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Comparitive Study and Rate Analysis of a Non-Rated Residential Building and A SVA-GRIHA Rated Green Building

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Abstract— In today's world the construction industry consumes a huge amount of energy. Due to the extreme use, the non-renewable resources are getting constantly depleted. Construction industry accounts for emission of large quantity of greenhouse gases which leads to climate change and depletion of the ozone layer. This adverse effect on the environment triggers the need for sustainable construction techniques which reduces the total embodied energy and carbon emissions.

Any green building works on the principles like sustainable site plan which makes sure that the site is planned taking the site topography and local climatic conditions into consideration, usage of green materials and resources which have the least embodied energy, water conservation techniques to use as less water as possible, energy conservation by making use of passive design and using solar energy and maintaining good indoor air quality by using low-VOC paints and other less hazardous materials in construction.

The study focused on a conventional building's cost that was compared with that of the Green building of same site area after including all the Green criteria recommended by SVA GRIHA (Small Versatile Affordable Green Rating for Integrated Habitat Assessment) council. It was found that the total construction cost of the Green building after incorporating 14 criteria recommended by the council for a five-star rating was 9.05% more than that of the conventional building. Also, by performing the Cost Benefit analysis the payback period of the green building was found to be 6.67 years. ECOTECT and DIALUX are used for the effective design of fenestrations and artificial lighting system respectively.

Keywords – Green building, SVA-Griha, Portland Pozzolona Cement, Porotherm blocks.

1. INTRODUCTION

The land used by buildings, production of building materials, transportation of building materials, treatment and disposal of waste etc., from the construction industry has huge impacts on the environment (Zhiwei,Y et.al 2014). Due to the large-scale construction throughout the world, the resources like water, sand etc., are getting constantly depleted and also construction accounts for a huge amount of greenhouse gases in the environment which leads to climate change and depletion of the ozone layer. These factors led to the need of construction techniques which demanded less resources and sustainable method with minimal use of resources like water, artificial energy etc., and making optimum use of natural resources like wind and sun. Such techniques are known as green construction techniques (Abhinaya et.al 2107).

Environmental Sustainability in the present days has become a major concern for the construction industry. Buildings are the world's largest consumers of natural resources and it accounts for 40% of total carbon dioxide emissions and 30% of raw material consumption and the output of solid waste.(McGraw-Hill. Construction, 2008).Hence the construction industry has a huge potential to reduce the carbon dioxide emission reduction. To reduce the environmental impact due to the construction sector, Green buildings that are energy efficient and environmentally friendly structures are proposed. These buildings not only save energy and water, they also contribute to the occupant's health and comfort through the measures that are taken in terms to control the humidity, indoor air quality, temperature, natural lighting and also the waste management.

Hence to meet the current needs of the generation without affecting those of the future, certain strategies have to be adopted by determining what should be measured to understand principles of sustainability and to measure the set of criteria that has to be addressed. This will help explain certain areas in sustainability reporting.

Green buildings help in conservation of perishable non-renewable resources and also help to keep a check on environmental issues like pollution, water contamination, ground water depletion, ozone layer depletion, greenhouse gases in the atmosphere etc. Therefore, it becomes the need of the present as well as the future to promote and implement green techniques in the construction industry (Gupta, 2017).The Energy and Resources Institute(TERI) have estimated that if green building concepts are adopted in India, 8400MW of power can be saved annually which will be sufficient to light up 550,000 houses annually (Abhinaya et.al 2107).

There are different Green building certification bodies. **Leadership in Energy and Environmental Design (LEED)** is a rating system for the construction, operation, design and maintenance of green building which was developed by U.S. Green Building Council. **Building Research Establishment Environment Assessment Method (BREEAM)** is a certificate system that confirms the sustainability of buildings in British of large scale. **The Indian Green Building Council (IGBC)** is a division of the confederation of the Indian industry that works closely with the government and it aims at sustainably built environment. IGBC rates the building in four levels which is valid for 3 years which are Platinum, Gold, Silver and Certified. The **Energy Conservation Building Code (ECBC)** was established by the Indian **Bureau of Energy Efficiency (BEE)** to set the efficiency standards for the design and construction of the buildings. **TERI GRIHA** is the Green Rating for Integrated Habitat Assessment is the national rating system for green buildings that is adopted while evaluating and designing new buildings.

2. LITERATURE REVIEW

In this section we discuss about the various literary works obtained through various means.

"Green Building Certification process of existing buildings in developing Countries: Cases from Turkey", Bahacan Aktas and Beliz Ozorhon) investigated the green building certification of the existing buildings in Turkey. They adopted a qualitative case study methodology to give a clear understanding of the green process and the success factors of any project. For this study six Leadership in Energy and Environmental Design(LEED) certified projects of different certification levels were examined.

