Studies on Sustainability Aspects of Building with Different Roofing Systems and Block Work

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Abstract: In today's world a massive amount of energy is used by the building industry. The non-renewable resources are increasingly being exhausted because of the intense use. Construction industry accounts for large quantities of greenhouse gas emissions which lead to climate change and ozone layer depletion. This adverse environmental impact stimulates the need for innovative construction strategies that reduce the overall carbon emissions and embodied energy that are represented.

The study focused on a conventional building whose slab and block work is changed with different slab and block work and the embodied energy calculation of energy analysis, and the sustainability index and its different parameters that was compared with all the Green criteria recommended by SVAGRIHA a denotation for 'Small Versatile Affordable Green Rating for Integrated Habitat Assessment' council.

It was found that the total construction of the Green building is more recommended in terms of environmental and ecological parameters. Semi Pro and Revit are used for them to calculate embodied energy and effective design respectively. A radar diagram has also been drawn to help with selecting the type of roofing and block work with respect to sustainability indicators.

Keywords: Green building; embodied energy; SVAGRIHA; Revit, Semi Pro

1. Introduction

The property used for buildings, the production of building materials, the transport of building materials, waste management and recycling, etc., from the construction sector has tremendous environmental impacts [1]. Because of worldwide construction, materials such as soil, sand, water etc. are continuously being exhausted, and development often accounts for an immense amount of greenhouse gasses in the atmosphere that contribute to climate change and ozone layer depletion. 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., [2].

Green buildings contribute to the protection of perishable non-renewable energy and also help to track environmental problems such as emissions, water waste, degradation of soil, loss of ozone levels, ambient greenhouse gases etc. Therefore, it becomes the need of the present as well as the future to promote and implement green techniques in the construction industry [3]. Live sustainably requires, according to others, that we use resources to satisfy our present needs without undermining future generations' capacity to satisfy their needs. Many roofing materials require more energy, and the service life is shorter. Others require less resources and the service life is longer. The latter is the strongest. Sustainability requires a balance between humans, energy and the environment. A sustainability index calculates the overall advancement towards environmental and social sustainability by presenting a combined environmental and social management profile using a set of underlying data indicators.

The concept of sustainability has been restricted to only large-scale projects and people are not that concerned about sustainability at micro level though almost 50% of the buildings in India are residential and less than 2500 sqm. It is very necessary to encourage and give clarity to people to opt for sustainable development at micro level.

A. Embodied Energy

The Embodied energy is a certain amount of energy used by all activities involved in constructing a home, from the mining and refining of natural resources to the production, shipping and sale of materials to the procurement of items [4].

The energy a building uses over its lifespan comprises:

1) *Initial embodied energy*: it is the energy used in building design, including mining, refining and assembling, transport and assembling it.

2) *Recurring embodied energy*: it is the energy used when the house was being refurbished and restored.

3) *Operational energy*: it is the energy used in the building's heating, cooling, lighting and running equipment.

4) *Demolition energy:* it is the energy expended as all the construction materials are removed and disposed of at the end of its useful life.

Embodied energy does not require the refining and disposal of the construction material and should be used in a life-cycle strategy. Incorporated energy is typically measured as the volume of non-renewable energy per unit of building material, component, or device [5].

The use and recycling of construction materials that should be found in a life-cycle approach does not contain embodied energy.

- Cradle-to-Gate: it is denoted for those from Material extraction to Manufacturing gate.
- Cradle-to-Site: it is in the form of 'from Material extraction to Building site'.
- Cradle-to-Grave: it is from Material extraction to End-of-life

Consideration must be given to extracting, processing, transport, construction, operation, disposal, reuse and recycling.

Embodied energy is determined as the volume of non-renewable energy per unit of construction material, component or system [6]. Embodied energy is calculated using the Semi Pro software. The calculations obtained from the software are shown below in Fig.3 and Fig.4 of the two floors respectively.

B. Electricity Calculations

The electricity is calculated by taking all the energy producing equipment's like lights, air conditioner and other appliances which are used in the building.

C. Energy Analysis

Energy analysis on the design of buildings is carried out throughout all phases, from the earliest conceptual phase to detailed design, to achieve the most energy-efficient construction possible.

D. Sustainability Index

The indicator allows us to understand where we are, and how far we are from what we desire. Sustainable society metrics point to places where the social, economy, and environmental links are poor.

Efforts to address the globe wide environmental issues and mitigate environmental impacts directly or indirectly from the construction and building industry, including, for example, the depletion of naturally available resources (e.g., non-renewable resources such as oil , natural gas and raw materials), CO2 pollution and other green-house gases, and soil degradation [7].

