Research Article

Applications of Renewable Energy Technologies and Embodied Energy Concepts in Housing Complex at Bangalore India: A Case Study

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Abstract
There is a large number of building design options for energy efficient building design; however, a careful blend of these options is required. The present paper studies the development of an eco-friendly and energy efficient housing complex called T-ZED (Total Zero Energy Development) in Bangalore India. Energy conservation options using CFL and LED based lamps and luminaries instead of incandescent bulbs have been achieved. Use of renewable energy sources, zero energy building materials and solar passive architecture to minimize thermal loads in buildings have been shown. The project has been compared with a housing complex where conventional energy and building materials are used in terms of reduction in embodied energy, CO_2 (Carbon dioxide) emissions and operational energy and thus the benefits of zero energy development have been identified.

Keywords: T-ZED, Embodied Energy, CO_2 emissions

1. Introduction

Energy conscious and eco-friendly development hold the key potential to significantly reduce thermal loads and electricity use in commercial buildings. The construction sector consumes considerable amount of energy from the production of basic building materials, its transportation and assembling called embodied energy. Low embodied energy materials conserve energy and limit green house gases (GHG) emissions thus limiting the impact on the environment. Energy requirements for the production and processing of common building materials and respective CO_2 emissions have been cited by Buchanan et al[1],Suzki et al[2],Oka et al[3],and Debnath et al[4].Embodied energy of common building materials has been presented by Venkatarama Reddy et al[5]. Total expense of energy consumed on bricks, cement, aluminium and steel that are used for building structure amounts to $1684x10^6$ GJ per annum. The GHG emission contributed by construction sector in India is 22% and there is an ever-increasing demand for building materials [6].

For the construction of multistoried apartment buildings the use of Reinforced Concrete (RCC) framed structure is very common. For 2-3 storied buildings load bearing brick wall and concrete slab is a common practice.

The multistoried building consumes the highest amount of energy at 4.21 GJ/m^2 of built up area whereas the energy consumed by the load bearing 2 storied brickwork structures is 2.92 GJ/m^2.

Based on the study carried out by Development Alternatives has indicated that the four most common building materials viz. Cement, Steel, Brick and Lime are energy intensive and highly polluting as shown in fig 1[7,8].

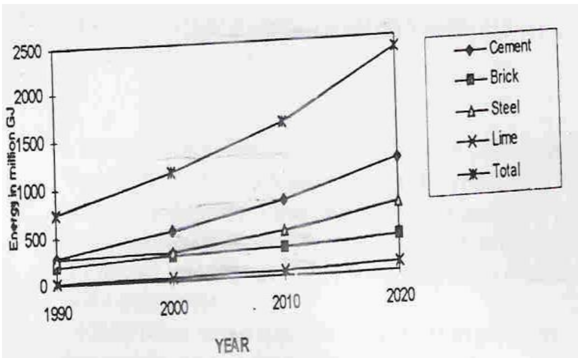


Fig.1.Total Energy by demand (1990-2020)

A two storied building using alternative building material like Stabilized Mud Blocks walls (SMB) and SMB filler slab roof consumes 1.61 GJ/m^2 [9], which clearly indicates that the use of alternative building technologies would result in considerable amount of reduction in embodied energy and thus less GHG emissions thereby protecting the environment.

The challenge therefore is to meet the demand using alternative building material and technologies.

There is no dearth of low energy building materials and passive solar architectural principals available but a few numbers of buildings are being built using these alternative building techniques and therefore there is an urgent need for these principals being incorporated in the present buildings.

This paper aims to demonstrate the practical use of low embodied energy materials, renewable energy technologies to the housing complex in Bangalore. A detailed account of reduction in embodied energy, operational energy in the households and estimation of emissions from the project in comparison to baseline emissions has been presented.

The project activity is about the development of energy efficient housing complex by BCIL (Bio-Diversity Conservation India Limited) named T-ZED consisting of 80 apartments and 15 villas extended at an area of 250,000 ft^2.Development of T-ZED is based on construction alternatives that have the potential to improve living while reducing the collective environmental impact. Every single aspect of T–ZED has been designed to conserve finite natural resources using first principles on quality of water, air and energy.

2. Location and climatic conditions

Bangalore city is located in the Southern part of India at an altitude of 920 m above MSL and latitude 12.8^0N and longitude 77.5^0E.The climate of Bangalore is moderate with mild summers and cool winters. The project is located on Airport Whitefield road a close suburban area of Bangalore. The project involves the development of eco- housing in a suburban area of Bangalore city.