A framework was designed which included the reasons for opting green buildings, resources used for green certification, tools used for green certification, main challenges faced, factors used to overcome the challenges faced and achievements from the greening process. Keeping this framework in mind at least two individuals were interviewed in each of the six LEED certified projects selected. The different drivers, resources, green implementations, barriers, enablers, impacts and benefits were known from this study and was found that majorly the private sector concentrates more on the greening of existing buildings as the public sector is more focused on new construction. The findings of research answered a lot of questions like what are the constraints in greening of existing buildings, what are the measures to be taken, what are the benefits of green certification and so on. Hence this research work gives a generic framework which can be used in other countries for different projects as different countries have different weather conditions, resource availability and regulations.

"What does it cost to convert a non-rated building into a green building?", G.S. Vyas and K.N. Jha did a research to find the incremental cost or the increase in the initial investment for a green building as against a non rated building. A total of eleven government green buildings of different levels of certifications were chosen and their bill of quantities(BOQs) were obtained from Central Public Works Department(CPWD) by filing right to information(RTI) act. From the initial cost of the buildings obtained from the BOQs, the cost of the green building attributes were determined and then by comparing the costs of a green building to a non rated building, the incremental cost of green building was determined. Also an analysis was done to find the savings in energy using the software solar PV for ALL(SPV4ALL). This gave the potential savings of a project which was useful for calculating the payback period and life cycle cost of the projects. It was found that the average incremental cost for green buildings is 3.10% and 9.37% for 5 stars and the discounted payback period is 2.04-7.56 years and 2.37-9.14 years for 3 star and 5 star GRIHA rating respectively.

"Building a Green Home Using the Local Resources and sustainable Technology in Jammu Region- A Case study", Abhiney Gupta conducted a research on building green home in Jammu region using locally available materials and sustainable techniques. The work mainly focuses on efficient utilization of various natural resources like water, solar etc.

The proposed green concepts included efficient site planning, daylight harvesting, heating-ventilating and air conditioning (HVAC) system, usage of green materials, water conversation, roof garden and building insulation. Efficient site planning and daylight harvesting included the proper orientation of the building to avoid direct sun glare in the summer and also utilizing solar energy for hot water. The green building materials used for construction were locally available materials like UPVC windows and ventilator frames, fly ash cement bricks, insulating window glass, low VOC paints, LEDs etc.

The water conservation techniques like rain water harvesting system and use of low flow fixtures. Also roof garden technique was provided for better building insulating. The research gave a brief idea of the simple green techniques that can be adopted by a common man in the construction of a residential building. The limitation of this study is that it considers only limited concepts of sustainable construction.

"Planning, Analysis, Design and management of Multi-Storey Green building.", Anjali Gupta conducted a study in which she planned, analyzed, designed a green building by implementing green techniques. In the research work, she has planned a residential multi-storied building with five stories. The intent of planning was to orient the building in a way where maximum passive light from the sun could be utilized. Also the building was analyzed and designed as if it were a conventional building and as a green building so that a comparative analysis could be done. The study majorly concentrated on the design of green concepts such as rainwater harvesting and solar panels. Finally the cost estimation of conventional building and green building was done and the cost increment of the green building was shown. The findings of the research work also showed the payback period of the green building along with the energy difference in the buildings. It stated that the initial investment of the green building is 1.56% higher but the savings are 2.95% more which will prove to be beneficial in the long run. The limitation of this study is, that it concentrates on only two aspects of sustainable construction viz., rainwater harvesting and solar panels. Therefore, a more detailed work can be done by incorporating other concepts of green construction.

"Design of Self –Energy Sufficient Building in India", Ram Joshi et. al(2014) conducted research work which focused majorly on utilization of alternative sources of renewable energy, mainly solar energy to satisfy the daily energy demand of the building. Their work mainly focuses on designing and implementing building integrated photo-voltaic (BIPV) to produce electricity from solar radiations and to improve the energy efficiency of the building through passive solar design.

Two cases have been considered in their research work:

- If the BIPVs are retrofitted in an existing building
- If the building had been designed with BIPVs as a pre thought.

The researchers have concluded that it is always beneficial to design a building with BIPVs as a pre thought rather than retrofitting BIPVs in an existing building because retrofitting is found to be more expensive as it restricts the installation on potential sites and positions of the panels. The priority for available surfaces for installation of the BIPVs in the decreasing order is sunshade, skylight, rooftops and facades. Also the payback period for a residential building is found to be less than 7 years and that of an institutional building nearly 10 years. Furthermore, the BIPVs will cut down the carbon emissions by almost 30.47%. Therefore, it is worth investing in BIPVs for a better environment.

It can be concluded from the literature study that implementing green construction techniques can be helpful to preserve non-renewable resources of energy and to conserve the environment. Green construction also reduces the operation and maintenance cost but the initial investment is a little higher than that of the conventional buildings. The findings of the paper gave better understanding of green construction technique and the benefits derived from greening techniques encourages people to adopt such techniques for the betterment of the environment and the society.