In recent years, there are new building technologies which are sustainable have been developed and applied to the building construction and other processes in order to achieve greater energy efficiency and to reduce energy consumption and wastage along with disposal. Construction ecology requires a clear and comprehensive understanding of natural resource management based on measuring their real "environmental cost," which depends on their availability, recycling rate and environmental impact (waste absorption) with respect to natural constraints. Any of them are obstructive research on environmental evaluation of buildings in the cited literature [8][9].

This is proposed that an ecological evaluation of buildings will analyze construction technology and materials and identify criteria for making decisions, taking into consideration the various stages of the construction cycle "from the cradle to the grave' meaning, from the production of raw materials required or being used to their installation and usage in the process, and also their disposal or recycling. This is then predicted that the application of accounting approaches and synthetic metrics would provide general knowledge on the viability of buildings [10].

E. Indicators Applied to the Building Industry

The mentioned "indicator" is a device capable of presenting quantitative knowledge in a wider context regarding a more complicated phenomenon; it aims to make a pattern or mechanism that is not instantly apparent. Indicators clarify knowledge which is often linked to multiple variables, and allow researchers to interact and compare outcomes.

The estimation of metrics meets different goals by one of the two groups is noted:

Sustainability metrics include a general evaluation based on a robust equilibrium, integrating a multiplicity of exceptions that may also be non-homogeneous; they seek to quantify best practices from a global sustainability perspective, with special regard to land and energy waste over-exploitation problems [11].

Techniques for evaluating buildings are generally based on indices of environmental state impact. Such methods are known around the world and established globally. Some examples are the Building Research Environmental Assessment Method that is named BREEAM in UK and the Leadership in Energy and Environmental Design which is referred to as LEED, in the USA. These approaches include a list of metrics based on realistic principles that equate the efficiency and effect of buildings with their environmental restrictions, described as their threshold for sustainability [12][13].

Global sustainability indicators are generally obtained by using thermodynamic based programs and algorithms to process the data relative to specific parameters (given in energy and mass units). The development of a particular synthetic equilibrium will require different steps. Such methods allow the analysis of buildings' relationships to their environmental background, an ecosystem. Therefore a holistic approach (the whole is more than its parts) is formed by collecting knowledge and making general assessments of buildings.

2. Methodology

The normal trend of residential housing development in India was unsustainable due to the lack of Green building certification for projects with less than 2500 sq.m built-up area. Therefore, GRIHA denotation for 'Green Rating for Integrated Habitat Assessment' has developed a Green certification for such buildings called SVA denotation for 'Small Versatile Affordable' GRIHA.

The methodology includes the analysis, design, costing, embodied energy and sustainability Index of a standard residential building with different roofs and block work and then checking it with SVA-GRIHA and LEED.

1) *Literature Review:* Referring to relevant journals, thesis and reference books.

2) *Design 2 different types of roofs and different blocks for wall:* Planning a G+1 Building. The building was planned based on the NBC of India of minimum sizes of the required plan.

3) *Analysis of the Design model:* The structural analysis of a building and design of Footing, Columns, Beams and Slab have been done. The Reinforcement detailing and bar bending schedule are obtained from the software. Estimation has been done.

4) *Selection of slabs and Block work:* Conventional slab, Filler slab, Concrete blocks and Air Aerated blocks are selected with criteria's that are considered are Thermal Insulation, Carbon foot print, HVAC efficiency and Cost. A 3 BHK villa was chosen with area of 2483 sq.ft.

5) *Calculation of Embodied Energy (EE):* EE is calculated from manufacturing stage to the transportation to building site.

6) *Energy Analysis:* Building with green materials and aspects has been modeled and energy analysis has been accomplished using REVIT software.

Comparison and study: A comparative study on different aspects of the materials is done. An analytical solution is drafted

