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INTEGRATED APPROACH TO ENHANCE GREEN BUILDING RATING OF A RESIDENCE: DESIGN, ENERGY AND MATERIALS

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ABSTRACT

Architectural design, energy, and materials play a significant role in determining the green rating of a residential building. The green building rating systems available for assessment are IGBC rating, LEED, GRIHA, and SVAGIHA rating systems. In India, the GRIHA Rating, as well as IGBC Rating, are developed for multi-residential and commercial structures only. This study is based on the SVAGRIHA rating system. SVAGRIHA rating is applied for small versatile and affordable buildings. This study aims to enhance the sustainability and environmental susceptibility of a proposed conventional residential building in Kerala based on the criteria for the SVAGRIHA green building assessment. This is done by defining methods to convert the conventional structure into a green structure. The methods adopted for improvement include variations in materials used, architectural design, and energy aspects of the building this study showed an improvement in rating from zero-rating to three-star rated green building. The implementation of vernacular architecture, traditional building materials, and technologies adopted by Laurie had a huge impact on the development of a green building. The renewable energy systems preferred for rating have a high cost of installation but have a long-term advantage. This is ideal especially in high energy-consuming buildings to attain energy at no cost. The study also shows the necessity of developing advanced low-energy materials and devices for the construction of green buildings.

1. INTRODUCTION

The construction sector has a tremendous impact on the environment. This is caused by various factors such as the area required for buildings, the manufacture of building materials, the transportation of building materials, the treatment and disposal of waste, etc. Natural resources are constantly exhausted as a result of large-scale infrastructure development around the world. Building construction also emits a significant amount of greenhouse gases into the atmosphere, contributing to climate change. The ozone layer is being depleted due to extensive carbon dioxide emissions. We should develop a sustainable method for infrastructure development that require a minimum amount of non-renewable resources while maximizing the usage of renewable natural resources.

Table 1. Impact of Infrastructure development

Infrastructure Development	
Total Carbon dioxide Emissions	40%
Raw Material Consumption	30%
Solid Waste Production	30%
Power Consumption	70%
Asset Utilisation	40%
Water Consumption	12%

From table 1, it is clear that structures have a huge impact on the environment. Here lies the importance of green infrastructure development and its assessment. The conventional methods of construction are also responsible for a large number of harmful outflows. Infrastructure development accounts for 30% of ozone-depleting compounds. An additional 18% of ozone layer depletion is triggered by material overuse and transportation. Infrastructure development also consumes two-thirds of the total crude which include stone, rock, and sand used annually, as well as one-third of all timber consumed (Abouhamad & Abuhamad, 2021).

The selection of materials used in construction and designing of layouts for the building is important to control the impact of construction on the environment. It has become necessary to develop alternative eco-friendly and cost-effective structural materials with fewer innovations for the development of green buildings. The identification of construction materials and designs with the minimum impact on the environment is essential for the sustainable development of a nation. As a result, developing a sense of responsibility for the environment is critical. Choosing items that are naturally great for structure is a brilliant concept. Choosing naturally suitable building materials, designs and conventional methods of energy conservation such as biogas is an excellent way to improve the ecological performance of a residential building (Sharma, 2020).

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2. METHODOLOGY

This study is based on the green building rating assessment for small buildings by SVAGRIHA. The two major systems adopted for green building assessment, IGBC rating and GRIHA rating are not applicable for buildings below 2500 square meters. In this study SVAGRIHA approach is used for the measurement of the green building rating for a proposed residential building in Kerala.

The initial stage of this research involves the planning and design of the proposed residential building. This should be done considering the requirements of the residents. The SVAGRIHA Rating of the project is calculated based on the different criteria prescribed by the system. The following are the methods involved in this research to assess the improvement in the green building rating of the building.

1. The initial assessment of the green building rating is carried out for the proposed residential building based on SVAGRIHA System.