There were several research gaps like detailed quantity survey of all the major items of construction was not shown, most of the studies focused only on a few green construction concepts ignoring the rest and hence failing to provide a complete package of green construction techniques, methodology to achieve green building certification from various rating systems was not shown and detailed evaluation of embodied energy and its carbon footprint was not demonstrated.

3. METHODOLOGY

The overall aim is to design a green residential building which meets all the SVA GRIHA criteria and to show the cost and energy difference with respect to a similar non-rated residential building. In order to accomplish the same, several objectives are to be set-up and fulfilled by adopting appropriate methodology and also making use of the relevant resources. The objectives and methodologies adopted are as follows:

Statement of the Objective	Methodology	Resources Required
Selection of a conventional building and estimating the quantities of various items of construction.	Selecting a recently constructed or an on-going conventional residential building and estimating the quantities of various items used for construction.	Auto-CADD, Excel.
To design the green building by adopting all the SVA GRIHA criteria for a five star rating residential building.	Designing various Green parameters like Solar panels, sewage treatment plant, efficient artificial lighting , Rainwater harvesting etc.	Auto-CADD, IS Codes, ECOTECT, Dialux, Rainwater harvesting manual, details from IMD.(India Meteorological Dept.)

Estimation of the quantities of green building and performing cost benefit analysis and comparing it with the conventional building.	Finding the quantities of materials and their cost and doing a comparative study. Calculating the payback period of green building and comparing the energy differences.	Excel, Schedule of rates.

Table 3.1 Objectives and Methodologies

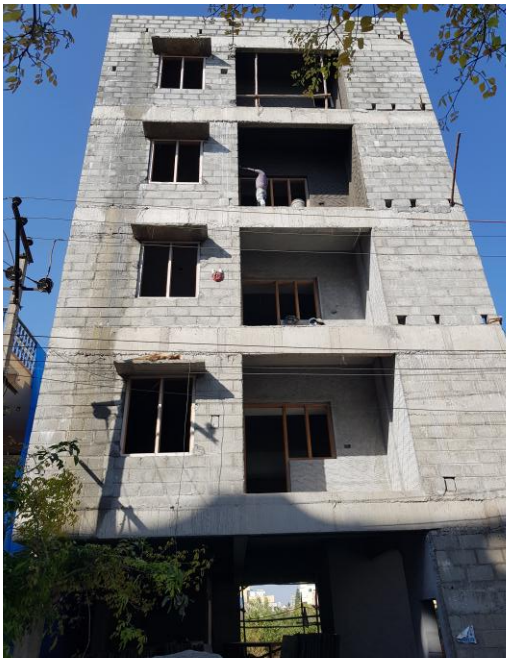


Figure 3.1 Conventional building

The conventional building which is chosen for the comparative study is a 4 storied residential building with a stilt floor. It has a site area of 2400sft and built up area of about 7208sft.It is located in Bhuvaneshwarinagar and has 4 residences, one in each floor.To find the total construction cost of the building, quantity survey is done and a BOQ is prepared for the following major items: Excavation, PCC in foundation, Plastering(internal, external and ceiling), RCC(columns, slabs, beams, staircase, lintel, chejja), Flooring(marble, granite, antiskid ceramic), Painting(interior and exterior), Block work and Dadoing.

The estimation of quantities and rate analysis is done for the mentioned items. The cost of labor and materials is taken as per the SR 18-19.

The abstract cost for conventional building is shown in the below table

Sl.No.	Item	Amount (INR)
1	Excavation	2,64,507.40
2	PCC in foundation	1,12,395.00
3	Total RCC	44,08,509.59
4	Flooring	16,65,156.05
5	Plastering	16,21,008.00
6	Painting	4,61,074.02
7	Block work	10,31,893.00
8	Dadoing	1,81,339.86
9	Electrical and sanitary work (15%)	14,61,882.44
10	Front elevation	2,00,000.00
	TOTAL	**1,14,07,765.37**

Table 3.2 Abstract cost for conventional building

Design of Green building parameters

As per the next objective, the green building shall be designed in such a way that all the 14 SVA-GRIHA criterions are incorporated for the design of five-star rating residential green building.

The 14 criteria under SVA GRIHA that has to be satisfied in any project for different ratings are put under 5 groups namely

1. Landscape
2. Architecture
3. Water and Waste
4. Materials
5. Lifestyle

The design of green building components follows the guidelines and ratings of SVAGRIHA system. This system is applicable for projects which are less than 2500 sqm built-up area. The rating has 14 criterions and total points that a project can achieve are 50.The rating will be done on 1-5 star scale.
The table below gives the maximum points that can be achieved and minimum points that have to be achieved for getting green certification.

Sub-Group	Maximum points	Minimum points to be achieved
Landscape	6	3
Architecture & Energy	21	11
Water & waste	11	6
Materials	8	4
Lifestyle	4	1

Table 3.3 Sub-groups (SVA-GRIHA Manual)

The various criteria in each sub group are given in the table below.