3. Energy Efficient Features employed at T-zed

Energy saving and environment friendly construction materials and solar passive architecture to reduce thermal loads for air-conditioning and to enhance the use of natural daylight for visual comfort techniques are incorporated. The entire Zed Homes stretch is dotted by courts and plazas, and pergolas with benches which modify its micro- climate. Figure 2 presents the layout plan of the development.

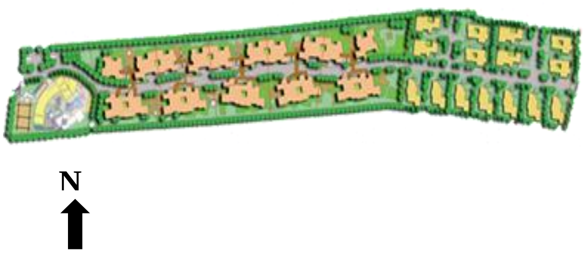


Fig. 2 The layout plan

The apartments are developed along East-West axis with openings towards North and South orientations. This would not only provide diffuse daylight from the North façade but also direct gain during winters through the South facade. The planning is elongated and court yarded rather than compact which would result in good ventilation.

3.1 Measures to reduce embodied energy

The embodied energy has been reduced through diligent use of building materials. 60 watt incandescent bulbs and 55 watt fluorescent tube lights (40 watt for the tube and 15 watt for the electromagnetic choke) are replaced by 11 and 16 watt CFL (compact fluorescent lamps) in the households and other areas. Customized refrigerators with central chilled water supply; and innovative air-conditioners based 100 percent on fresh air are used. Installation of solar water heaters would result in reduced peak demand as heating loads peak in the evening in winter even if the systems are backed up by a gas or electrical heaters. Grey water is treated in a 32 klpd (kilo liters per day) filtration plant and used to irrigate the ground floor garden, finally recharging the earth. Black water is treated in a 22 klpd Sewage Treatment Plant and is used for horticulture purposes.

4. Calculation of Energy savings

4.1 Embodied energy

The calculation of energy required in estimating the emissions from the project activity has been calculated as follows.

Embodied energy=Quantity of the material* Embodied energy coefficient (1)

CO_2 Emissions (MT) = Energy Consumption (kWh) x Emission Factor/1000 (2)

Emission Factor=0.76 (kg/kWh) (3)

4.2Calculation of Air-conditioning Refrigeration and lighting load

Total energy used in kWh =Number of devices * rated power of the devices * average annual operating hours (4)

5. Comparison

The project has been compared with a housing complex called Sobha Primrose for baseline study with a site area of 91494.65 ft^2 at Belandur area in Bangalore. About 140, 3 bed room flats are built as compared to 80 flats and 15 villas at T-ZED on one third of the site area confirming that the project is highly energy intensive. Table 2 below presents a comparison of material specifications, power and water demand, heating refrigeration and air conditioning use at T-Zed and Sobha Primrose.

Specifications	T-Zed	Sobha Primrose
Structure	RCC footings and columns, Load bearing hybrid structures and Laterite walls	Basement plus ground floor 10 storied RCC framed structure with concrete hollow blocks
Foyer/Living/Dining	Internal finishes: Lime rendered, External finishes Water soluble PU coating; stone grit finish	Superior quality, ceramic tile flooring and skirting, plastic emulsion paint finishes for walls and ceiling
Toilets	Flooring sadarhali stone rough	superior quality, ceramic tile flooring and skirting
Kitchen	Flooring with granite stone	superior quality, ceramic tile flooring and skirting plastic emulsion paints for ceiling
Stair case	Tandoor stone cladding	granite treads and risers ,MS hand rail
Common areas	Combination of polished and rough slate	granite tile flooring and skirting ,textured paint for walls, plastic emulsion paint for ceiling
Balconies and utilities	Kota stone finish	Textured paint for walls, plastic emulsion paint for ceiling ,plastic emulsion paints for ceiling, ceramic tiles for floor
Internal doors	Teak wood frame and rubber wood shutters	Lacquered melamine finished frames and shutters
External doors	Teak frame and shutters	Aluminum extruded frame
luminaries	CFL and LEDs	Incandescent lamps
Air conditioning and refrigeration	centralized	Window air conditioners and common refrigerators
Heating	Electric heaters	Solar water heater
Water demand	Recharged at the site	Local municipal corporation
Electricity demand	Green electricity	Bangalore Electric supply company

Table 1 Specifications per flat at Sobha Primrose and at T-Zed a comparison

As can be seen from the table very high embodied energy materials are used at Sobha primrose. Such specifications are a common practice for construction not only in Bangalore but also almost every climatic region in India.