2. The measures required to enhance the green building rating of the building is adopted based on the minimum criteria proposed for various sub-groups in the SVAGRIHA System.

3. The variation in the criteria points required for rating is assessed after the adoption of the measures proposed.

4. The final green building Rating of the building is measured as per the criteria points acquired after implementing improvement measures.

3. PROPOSED BUILDING DESIGN

The assessment of green building rating is to be conducted for a proposed residential building in Kerala. The building design is proposed based on the conventional practices in the region.

Fig 1. Elevation of the Proposed Building

Table 2. Design Details of the Proposed Building

Area	m^2
Total Built-up Area	263.56
Plinth Area of ground Floor	170.27
Plinth Area of First Floor	93.29
Total Plinth area	263.56
Total Coverage Area	170.27
Floor Area of Ground Floor	155.89
Floor Area of First Floor	86.19
Total Floor Area	242.08

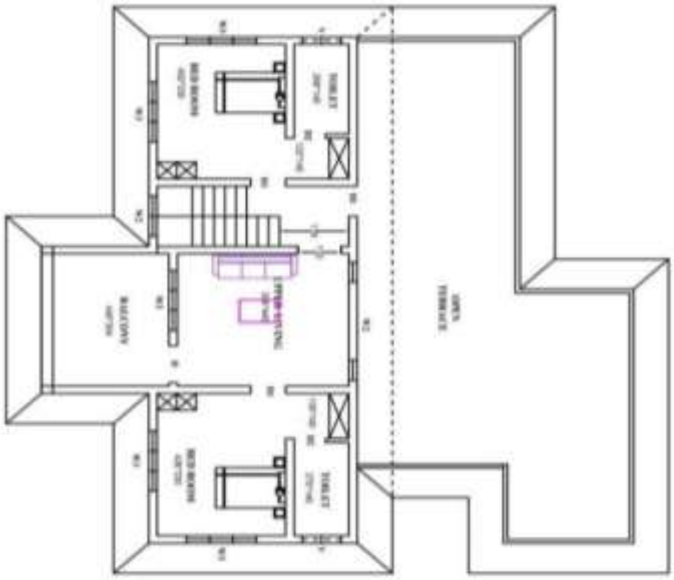

Fig 2. First-Floor Plan of the Building

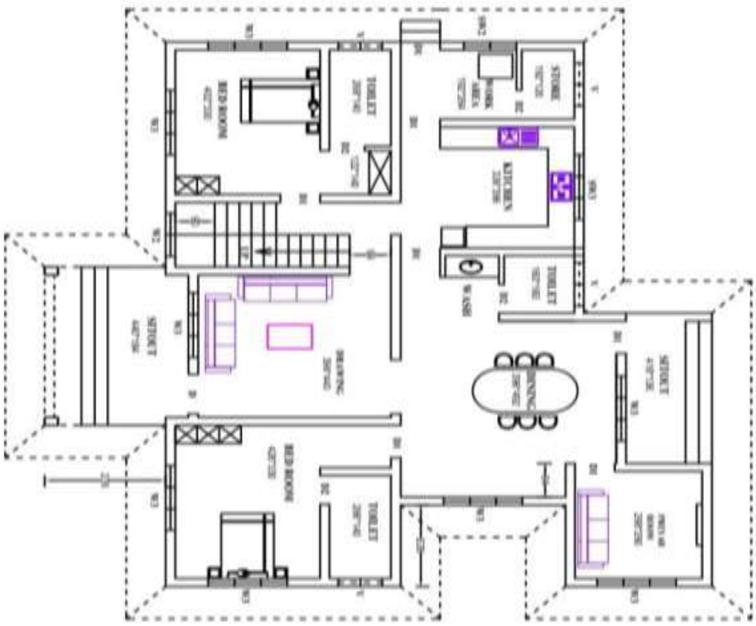

Fig 3. Ground floor plan of the building

As per the estimation and design details, the above structure is to be constructed using reinforced cement concrete. Concrete bricks are proposed for the construction of walls Reinforced concrete slab is preferred for roofing. The foundation is proposed to be built on Random Rubble Masonry considering the availability and economic factors. Cement Plastering is to be adopted in the building construction. Vitrified tiles, as well as ceramic tiles, are preferred for flooring.

