrene claddings have been a successful method of creating student interest and debate, similar outcomes and debates are expected with the current project.

In the case of the 1999 project, the time taken to source *appropriate* soil have it sieved and then transport it to site was established in itself as a costly and energy consuming exercise. Then there was the laborious time and labour consuming task of making the bricks on top of getting the soil to site. The mud bricks themselves contained 10% cement to stabilize and strengthen a weak product that also displayed dimensional variation and quality concerns.

The students learnt from this exercise that the economics of compressed earth blocks are different for a country such as India, which has cheap labour, but in the case of Addison Rd, Sydney, where labour is expensive, it is very hard to justify the use of hand made mud bricks, even when labour is not a cost contributor (students), the time factor is unacceptable as the projects must be completed to lock up stage working 2 days a week for a semester, being 25 days.

Likewise, polystyrene has its own limitations i.e. as well as being petrochemical-based (5% of volume) and if it is not recyclable, it may have a waste issue. Balancing the negative aspect is the speed of construction (lightweight easy to handle and transport) and the excellent insulation properties of polystyrene, which are strong positives for the use of the product.

The exercise now in regard to looking at a project in Tamil Nadu, is to apply the designs developed for their environmental and economic sustainability / buildability features in Australia and to see if they are applicable to the Indian environmental constraints. In assessing likely products, aerated concrete panel on steel framing has arisen as a potential product for use in India, other products such as polystyrene will also be considered.

The experience of designing and building using polystyrene, insulated steel cladding and aerated concrete building systems has enabled UTS to be in a unique situation of having developed practical educational competencies that have been realised into much appreciated community buildings- unique tangible community assets. A function that has evolved with designing and specifying community assets is the close attention to economic sustainability and justification of materials used in projects, which requires a comprehensive evaluation of embodied energy.

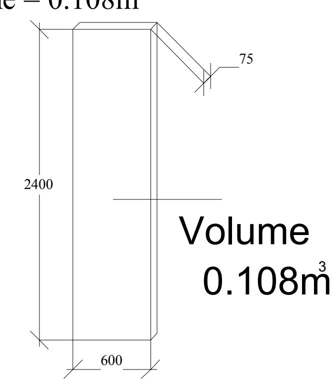
Embodied energy – work in progress!

The arguments relating to accurately assessing various materials embodied energy is on-going and depends on thorough evaluation of data, which varies from location to location (Tasmanian hydro - Victorian brown coal), building design and appropriate design for climate suitability to name a few variables in this complex assessment.

In an assessment of the embodied energy of three common wall panel building products: 1) in-situ concrete 2) aerated concrete (Hebel panel) 3) polystyrene, some very interesting findings relating to embodied energy need to be considered along with durability and buildability issues.

Interpretation of published data requires careful evaluation eg as a case study of wall panels (in -situ concrete, aerated concrete (Hebel) and polystyrene). The three materials chosen for evaluation were examined using a standard sizing common to project home wall panels being:

2400 x 600 x 75 = volume = $0.108m^3$



panel comparison

An initial assessment from embodied energy tables (Lawson 1996) reveals the following embodied energy measured in MJ/kg [2]

1. Insitu concrete has 1.7 MJ/kg.,
2. Aerated concrete (Hebel) has 3.6 MJ/kg
3. Polystyrene, which has 96 MJ/kg

On the basis of the above it would appear that polystyrene would be the last choice to ever use! However, with durability, insulation and buildability as considerations let us analyse a wall cladding panel system for all three materials, comparing MJ/ m^3

Thermal mass and insulation are sometimes confused and low embodied energy materials / high thermal mass materials such as concrete, which is very dense and high conductance, present a problem for insulation.

Concrete in total construction because of the large amount of material used-in Australian slab on ground project homes is classed by CSIRO as being the highest embodied energy *component* in a house.

Concrete has high thermal flow i.e. it is a good conductor and offers little resistance to heat flow- it has poor resistance and thus low insulation properties.

In a temperate climate with reasonably stable soil temperatures a concrete slab on ground floor with carpet insulation will correspond to soil temperature range, which is acceptable in Sydney. However, in cooler climates insulation would be beneficial especially to exposed slab edges as concretes insulation value is very poor. While concrete provides high thermal mass, using carpets, which insulate the slab from absorbing incident radiation, may severally diminish this advantage.