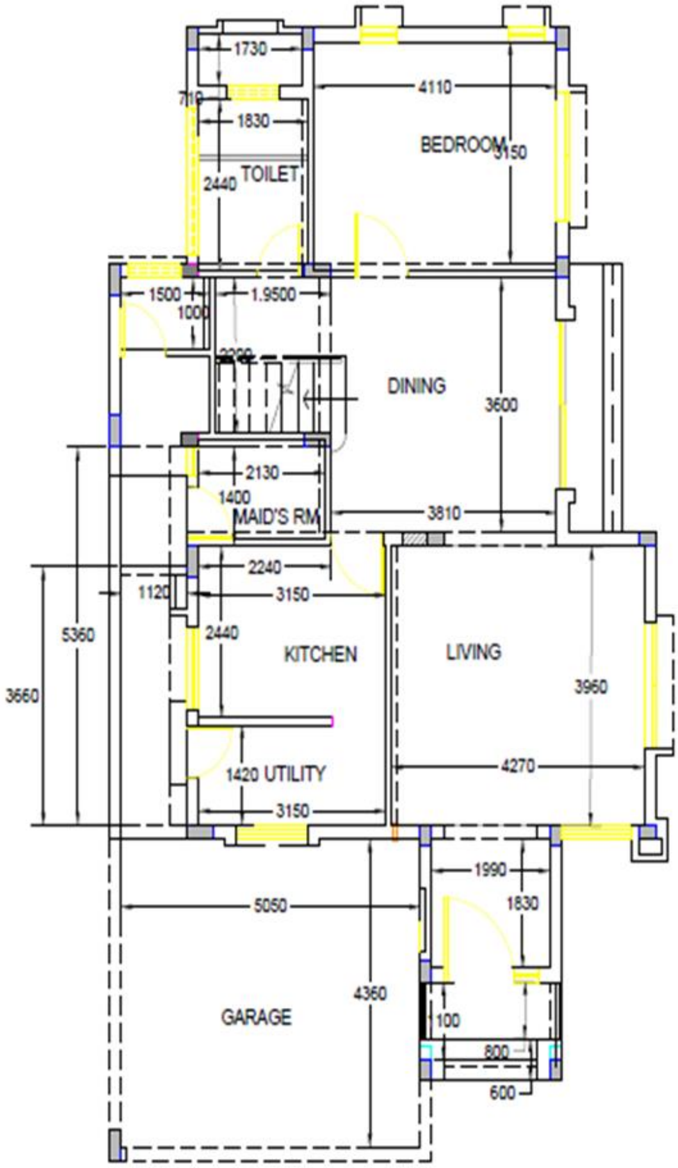

Fig. 1: Ground floor plan of Building

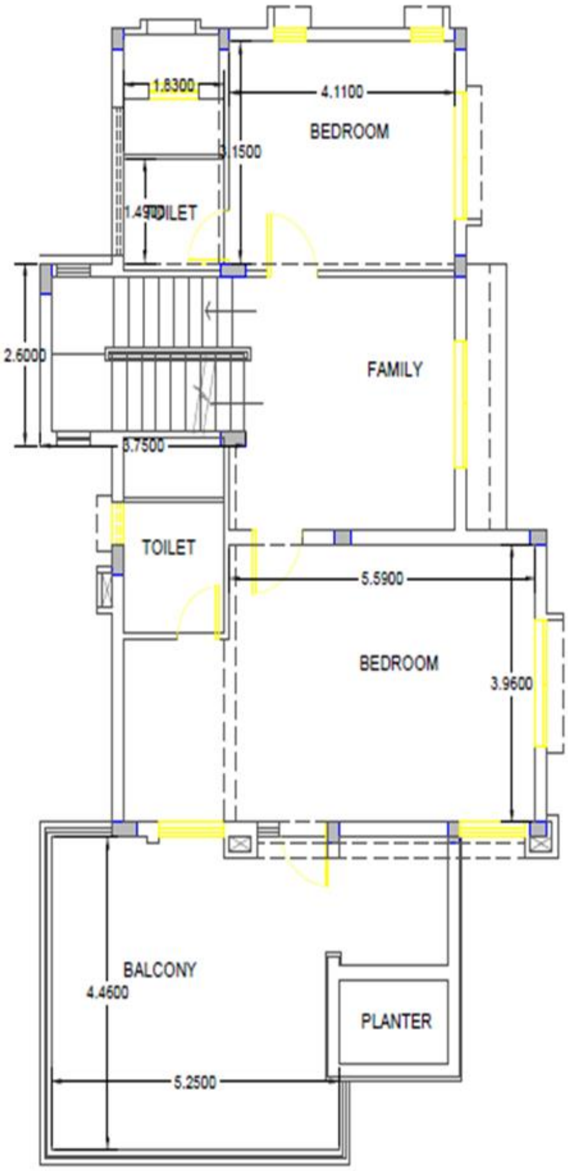

Fig. 2: First floor plan of Building.

Modeling and analysis of the G+1 building of the above mentioned plan is carried out. Fig.1 shows the ground floor of the plan. Fig.2 Shows the First floor of the plan.