Criterion number	Criterion name	Points
1	Reduce exposed, hard paved surface on site and maintain native vegetation cover on site	6
2	Passive architectural design and systems	4
3	Good fenestration design for reducing direct heat gain and glare while maximising daylight penetration	6
4	Efficient artificial lighting system	2
5	Thermal efficiency of building envelope	2
6	Use of energy efficient appliances	3
7	Use of renewable energy on site	4
8	Reduction in building and landscape water demand	5
9	Rainwater harvesting	4
10	Generate resource from waste	2
11	Reduce embodied energy of building	4
12	Use of low-energy materials in interiors	4
13	Adoption of green Lifestyle	4
14	Innovation	2
Total		50

Table 3.4 Criterion specified for each sub group

The above mentioned 14 criteria are discussed in detail below with its methodology.

Criterion 1-Reduce exposed hard paved surface on site and maintain native vegetation cover on site

This criterion intends to reduce the exposed hard paved area on site which is the open area surrounding the building or shade them in order to minimize urban heat island effect (UHIE).

Total paved area=site area- (building footprint + landscape area)
=60x40 – ((49x32) +(40x7))
=552sft

This total paved area is 100% soft paved by trees and shrubs to reduce the hard-paved area on the site and hence to reduce the negative effects of urban heat islands.

The second part of this criterion is to maintain tree cover on site. Since the site did not have fully grown trees, SVA GRIHA recommends plantation of trees in the following ratio

The site area of this project is 223 sqm, therefore planting 2 coconut trees on the site as shown.

Site Area	Number of trees
Less than or equal to 250 sq.m.	2
Between 250 sq.m and 750 sq.m.	3
Site area greater than 750 sq.m.	3+1 for every additional 250 sq.m.

Table 3.5 Description of the site area

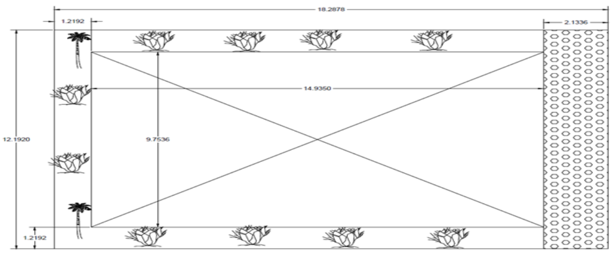


Figure 3.2 Plan showing location of trees and plants

Criterion 2-Adopt passive architectural design strategies
The objective of this criterion is to adopt passive architectural design strategies while in planning stage to reduce energy consumption and maintaining the comfort of the occupants.

As Bangalore falls in moderate climatic zones SVA GRIHA recommends the following passive design strategies to satisfy this criterion:

1. Orientation of the building and internal distribution of spaces
It is always recommended to orient the buildings in such a way that the longer dimensions are along the northern and southern directions to avoid direct heat gain from the sun. Since the site itself is oriented in such a manner this criterion is satisfied by default.

Now as the eastern and western facades of the building receive maximum insulation during the day, the spaces in the building adjoining these facades will have more heat gain. Therefore, the design of the building is in such a way that the spaces which are less functional are placed adjoining to eastern and western facades. Keeping the comfort of the occupants in mind, the initial layout of the building is designed in such a way that less occupied place like toilets and staircase are placed along the eastern and western orientation and the most of the living spaces are designed along the northern and southern directions.

2. Location of building openings
Further, to reduce even more amount of heat gain, the building openings are provided on the facades with least insolation. In this building, maximum openings are provided on the northern and southern facades of the building and minimum along eastern and western facades of the building to allow maximum daylight and minimum solar radiation into the building. Figure shows the schedule of openings for the building.

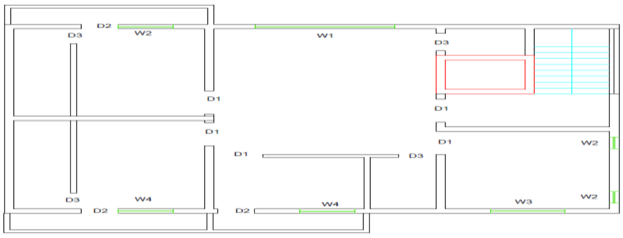


Figure 3.3 Site Layout

3. Light colored external surfaces
Criterion 3-Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration

The objective of this criterion is to provide a good fenestration design and to promote the openings such that the direct heat gain through fenestration is minimum and the daylight penetration is maximum. Shading of fenestrations in the form of chejjas or what is known as horizontal shading devices.

The exact location and the size of the fenestration is designed in Autodesk Ecotect analysis. Check the day light factor of the area that has to be achieved
Steps: i) create a project and upload- Bangalore weather file- Sun path diagram.ii)Upload plan from Autocadd.iii)Model the building.
Step 4: Add shading device.