4. GREEN BUILDING RATING SYSTEMS IN INDIA

In India generally, we have two systems for assessing green buildings. They are, the IGBC Rating System based on LEED and GRIHA Rating System is applicable for commercial and multi-residential structures. In this research, we adopted the SVAGRIHA approach of green building rating. This method is appropriate to assess buildings below 2500 square meters of area.

The fourteen factors affecting the rating of green building is given in table 1. Minimum requirements for green building rating are classified into five sub-factors. As per the list Landscape, waste and water have attained the minimum requirement of points. So, to qualify for SVA GRIHA Rating the three major factors to be considered for improvement are architecture energy, and materials.

4.1 SVAGRIHA

SVAGRIHA Manual (Adarsh & TERI, 2013) is a guidance-cum-rating system being created for small housing and affordable structures, such as dwellings, and schools, as well as buildings having a total built-up area of less than 2500 square meters. SVAGRIHA was created as an advanced tool for the reduction of the environmental impact of minor infrastructural developments. SVAGRIHA is a basic green building rating assessment tool with parameters based on criteria to evaluate the performance of a construction project as per different criteria in a simplified and efficient manner.

Methods and techniques for the assessment of green building rating through the SVAGRIHA system are given below.

1. The projects with a built-up area of less than 2500 Square meters are eligible for the green building rating assessment based on the SVAGRIHA system.
2. There are 14 factors in the SVAGRIHA system. Architecture and energy, water and waste, materials, landscape, and lifestyle are the primary sub-groups.
3. Criteria points in each sub-group are required to be attempted. each subgroup should acquire the minimum criteria points suggested by the green building rating system otherwise the building will not be eligible for rating.
4. A project can get up to 50 maximum points. For design or material innovation, two extra points are awarded for the project.
5. Rating is measured on a scale of one star to five stars based on the fourteen criteria points.

Mandatory Regulations in SVAGRIHA:

1) The project for construction should have all necessary sanctions and permits from municipal authorities.
2) The project should comply with the regulations for ecological and climate sensitive zones or any other regulation concerning a potential hazard area.

Table 3. List of Criterion Points

SI No.	Criterion Name	Maximum Points
1	Reduce exposed, hard surfaces and maintain native vegetation cover	6
2	Passive architectural design and systems	4
3	Design for reducing direct heat gain and glare while maximizing daylight	6
4	The efficient artificial lighting system	2
5	Thermal efficiency of the 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 resources from waste	2
11	Reduce embodied energy of building	4
12	Use of low-energy materials in interiors	4
13	Adoption of a green Lifestyle	4
14	Innovation	2
	Total	50

The 14 different criteria mentioned here for assessment have variations in the weightage based on their significance. Architectural design, energy devices as well as technologies used for the construction, and the type of materials used play a significant role in the assessment of green building rating. The maximum, as well as the minimum points required for each sub-group, are given below.

Table 4. Subgroup Point Range

Sub-Group	Maximum points	Minimum points
Landscape	6	3
Architecture & Energy	21	11
Water & waste	11	6
Materials	8	4
Lifestyle	4	1
Total	50	25

As per table 4, the minimum total points required for being eligible for assessment based on SVAGRIHA is 25 (Chaudhary et al., 2018).