3. Analitical Calculations

Once the design and Analysis is carried out, other analysis processes are carried out. These include, cost analysis, Embodied energy calculation, Life cycle cost, Electricity calculations and energy analysis is carried out.

There are 4 different combinations considered in order to attain mediums for comparison:

- RCC with Concrete Blocks (Conventional type)
- RCC with AAC blocks
- Filler Slab with Concrete Blocks
- Filler Slab with AAC Blocks

A. *Cost Analysis:* Cost estimation for all the different types of combinations is carried out. The BOQ is used in order to estimate the cost and quantities.

Embodied Energy Calculations: SemiPro software allows calculating the embodied energy for each element from the point of generation to the point of usage. Mentioned below are the outputs of the calculations using the software SemiPro. Fig. 3 shows the embodied energy for Cement and Fig.4 shows the calculation for Soil

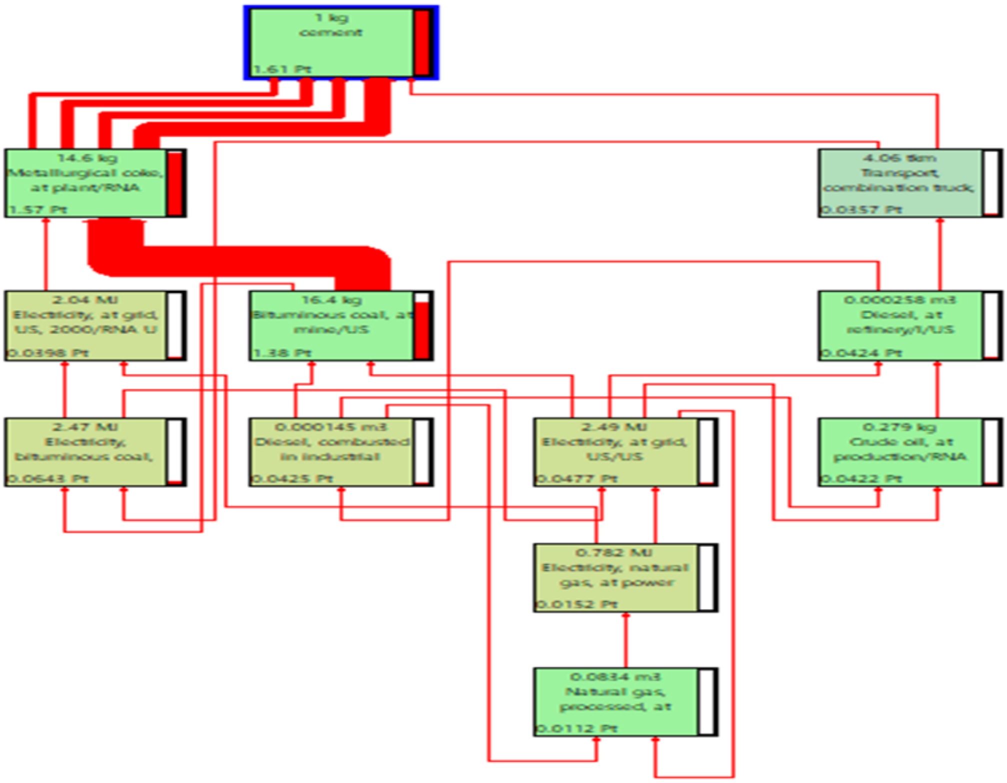

Fig. 3: Embodied energy calculation using SEMI PRO

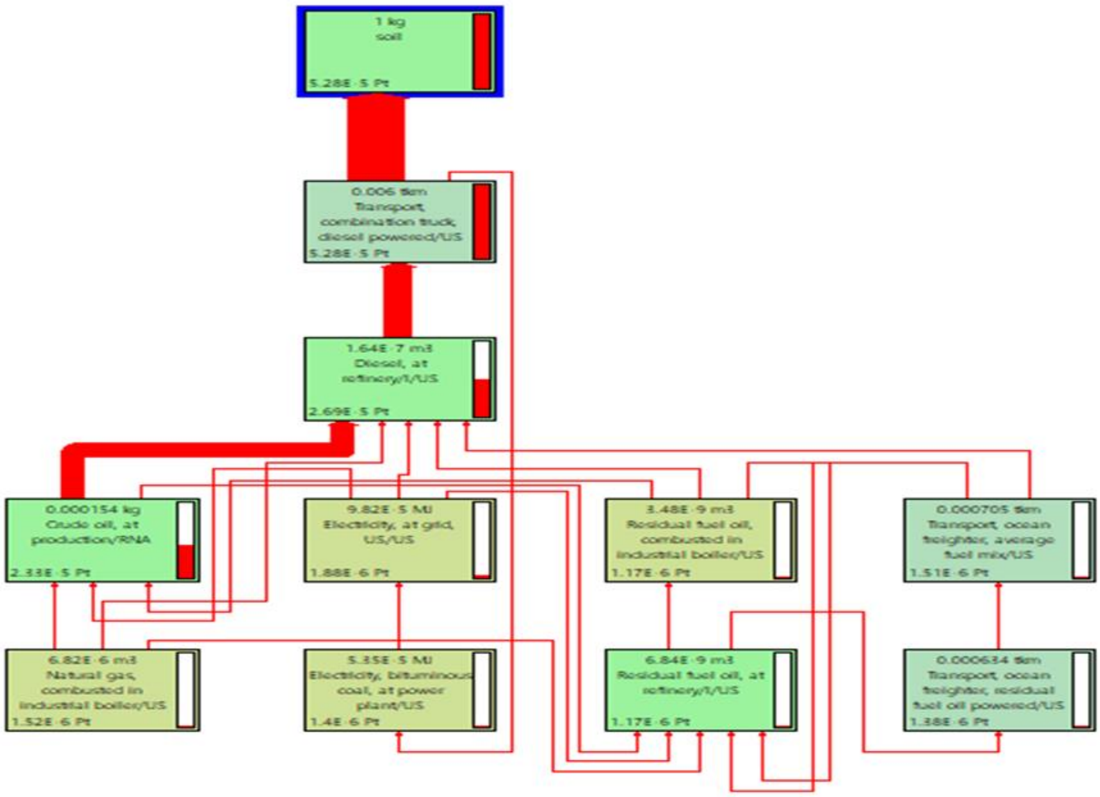

Fig. 4: Embodied energy calculation using SEMI PRO

C. Electricity Calculations: The electricity is calculated by taking all the energy producing equipment's like lights, air conditioner and other appliances which are used in the building. Below mentioned is the tabular representation of the calculation and estimation of the Electricity calculations

Table I. Total electricity energy consuption calculations

Space	Energy Consumed By	Number	Wattage (W-H)	Working Hours (Hr)	Energy (Kw-H/Day)
Exterior	Calling Bell	1	20	0	0.6
	Light	3	40	10	1200
Verandah	Fan	1	75	3	225
	Light	1	40	8	320
	Power Plug	1			