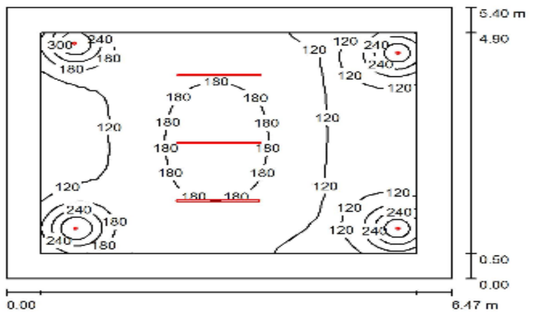
On performing the analysis without any shading devices for the bedroom on the northern side of the building, it is noted that there is maximum glare near the openings and also the average daylight factor is 6.28% as against the minimum value of 1.9% prescribed by the National building code. Also, from the sun path diagram it can be seen that the opening is not shaded in the months from April and October. It is recommended that the opening should at least be shaded from morning 10am till evening 4pm when the heat gain in the building is maximum. Therefore, it is necessary to add a shading device to shade the window on these months.
On adding a shading device of width 800mm and length of 2850mm along the glass door and window in the bedroom, the daylight factor has come down to 4.95% which is acceptable.

Criterion 4-Design of efficient lighting system
To design and adopt energy efficient artificial lighting systems in order to reduce the overall lighting power density (LPD) below recommended ECBC levels. The lighting levels should meet the recommended levels in NBC-2005 and at the same time the LPD (lighting power density) should meet the benchmark prescribed by ECBC-2007.

The design of artificial lighting system depends on the following two points
1. Recommended values of illuminance
2. Recommended lighting power density.
To satisfy this criteria dialux 4 is being used.
According to the National building code the average luminance value of the rooms in house shall be 100-200 lux.

Design steps: i) Designing the room ii) inserting the luminaries The liminance of the LED lights used and their power consumption in watts are all given in their IES files which are downloaded from the philips website iii) calculating the luminance and LPD iv)Single output sheet.

living / Single Sheet Output



Height of Room: 2.800 m, Mounting Height: 2.800 m, Light loss factor: 0.80 Values in Lux, Scale 1:70

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	154	69	358	0.451
Floor	20	124	64	263	0.515
Ceiling	70	56	23	5015	0.415
Walls (4)	50	69	39	167	/

Workplane:
Height: 0.500 m
Grid: 128 x 128 Points
Boundary Zone: 0.500 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.453, Ceiling / Working Plane: 0.365.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3	PHILIPS (1.000)	2100	2100	18.0
2	4	PHILIPS (CHINA) Investment CO., Ltd NA (1.000)	398	420	5.5
			Total: 7892	Total: 7980	76.0

Specific connected load: 2.18 W/m² = 1.42 W/m²/100 lx (Ground area: 34.94 m²)

Figure 3.4 Single sheet output from Dialux

From the output it is seen that the average luminance levels in the room at the workplane which is 500mm from the floor is 154lux which is well within the limits. Also the output shows the number of luminaires used in the room and the LPD of the room is 2.18W/sq.m which is less than the threshold of 7.5W/sq.m recommended by ECBC. Similarly LPD and lux levels of all the rooms is found out by using dialux4 and is seen to it that the artificial lighting is neither under designed or over designed.

Criterion 5-Design of building envelope to reduce overall heat gain. The thermal efficiency of the building envelope depends upon the materials used in its external facades like glass, wall and roof. The measure of heat gain from the surrounding depends upon the SHGC of the glass and U value of the glass, walls and roof. **Glass used in the green building**: The glass selected for all the windows in green building is Saint- Gobain double glazed 6mm thick. The model is Antelio plus ST-167 which has a SHGC value of 0.59 which means that only 59% direct solar radiations can pass through the glass and also has a low U-value of 2.8 W/sq.m-K. which is comparatively very less as compared to the U-value of ordinary single glazing window which is around 5.88 W/sq.m-K.

Materials used for wall and roof construction: The blocks used in the construction of the walls of the green building are Porotherm blocks from the brand Wienerberger.

The U-value of porotherm blocks is 1 W/sq.m-K and the U-value of conventional concrete blocks is 2 W/sq.m-K which is twice as much as that of the porotherm blocks. This means that by using porotherm blocks, there will be better insulation and occupant comfort and also the energy consumed by the HVAC system will reduce.

Also, filler slabs are adopted in the construction of green building in which 50mm of the concrete in the tension zone is replaced by terracotta tiles which again have a U-value half of that of concrete. There by improving the thermal efficiency of the building envelope.

***Criterion 6*-**Use of energy efficient appliances

1. Air conditioners

For the purposes of this schedule, the definitions are given in IS 1391 Part 1 and Part 2 with all amendments to guide the use of air conditioners.