High density, high thermal mass is assumed to be beneficial for energy efficient house design but little consideration has been given to insulation. High thermal mass is often over rated as a means of providing sustainable qualities (as it contains large amounts of material/ energy and is a poor insulator)

Under many conditions lightweight highly insulated structures may be considered more sustainable- By way of example; comparing density and insulation of our wall panels densities we find:

Density of concrete say 2400 kg/m^3
Density of aerated concrete say 600 kg/m^3
Density of extruded polystyrene 30 kg/m^3

So reworking the formula:

The embodied energy of the panels is:

Insitu concrete (2400 kg/m^3 x 1.7 MJ/kg)=**4080** MJ/m^3
Aerated concrete (600 kg/m^3 x 3.6 MJ/kg) =**2160** MJ/m^3
Extruded polystyrene (30 kg/m^3 x 96 MJ/kg) = **2880** MJ/m^3
Expanded polystyrene (16 kg/ m^3 x 96 MJ/kg) = **1536**MJ/ m^3

From the density of materials we can derive the mass of each panel and its embodied energy:

Mass of concrete panel **260 kg** = 440MJ embodied energy / panel
Mass of aerated concrete 65 kg = 230MJ embodied energy / panel

Mass of extruded polystyrene **3.2 kg** = 307MJ embodied energy / panel
Mass of expanded polystyrene 1.73 kg = 166MJ embodied energy / panel

From a health and safety aspect and buildability the polystyrene at 3.2Kg / panel is easiest to handle.

What about insulation value / panel?

R-values: were compared for 75mm thick panels:

In-situ concrete panel = **0.06**
Aerated concrete panel = 0.97
Polystyrene panel = **2**
In-situ concrete has 40 times the conductance of polystyrene.
With sarking backing, aerated concrete will achieve an R rating of 1.57, which is very acceptable.
On-going operational energy savings due to better insulation is therefore best achieved with polystyrene.

Polystyrene requires high amounts of energy during manufacture, however the benefits associated with insulation indicate polystyrene to be favourable over a complete lifetime.

Ground breaking research was conducted in this area by (Evans and Ross, 1998) This was highlighted in a report prepared for the NSW Department of Urban Affairs and Planning by Manidis Roberst Consultants(1996). The report looked at using insulation over a complete life cycle for the Sydney 2000 Olympic games village. The report concluded" *The reduction in energy consumption over the whole life cycle of a typical building through the use of insulating material was quite spectacular. The savings in energy for heating the building was around a hundred times the amount of energy used to manufacture the insulating material. This was reflected in similar reduction in the lifecycle emission of greenhouse gases*."[3]

It should be noted that only Process Energy Requirements (PER) were evaluated: Cost of transport and haulage (crane lift for in situ concrete for example), time to erect, must all be considered, which in this instance again enhances polystyrenes application.

Gross Energy Requirements (GER) considerations i.e. polystyrene being a waste by-product of oil refining and the aluminium content of aerated concrete i.e. was the aluminium refined by hydro or coal fired power source? – These are complex assessments and need to be calculated to arrive at accurate figures.

Applying the embodied energy factors evaluated in Australia to Indian products requires further evaluation, due to local material sourcing and differing methods of fabrication and energy used.

Timber is a good example, we have used plantation pine as the structural frame in our projects in Australia because of the outstanding features of this renewable resource, with its ability to lock in carbon and give off oxygen during its growth

In modern day India however, timber and plantations are not sufficient enough to sustain the construction needs and the use of timber has reduced dramatically in the Indian construction industry. Even though timber is seen as a very environmentally useful product, economics preclude its use as a framing material.

It would be an interesting exercise to fully assess large-scale plantations as an alternative building material for use in India.

As a result of the unique scale and track record of the practical projects undertaken (both educationally & design and construction) it has enabled UTS to assess a potential project in Tamil Nadu, working with colleagues from Anna University and the IIT Madras. Without the experience gained in past projects, the ability to participate in a joint educational / construction project would be severely limited to academic theory.

Initial discussions are to produce a design for the Tamil Nadu Slum Clearance Board. In situ concrete frame is the favoured product of the new buildings currently being undertaken by the Tamil Nadu Slum Clearance Board. The structural frame having been decided, appropriate wall panelling is under evaluation.

The Indian subcontinent has a massive and growing housing dilemma –17.8% of the population according to the Census of India (2001) are classified as slum dwellers by the Indian government – that is 178,393,941 people.

The need to provide housing in these quantities is a tremendous humanitarian task that requires input at a global level. It is a task that surpasses the western philosophy of sustainability and transcends to a much higher level- the need to provide basic hygienic shelter.

Tamil Nadu state has a population of 62,110,839 according to the 2001 Census of India of which 14,175,792 are classified slum dwellers- that is 22.8% of the population. The current approach adopted by the (TNSCB) to tackle this problem is to find funding and experiment with affordable housing designs.