Living	Fan	1	75	4	300
	Light	1	40	4	160
	Power Plug	7			
	> TV	1	70	5	350
	> Landline	1	3	24	72
	> Modem	1	20	16	320
Dining	Fan	1	75	3	188
	Light	1	40	6	240
	Power Plug	2			
Kitchen	Fan	1	75	1	75
	Light	1	40	4	160
	Exhaust	1	150	2	300
	Power Plug	6			
	> Refrigerator	1	150	24	3600
	> Microwave	1	1200	1	600
	> Induction Cooker	1	225	1	225
	> Mixer	1	500	0	150
	> Chimney	1	200	1	200
Work Area	Light	1	40	5	200
	Power Plug	1			
	> Washing Machine	1	200	1	200
Utility	Light	1	40	2	80
Maid's Room	Fan	1	75	10	750
	Light	1	100	4	400
	Power Plug	1			
Maid's Toilet	Light	1	40	1	40
	Exhaust	1	150	1	150
	Power Plug	1	120		
Bedroom 3 Nos	Fan	1	75	12	900
	Light	1	40	15	600
	Ac	1	2210	36	79560
	Foot Lamp	1	3	30	90
	Power Plug	2			
Toilet	Light	3	40	6	720
	Exhaust	3	150	3	1350

	Heater/Geyser	3	2000	9	54000
	Power Plug	1			
Balcony	Fan	1	75	1	37.5
	Light	1	40	3	120
Head Room	Light (Led)	1	40	4	160
Family	Light	1	40	6	240
	Fan	1	75	6	450
	Power Plug	1			
Garage	Light	1	40	4	160
	Power Plug	1			
Additional (Mobile/Battery Charging/ Hair Drying /Mosquito Repellent)					200
				TOTAL	**148892.6**

D. Life Cycle Cost Calculations: It is a method to analyse the total cost of the building from its point of acquiring, building, maintenance etc up to the point of disposal or demolition of the building. Mentioned below are the cost estimates for different combinations. Table I shows Life cycle cost calculations for RCC with Concrete Blocks, Table II shows Life cycle cost calculations for RCC with AAC Blocks, Table III shows Life cycle cost calculations for Filler Slabs with Concrete Blocks and Table IV shows Life cycle cost calculations for Filler Slabs with AAC Blocks respectively