Considering the apartment block surveyed a comparative carbon reduction measure at T-zed and a conventional building if planned on the same site was done.Table.2 depicts the specifications and quantities for the calculation of carbon emissions.

S.	Item	Specifications at	Specifications Conventional

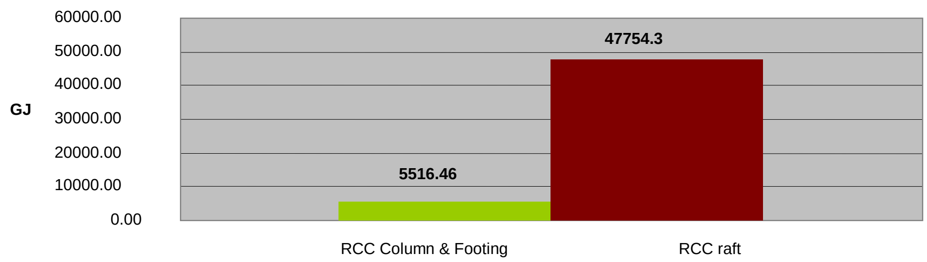
No.		ZED	
1.001	**Highlights**		
1.002	Total Built up area	2.5 Lac sq ft	4 Lac sq ft
1.003	No of Homes @ 2500 sq ft/ home	95	140
1.005	Water from city supply	0%	100%
1.006	Waste water to city sewers	0%	100%
1.007	Solid waste management	100%	0%
1.008	Power consumed	Green power	Fossil Fuel; Large Hydro; Thermal Power; Atomic Power
1.009	Quantities	Quantities as per 95 homes	T-Zed Quantity*(140/95)

Table 2 specifications and quantities for the calculation of carbon emissions

Based on the above quantities CO_2 emissions through specifications at T-Zed as compared to a conventional building and hence the total CO_2 saved in Metric tones (MT) was estimated.

5. Results and discussion

Figures 3, 4 and 5 present the comparative energy consumption through a conventional building and a T-zed building in he building structure.



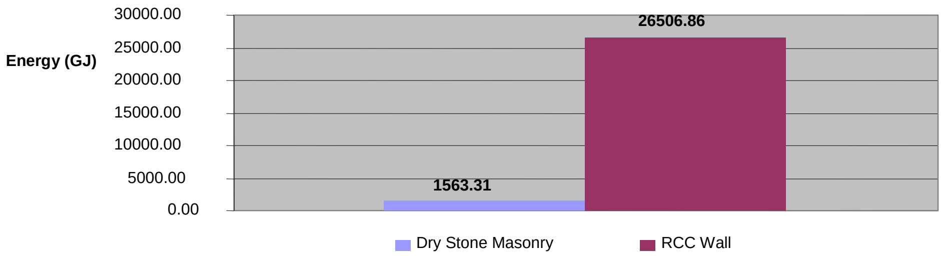


Fig 4 Comparative Energy Consumption in Dry stone Masonry wall & RCC Wall

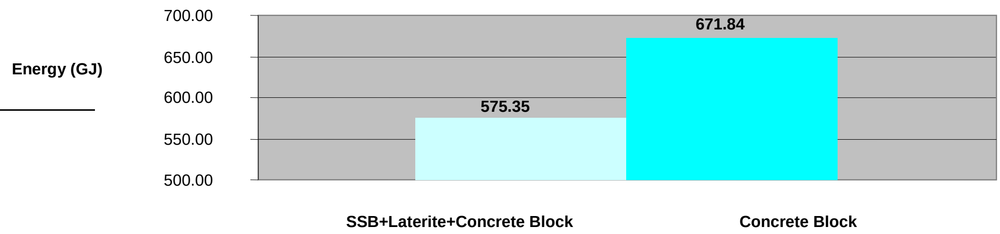


Fig5 Comparative energy consumption in SSB wall and Concrete block wall

As is evident if an Energy of 42238 GJ is saved which results in 11742 CO_2 emissions reduction equivalent to 3205.6 T Carbon if RCC column and footing is preferred in comparison to RCC raft foundation, further if dry stone masonry wall is preferred against concrete wall and SSB walls are preferred against Concrete block walls it would result in the reduction of 6934 T and 26.8 T of CO_2 emissions respectively. However, the selection of material would depend upon the availability and on the transportation cost.

Table 3, 4 and 5 depict the estimation of CO_2 emissions and savings in power, built features, water heating and refrigeration and air conditioning respectively in comparison to a conventional building.