"Star rating or star level" means the grade of energy efficiency displayed on the label of the room air conditioner based on the energy consumption standard notified under clause (a) of section 14 to denote the energy efficiency of the air conditioner. The available stars are between a minimum of one and a maximum of five shown in one-star interval. Considering Voltas 1.5 Ton 5 Star inverter Split. Product cost: Rs. 38500

2. Fans

This schedule specifies the requirements for participating in the energy efficiency standards and labelling for ceiling fans covering 1200mm sweep. The referred Indian Standard are IS 374 : 1979 (Specification for Ceiling Type fans and regulators) with all amendments, as applicable. The performance requirements will be in accordance with clause 8 of prevalent IS 374:1979**. Considering Gorilla Efficio energy saving 5-star rated ceiling fan, 1200 mm. Product cost: Rs. 3469.**

3. Water Geyser

"Star rating or star level" means the grade of standing loss (KWH/24Hr/450C) displayed on the label of the electric storage water heaters. The available stars are between a minimum of one and a maximum of five shown in one-star interval**. Considering AO Smith HSE-SGS-015. Product Cost: Rs 9345**

Criterion 7-Use of renewable energy on site

The use of renewable energy is applied in two things viz, solar PV systems to generate electricity and solar hot water systems for the hot water demand of the building.

1. Solar PV systems

Solar photovoltaic system is one of renewable energy system**s** which uses PV modules that convert the energy from sunlight into electricity energy. The electricity energy can be either stored for later use or used directly for the appliances. Solar PV system is a reliable and green source of energy that has a wide range of applications such as residential, commercial, industry etc. The major components of solar PV system are PV module, Solar charge controller, Inverter, Batter**y** and Load**. Considering 1 solar PV system of 3kW for each residence.**

2. Solar Hot Water System

Each house has been provided with a solar hot water system of 100L capacity which will meet the daily hot water demands of the building. It can save up to 15000 units of electricity every year for Bangalore conditions.

***Criterion 8*-**Reduction in building landscape water demand

1. **Use of low-flow fixtures:**

Standard plumbing fixtures such as shower heads, toilet and bathroom sink faucets can be adopted.

a. Bathroom sink faucets: Faucets account more than 15% of indoor household water uses. Average family can save 700 gallons of water for a year when the standard 2.2 gallon per minute (gpm) faucet is replaced with 1.5gpm faucet which will save 30% of the water flow can be reduced. Along with this ceramic disc will add to the benefit with no leakage and rusting.
b. Shower heads: Showering accounts about 17% of residential indoor water use. The shower heads with 2gpm can be adopted in bathrooms which will save around 2,900 gallons of water every year by an average family when compared to the previously used shower heads with 2.5gpm along with 370-kilowatt hour of electricity to pump that water every year.
c. Toilet dual flush system: The water sensor toilet flush uses 1.28 to 1.6 gallons of water per flush. Dual flush toilets use less water than regular toilets since they use different means to flush away the solid and liquid waste.

2. Use of native trees and shrubs

a. **Coconut tree** can be grown in humid areas with low annual precipitation. The coconut palm root system consists of an abundance of thin roots that grow outward from the plant near the surface. One sapling of coconut tree costs 50rs.
b. **Hibiscus** is a very hardy, versatile plant and in tropical conditions it can enhance the beauty of any garden. Being versatile it adapts itself easily to balcony gardens in crammed urban spaces and can be easily grown in pots as a creeper or even in hanging pots. Cost of one hibiscus sapling is Rs.25.
c. **Bougainvillea** can be kept as indoor house plants in temperate regions. In the landscape, it makes an excellent hot season plant, and its drought tolerance makes it ideal for warm climates year-round. Its high salt tolerance makes it a natural choice. Cost of one Bougainvillea sapling is Rs.12.

***Criterion 9*-**Rainwater harvesting

Rainwater harvesting simply means to collect water from where it falls. Roof top rain water harvesting is being adopted in this project as the water is being collected from the roof.

Parameters to be considered

1. **Mean annual rainfall:** The quantity of rainfall received over a year is known as annual rainfall and it is usually a statistical average of 30 years of rainfall. It is measured in mm/year.

2. **Runoff coefficient** Runoff coefficient is that water that flows away from catchment area after rain falls on the surface. The runoff coefficient (C) is the value that gives ratio of runoff to rain.

Components of a roof top rainwater harvesting system are catchment area, coarse mesh, drain pipe, first flush system, filtration unit and a storage tank.

Design steps

Amount of rainfall that can be harvested-The quantity of rainwater that can be harvested= area x runoff coefficient x mean annual rainfall= 1,15,010 litres

Coarse mesh-A PVC drainpipe of 100mm diameter has been used with a coarse mesh 0f 20mm wire as per the instructions given in IS797:2008.
First slush system-A PVC tee with ball valve arrangement of 100mm diameter is used as first slush device to divert the initial rainfall water as it contains the maximum impurities
Filtration unit-The drainpipe is connected to the top of the filtration unit which is kept above the storage tank or sump. A 100 litre barrel is used as a filtration tank.

Storage tank-The outlet of the filtration tank is connected to the inlet of the storage tank that is on its top. Designing the tank for one rainy season that is for 90 days and the consumption of water per capita from the rainwater is considered 30 litres.