Table I Lifecycle Cost Calculation For Rcc With Concrete Blocks

		(In Lakhs)
C	Initial Costs	76.22
R	Taxes	0.56
M	Maintenance	26.0549
S	Resale	90.20
E	Energy Costs	42.3389
		54.9738

Table II: Lifecycle Cost Calculation For Rcc With Aac Blocks

		(In Lakhs)
C	Initial Costs	72.72
R	Taxes	0.56
M	Maintenance	26.0549
S	Resale	90.20
E	Energy Costs	42.3389

Table III: Lifecycle Cost Calculation For Filler Slab With Concrete Blocks

		(In Lakhs)
C	Initial Costs	73.22
R	Taxes	0.56
M	Maintenance	26.0549
S	Resale	90.20
E	Energy Costs	42.3389

Table IV: Lifecycle Cost Calculation For Filler Slab With Aac Blocks

		(In Lakhs)
C	Initial Costs	72.82
R	Taxes	0.56
M	Maintenance	26.0549
S	Resale	90.20
E	Energy Costs	42.3389

E. Energy Analysis: Energy analysis is performed on the building design through all stages, from the earliest conceptual phase through detailed design, to ensure that we are making the most energy efficient building possible. The Energy Settings is one critical setting related to running the simulation and must be considered to generate a valid Energy Analysis Model (EAM). This is done on Revit software. Fig.5 shows the calculation process of Energy for the building that is considered

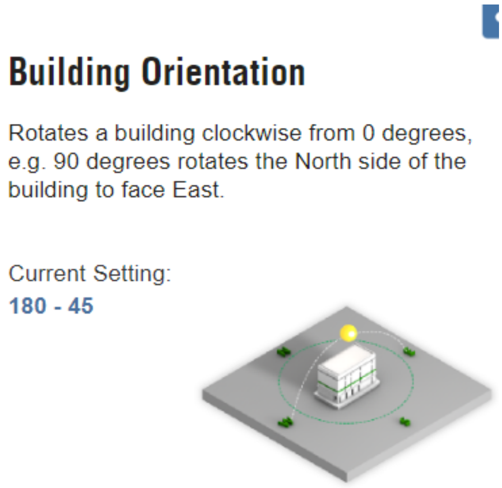

Fig. 1: Building Orientation

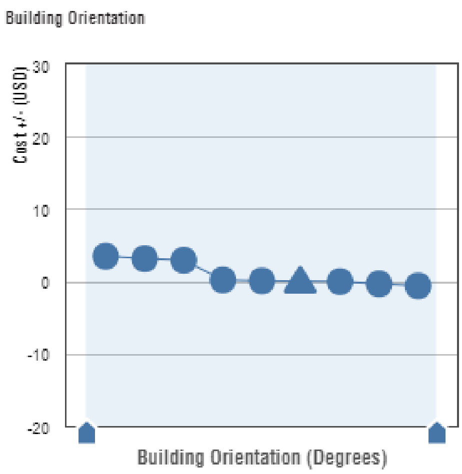

Fig. 2: Cost v/s Building Orientation

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

- Landscape
- Architecture
- Water and Waste
- Materials
- Lifestyle

The table below gives the maximum points that can be achieved and minimum points that have to be achieved for getting green certification. The global weight study scope is considered and the designed building is rated unbiased. Table VI shows the Global weight of study scope and Table VII shows the probable allotment of weights for the designed building

Table VI. Global weight of study scope

Study Scope (SS)	**Criterion (CR)**	**Global Weight**
Safety (SS1)	Structural safety against fire (CR1.1)	0.0322
	Safety and health in the execution procedure (CR1.2)	0.0612
	Safety measures in the construction process (CR1.3)	0.0322
	Maintenance and conservation of the industrial plant (CR1.4)	0.0163
	Safety against intruders (CR1.5)	0.0084
	Safety and health during deconstruction (CR1.6)	0.0163
Global weight ¼ $^{o}_{SS}$, $^{o}_{CR}$; $^{o}_{SS}$ ¼ 0:1667: The same weighting is proposed		
Social (SS2)	External mobility (CR2.1)	0.0714
	Respect for the urban environment (CR2.2)	0.0237
	Auxiliary services for personnel (CR2.3)	0.0716
Environment (SS3)	Integration in the natural environment (CR3.1)	0.0096
	Environmental impact during construction (CR3.2)	0.0285
	Use of ecological materials (CR3.3)	0.0164
	Environmental impact during utilization (CR3.4)	0.0565
	Waste management during utilization (CR3.5)	0.0165
	Impact of materials from demolition (CR3.6)	0.0392
Economy (SS4)	Cost of executing the work (CR4.1)	0.0290
	Construction timeframe (CR4.2)	0.0197
	Cost of supplies (CR4.3)	0.0528
	Cost of maintenance (CR4.4)	0.0528
	Cost of building demolition (CR4.5)	0.0125