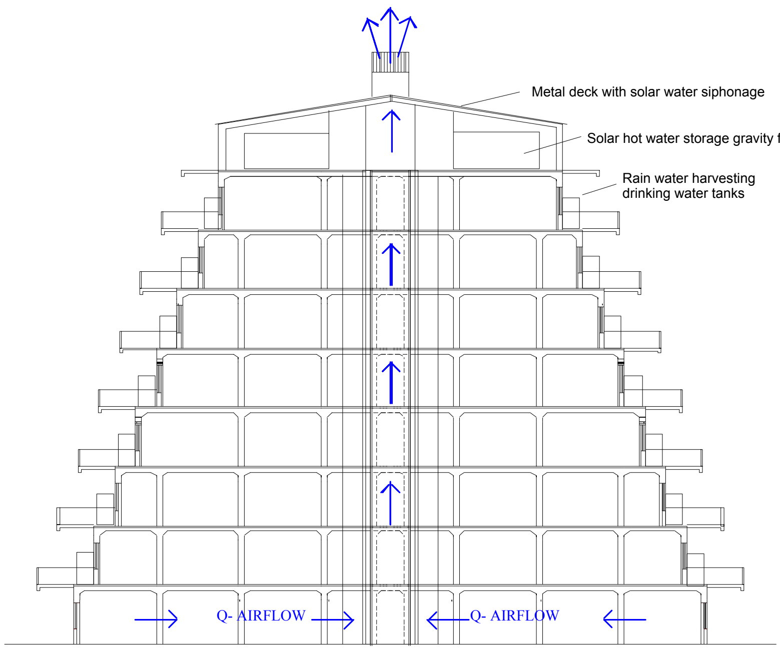
Listed in the TNSCB (Housing policy 2002)[4] the board's priorities are to include sustainable water saving features similar to what is now being mooted in NSW.

'Promotion of housing activities designed to harvest sun and rain so that solar energy capture and rain water harvesting become everybody's business.

As part of this programme the TNSCB has provisioned in designs to install rainwater-harvesting systems in tenemental areas in Chennai city- to ensure uninterrupted water supply. Furthermore, it is planned also to recharge the depleted ground water.

It is also a stated policy that "*All efforts will be taken to provide Solar Energy in the Housing schemes to harness solar water heating."*

An innovative design based on traditional south Indian temple architecture to meet the criteria of a multi storey tenement as described by the by boards priorities is shown in figure 3



Mahapalipuram- South Indian Temple design multi storey

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Figure 3 Mahapilpuram / South Indian Temple design for sustainable tenements

To realise the potential of possible sustainable technologies, it has been necessary to conduct research and gather data to scientifically give credence to their application. Several natural ventilation and daylighting applications have arisen from this research and an example of a patented outcome of this research is the wind directional skylight vent (refer to figure 4).

The results of our experiments have shown some surprising outcomes and we have achieved significants improvements with new designs, such as the long volume turbines and improved wind directional vanes giving rise to increased exhaust flow rates.

The wind directional skylight vent provides better ventilation performance than traditional wind turbine vents, is easier to produce (less components) and provides daylight. It can be used to vent attic spaces and provide light and also via shafts taken into ceilings to provide daylight / ventilation to internal room spaces, showers and laundries etc.

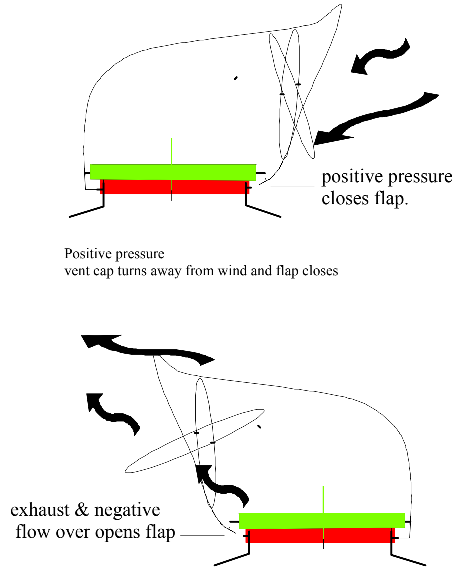

Figure 4 Wind directional skylight vent

Conclusion

In India, the construction of houses for the impoverished is considered to be one of the three basic fundamentals of life being, food, clothing and shelter. The pressing need to house a burgeoning population requires the utmost attention to sustainable practices, ecologically and most certainly economically.

We should question the high cost approach to designing buildings that consume less energy. In western society sustainability is generally thought of in terms of increasing energy efficiency in this way- “backing the foot off the accelerator”, while sustainability in India however, is a true perspective of life.

When assessing sustainability ratings the equation for sustainable buildings needs to be more than MJ/m^2per anum and CO_2 related emissions; it requires a cost conscious input – (ce) i.e. total energy cost (construction and consumption), including factors such as; renewable resources, recycling and importantly a building cost / occupancy ratio benefit needs to be brought into the equation.

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