Volume of the tank= no. of rainy days x no. of people using the tank x per capita consumption=54,000liters. Therefore, the dimensions of the tank will be 4mx4mx3.5m.

The overflow from this tank is diverted to a pit which is dug nearby the storage tank for underground water recharge.

Criterion 10-Generate resource from waste

The purpose of this criterion is to promote the measures on site which help in recycling and the conversion of waste into a productive resource. Vermin-composting is essentially decomposition of the organic material by the worms. Worms work both on the soil and the waste matter producing a nutrient-rich, soil conditioner and an organic fertilizer collectively called "Vermin-compost. Design of vermin-composting bin:

- The waste generated in Bangalore according to the resources is 0.4-0.6kg/capita/day
- Considering 0.5kg/capita/day for the present design.
- Number of people per house =5
- Number of residences =4
- Total number of people in the building= 20
- Total quantity of waste produced= 10kg/day
- The bin must be kept in a place where temperature is 15–25 °C and not in direct sunlight
- Wooden bin of length 4feet, width 3feet and depth 2feet (4'X3'X2') is considered.
- The worm: garbage ratio should be 2:1
- Waste = 10kg
- Worm = 20kg
- Bedding material= 2 kg
- Amount of water= 4.5 liters
- Amount of soil = 1kg

Criterion 11-Reduce the embodied energy of the building

Embodied energy is the total energy required for the mining/extracting, processing, manufacturing and delivering the building materials to the construction site. The methodology of this criterion involves usage of materials which have low embodied energy. The various materials used in green building are mentioned in the next criterion.

Criterion 12-Use of low energy materials in interiors

The intent of this objective is to adopt low energy materials in interiors and to maintain good indoor quality by using low VOC paints. The building materials with low embodied energy used in the green building are as follows:

PPC (Portland Pozzolona Cement)-eco-friendly and made of natural recycled waste. After curing, it achieves the strength equivalent to Grade 33 OPC.It has resistance against sulphate attack and is very fine cement hence very good when used for plastering works.It is also economical since siliceous materials reduces the cost.

Athangudi tiles- are basically cement tiles like mosaic, but unlike the machine pressed and produced mosaics, they are handmade over glass surfaces. It is maintenance free and does not require any polishing.

Recycled Steel- As steel products reach the end of their useful life, we want to see even more recycled into new steel products for future service to society.
It is always cheaper to recycle steel than to mine ore and move it through the process of making new steel.

Low VOC paints- As paint dries, harmful VOCs are released into the air at high levels. Asian paint Duralife can be used as low VOC paint.Products that are GS-11 certified are formulated without carcinogens, heavy metals and Alkylphenol Ethoxylates (APEOs), and comply with VOC limits specified in the GS-11 StandardThey are eco-friendly and provide good finish.

Mangalore tiles for filler slab- Filler materials are so placed as not to compromise the structural strength, stability and durability, resulting in replacing unwanted and non-functional tension concrete from bottom. It has advantages like CO2 reduction, Embodied energy reduction, Better insulation and Considerable cost savings.Other materials like M- Sand, Granite, Terrazzo tiles, porotherm Blocks and Ceramic tiles are considered in the green building as their embodied energies are low.

Criterion 13-Adoption of green lifestyle

The intent of this criterion is to adopt green lifestyle in daily life which will reduce the carbon footprint of the building occupants.

Part-1

A key component of green buildings and green lifestyle is to assess the area assigned per person in the building
SVA GRIHA gives threshold ranges for optimal spaces per capita as follows
Built up area of one residence= 14.94x9.75m=145.665sq.m
Space available per capita = 145.665/5=29.133sq.m

Part 2

Avoid the maximum use of private vehicles and opt for public transport as much as possible.
1.Restaurant-Nammoora Thindi:750m
2.School-VSS International public School:1km
3.Hospital-Shivashakti hospital:950m
4.Bus stop-Bhuvaneshwarinagar bus stop:500m
5.Railway station-Kengeri Railway Station:3.8km(10 min by bus)
6.Metro station-Mysore road metro station:6km(20 min by bus)

Criterion 14-Innovation

The intent of this criterion is to adopt strategies independent of the previous 13 criteria to make the building more sustainable.

This can be achieved by using bicycles for short distance travel, providing charging ports for electric vehicles in parking and avoiding usage of plastic by using cloth basket for shopping.