Table VII: Sustainability Index Weightage

Sustainability index	(IV)	Study scope	Valuation of each study scope (*V*SS)	Valuation of each Criterion (*V*CR)
S Index	0.34	(SS1) Safety	0.298	0
				0.037
				0.077
				0.036
				0.051
				0.098
		(SS2) Social	0.308	0.08
				0.057
				0.172
		(SS3) Environment	0.231	0.017
				0.087
				0
				0.127
				0
				0
		(SS4) Economy	0.439	0.117
				0.076
				0.054
				0.116
				0.075
		(SS5) Functionality	0.549	0.064
				0.098
				0.089
				0.049
				0.153
				0
				0.038
		(SS6) Corporate image	0.213	0.066
				0
				0.147

4. Results And Discussion

For RCC slab with concrete blocks the embodied energy obtained is 941206.54 MJ, for RCC slab with Air Aerated concrete blocks the embodied energy obtained is 651154.61 MJ, for Filler slab with concrete blocks the embodied energy obtained is 791762.97MJ and for Filler slab with Air Aerated concrete blocks the embodied energy obtained is 613410.13MJ.

For RCC slab with concrete blocks the Life Cycle Cost obtained is 54.97 Lakhs, for RCC slab with Air Aerated concrete blocks the Life Cycle Cost obtained is 51.47 Lakhs, for Filler slab with concrete blocks the Life Cycle Cost obtained is 51.97 Lakhs and for Filler slab with Air Aerated concrete blocks the Life Cycle Cost obtained is 51.57 Lakhs.

For the economy and energy usage of RCC with concrete blocks is more than the filler slab with concrete blocks and ACC blocks.

- Economy is 0.34
- Safety is 0.2
- Social is 0.1
- Environmental is 0.16

(For the designed building with respect to SVAGRIHA Criteria's).

Below mentioned is the tabular representation of the comparison of all the criteria and their functionality. Table VIII represents the conclusive results of all the calculated values. Fig. 7 shows the Steel Quantity used up for different materials used. Fig. 8 shows the Comparison of Concrete quantity required. Fig. 9 shows the Embodied Energy of different materials. Fig.10 represents the Life Cycle Cost Comparison. Fig.11 and Fig.12 are representations of 4 combinations with respect to different criteria.

Table VIII. Rate Analysis Of Conventional Building

Case No.	Roof Material	Block Work Material	Steel Quantity (Kg)	Concrete quantity (m^3)	Cost(Rs)	Embodied Energy(Manual)(MJ)	LCC

1	RCC	Concrete Blocks	2387.05	27.8	12.4	941206.54	54.9738
2	RCC	AAC Blocks	2302.31	25.4	11.9	651154.61	51.4738
3	Filler	Concrete Blocks	2443.03	24.5	12.4	791762.97	51.97
4	Filler	AAC Blocks	2223.08	21.4	12	613410.13	51.57