Power	Specifications Zed	Specifications conventional	Quantity Zed	Quantity conventional	CO_2 Emissions Zed MT	CO_2 Emissions Conventional MT	CO_2 saved
Power to each home	4 kW	5 kW	3650 hrs	3650 hrs	1054.12	1317.65	263.53
Power to entire campus	650 kW	1200 kW	2920 hrs	2920 hrs	1442.48	3994.56	2552.08
Total					**2496.60**	**5312.21**	**2815.61**

Table 4 Estimation of emission in Power

Built features	Zed Quantity m^3	Conventional Quantity m^3	Embodied Energy Coefficient MJ/m^3 Zed	Embodied Energy Coefficient MJ/m^3 Conventional	CO_2 Emissions Zed MT	CO_2 Emissions Conventional MT	CO_2 saved
Basement Type Apartments	357.075	535.6125	2350 RCC	2350	177.16	265.74	88.58
Basement structure-Apartments	745	1117.5	2350	2350	369.63	554.45	184.82
Basement retaining walls	371.45	557.175	1631.5 (RCC) +(stone masonry)	2350	127.95	276.44	148.49
Independent home superstructure	670	1005	1580 hybrid	2350	223.50	498.63	275.13
External Walls	1856.1	2784.15	1580 hybrid	4700 Solid Concrete Blocks/ Burnt Clay bricks	619.16	2762.72	2143.55

Internal walls	2429.375	3644.0625	810 SSB	4700	415.46	3616.01	3200.55
Total					**1932.86**	**7973.99**	**6041.13**

Table 3 Estimation of emissions in built features

Water heating	Specifications Zed	Specifications conventional	Quantity Zed	Quantity conventional	CO_2 Emissions Zed MT	CO_2 Emissions Conventional MT	CO_2 saved
Domestic	Solar heating system with electric backup (5 nos.)Average savings 6Kwh/day/no	Home electric geysers (380 No.)	600 hrs	91.25 hrs.	355.68	52706.00	52350.32
Total					**355.68**	**52706.00**	**52350.32**
Lighting & Ventilation							
Home lighting	CFL lights- average 450 watts (per home)	Halogen and Fluorescent lights- average 1600 watts (per home)	2190 hrs	2190 hrs	71.15	372.83	301.67
Corridor and basement lighting (515 no. approx.)	CFL and LED Hybrids- average 20 watts	Halogen and Fluorescent lights- average 40 watts	2190 hrs	2190 hrs	17.14	51.46	34.32
Street lights (125 no. approx.)	LED street light- average 4.8 watts	Halogen lamps- average 60 watts	3650 hrs	3650 hrs	1.66	31.29	29.63
Ceiling Fans (380 Nos.)	Low energy fans- 50 watts	Conventional fans- 75 watts	1920 hrs	1920 hrs	27.72	62.38	34.66
Total					**117.69**	**517.96**	**400.27**
A.C.							
Power consumption per AC	1 KW	2-3 KW	960 hrs	960 hrs	69.31	255.36	186.05
Refrigeration							
Power consumption of refrigerator per home	0.15 KW	0.35 KW	8760 hrs	8760 hrs	94.87	326.22	231.35

Total	**164.18**	**581.58**	**417.40**

Table 5 Estimation of emissions in water heating, lighting, refrigeration and air conditioning

As is evident 6041.13 MT of CO_2 emissions can be reduced by efficient site planning and use of low embodied energy materials. A quantity of 2815.61 MT of CO_2 emission reductions can be achieved by diligent use of power. If solar water heating system is resorted to against electrical heaters a reduction of 52350.42 MT of CO_2 emissions can be achieved. Further energy efficient luminaries and fans would reduce 400.27 MT of CO_2 and centralized air conditioning and refrigeration would incur 417.40 MT of CO_2 emission reductions.

6. Conclusion

The use of low embodied energy and renewable energy sources in a housing complex has been discussed in this paper. The paper focuses upon comparison of two housing complexes built on energy efficient and energy intensive technologies respectively It is evident that efficient site planning and use of natural resources result in considerable amount of carbon emission reduction. Use of stabilized mud and laterite blocks for walls and hybrid superstructure would save 75.33 % of CO_2 emissions in comparison to a conventional building where concrete and burnt bricks are a common practice. Use of solar passive architecture to augment ventilation and daylight, choice of energy efficient instead of incandescent lamps, preference on energy efficient fans and solar water heating would result in 77.27 % and 99 % of reduction in operational energy respectively in comparison to a conventional building. Switching to centralized air conditioning and refrigeration in a housing complex saves 71.77% of operational energy which is a very significant reduction.

7. Acknowledgement

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