Estimation and Cost benefit analysis of Green building

The various quantities of different items used in green building are quantified and rate analysis is done to find the total cost of construction. The estimation and rate analysis of the major items mentioned above was done in the similar manner of that of the conventional building. The rate analysis was also carried out similarly to find out the cost per unit of the item where the only difference was the cost of various materials for example the conventional concrete blocks were replaced by porotherm blocks and hence the cost per unit of block work varied. Similarly cost per unit of flooring, plastering, RCC etc., also varies because of the difference in cost of conventionally used materials and low energy green materials. The following is the plan of the green building from which various quantities of the items of construction are found out

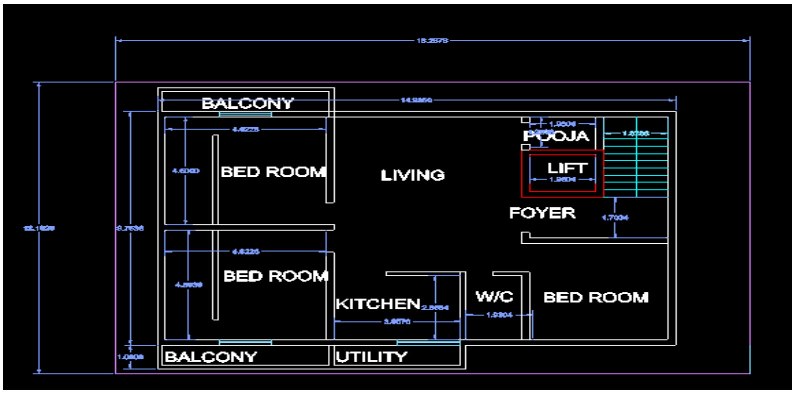


Figure 3.5 Typical floor plan of Green Building

The abstract cost for green building is shown in the below table

Sl.No.	Item	Amount (INR)
1	Excavation	91461.98
2	PCC in foundation	132930.90
3	Total RCC	3200815.86
4	Flooring	1378343.90
5	Plastering	915382.60
6	Painting	307901.42
7	Block work	1198912.19
8	Dadoing	209374.33
9	Electrical and sanitary work (25%)	1858780.79
10	Front elevation	2,00,000.00
11	3KW grid solar system for each floor	1140000.00
12	Solar hot water system of 100liters capacity	60000.00
13	Soft scaping in the stilt floor	20000.00
14	Sump for rain water harvesting, filtration unit and first flush system.	122684.48
15	Vermin composting system	20000.00
16	Cycle for each residence	40000.00
	TOTAL	**10896588**

Table 3.6 Abstract cost for green building

Cost benefit analysis

Cost benefit analysis was done to find the payback period of the Green building. Payback period is the time taken for the benefits to repay the cost of the initial investment on the green building. The savings due to the green parameters are shown in the table below.

Sl.no	Description	Units saved per year	Cost	Amount (Rs)
1	Solar PV system	19856 kW	Rs. 5.5 /unit	1,09,208
2	Solar hot water system	5600 kW	Rs. 5.5/unit	30,800
3	Rain water harvesting	1,00,000	Rs. 45 /1000 litres	4,500
			Total	**1,44,508**

Table 3.7 Savings due to green parameters

This is the total savings of the building every year and the extra initial cost which was spent on the green building is given in the table below.

Sl No	Description	Cost(Rs)
1	Solar PV system	11,40,000
2	Solar hot water system	60,000
3	Rain water harvesting	1,22,684.48
4	Vermin-composting	20,000
5	Soft scaping	20,000
6	Bicycle	40,000

The total cost is Rs. 14,02,684.48

Table 3.8 Extra initial cost which spent on the green building

Payback period

Payback period is the time taken for the benefits to repay the cost of the initial investment. The payback period is given by the cost divided by the savings. Here, the payback period= 1402684.48/144508=9.7 years. This means that the extra cost incurred will be recovered in the span of 9.7 years.

4. RESULTS AND DISCUSSION

The total cost of the conventional building was found to be Rs. 1,14,07,765.37 at the rate of Rs. 1,582.65 per sft and the cost of green building was found to be Rs. 1,08,96,588 at the rate of 1,719.70 per sft. The difference in the cost was because of the different built up area of conventional building and green building which was 7208sft and 6336sft respectively.

Also, the total cost of all the green parameters in the green building was Rs. 14,02,684.48/- which included solar PV system, solar hot water system, Rain water harvesting system, vermi-composting, soft scaping and bicycles. Solar PV systems of 3kW was installed for each residence that is 12kW for the whole building and 100 litres solar hot water system was installed for each residence. Nearly 1,00,000 litres of rainwater was harvested every year in the building. The savings due to the green buildings in energy and water was Rs. 1,44,508/- annually

It was found that the cost increment for the construction of the green building was 8.65% and the payback period was 9.7 years. By making use of low energy materials the overall embodied energy of the construction was reduced by 19.59%.

5. CONCLUSIONS

Construction industry has a huge impact on the environment. The building materials used in construction like cement, concrete blocks, river sand, marble etc. consume a lot of energy and emits huge amount of carbon di oxide which pose some serious threats to the environment and results in climate change and irregular rainfall patterns. To reduce the impact of these building materials, in this study, low energy materials like porotherm blocks, pozzolanic Portland cement, M-sand, filler slabs, low VOC paints, athangudi tiles and Terrazzo tiles were used.

Also in this comparative study between a conventional building and a green building, cost comparison and the payback period calculation is clearly shown which further encourages and motivates the people to opt the green construction by briefing them about the benefits and methods to achieve them.

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