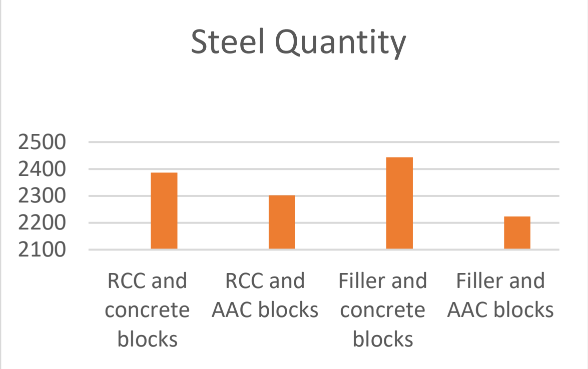

Fig. 3: Steel Quantity comparison

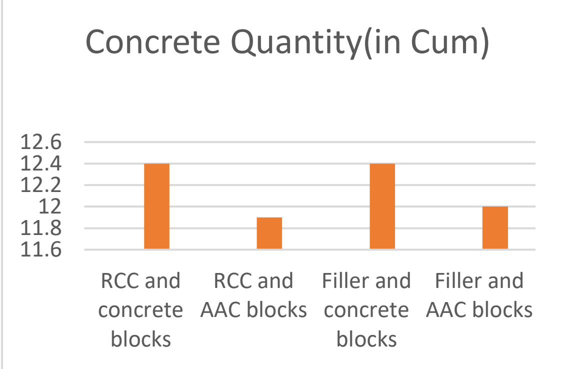

Fig. 4. Comparison of Concrete Quantity

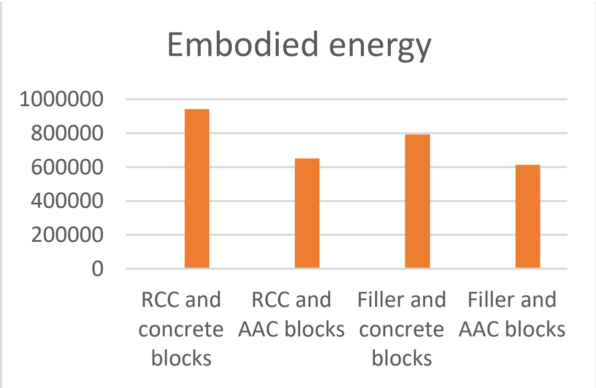

Fig. 5. Embodied Energy comparison

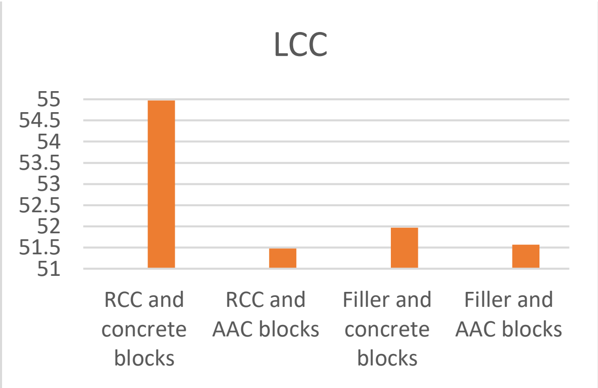

Fig. 6. LCC comparison

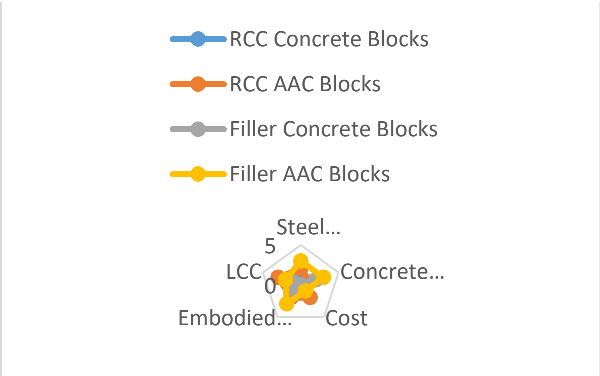

Fig. 7. Radar diagram for S.I

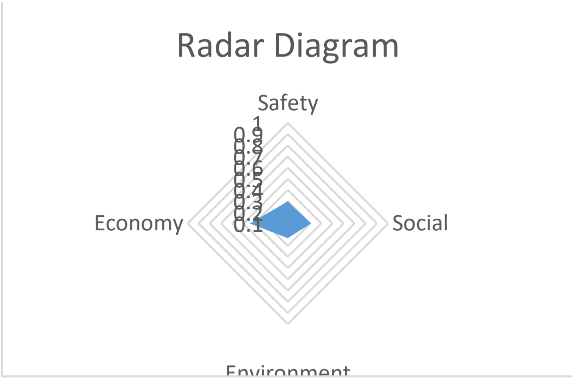

Fig. 8. Radar diagram for S.I

5. Conclusion

It is a known fact that sustainable construction is the need of the hour and it has to be incorporated at the micro level. Therefore, it is very much necessary to make the residential sector green as it comprises of most of the construction industry. This paper helps to get to know about the sustainability index and its indicators.

These indexes and its indicators helps with selection of type of material to be used and this work encourages and motivates the people to opt the green construction by briefing them about the benefits and methods to achieve them. The future of the construction industry rests in the hand of sustainable construction and minimizing the usage of energy by the building. Therefore this paper is a guide to sustainable index.

Further, scope of study can focus on Sustainability Index calculation for different kind of roofs with different block works. Sustainability index can be finalized or performed by using more parameters (social and economic).

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