Table 5. Star Rating for Green Building

SI No.	Criterion Name	Points
1	Reduce exposed, hard surfaces and maintain native vegetation (Landscape)	3
2	Passive architectural design and systems (Architecture)	2
3	Design for reducing direct heat gain and maximizing daylight (Architecture)	2
4	Efficient artificial light system (Energy)	2
5	Thermal efficiency of the building envelope (Architecture)	1
6	Use of energy-efficient appliances (Energy)	0
7	Use of renewable energy on-site (Energy)	1
8	Reduction in building and landscape water demand (Water)	2
9	Rainwater harvesting (Water)	2
10	Generate resources from waste (Waste)	2
11	Reduce embodied energy of building (Material)	2
12	Use of low-energy materials in interiors (Material)	0
13	Adoption of green Lifestyle (Lifestyle)	1
14	Innovation	2
	Total	21

4.2 GREEN RATING ASSESSMENT OF THE PROPOSED RESIDENTIAL BUILDING

The green building rating of the proposed building is measured based on the SVAGRIHA Rating System. The 14 criteria for rating are evaluated for the SVAGRIHA assessment.

Table 6. Initial Assessment of Criteria

SVAGRIHA Rating	Achieved Point Range
1 star	25-29
2 star	30-34
3 star	35-39
4 star	40-44
5 star	45-50

As per the total points attained as mentioned in table 6 and table 7 the proposed building is unable to satisfy the minimum points required for the green building rating.

Table 7. Initial Sub Group Points

Sub-Group	Criteria Points
Landscape	3
Architecture & Energy	6
Water & waste	6
Materials	1
Lifestyle	1
Innovation	2
Total	21

As per table 7, the architecture, energy, and material sections failed to attain the minimum points required to be eligible for assessment. Also, the above two categories account for nearly 60 per cent of the total points responsible for green building rating.

Thus, the improvement for these two subgroups can result in a drastic enhancement in the rating. This can be achieved by adopting low-energy materials, reducing the embodied energy of the building, energy efficiency, and designing environment-friendly buildings (Choudhary et al., 2021).

5. IMPROVEMENT MEASURES

5.1 Architecture

The architecture and elements of design constitute 26% of the green building rating with a maximum point of 13 accountable for its sustainable and environment-friendly design adopted. In the proposed design there is minimal consideration for thermal efficiency and design factors which results in achieving less than 40 % of the total criteria points as per the data given in table 8 where the criteria point achieved is 6 for architecture and energy.

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The methods proposed by Laurie Baker (1986) in his designs are an ideal way to convert the proposed residential building into a more environment-friendly and sustainable one. This includes the vernacular mode of architecture that encourages the usage of localized resources and technologies for construction. The regional and traditional designs in architecture will also make the buildings more resilient to climate and natural disasters.

In Kerala, sloped roofs are constructed traditionally. This method is appropriate for the tropical climatic condition of the region. Also, the shades for the building should never be limited to the windows and ventilators and should be constructed across the walls of the building. Before designing the foundation, soil testing should be done for residential buildings also. The cross ventilation of the building should be designed considering the thermal and wind factors. Also, a minimalist approach should be incorporated into the design by including maximum utility in the limited area. (Gupta, 2021)

Also, while designing the building the topography of the site should be taken into consideration. The design should not cause severe harm to the terrain by reducing the amount of excavation and earthwork. Also introducing traditional architectural design helps in the reuse of old material from demolished buildings. Vertical construction adopted for the proposed building is advisable in building construction as it reduces the foundation work and thereby the raw materials and labour required for foundation masonry as the area of the ground floor get reduced.

5.2 Materials

About 16% of the maximum points in the rating are influenced by the type of material used in the construction. Conventionally cement bricks are widely used in construction due to their economic and workability factors while clayey bricks have more cost and labour intensiveness. But the thermal insulation in clayey brick used construction and sustainability should also be considered. Also, minimum wastage of material including brickbats should be taken care of while construction. To reduce the number of bricks required it's advisable to use the rat trap bonding technique which not only reduces 30 per cent of brick required but also improves the thermal insulation of the building due to the cavities present in between the stretchers.

Clayey tiles are preferred for roofing as it provides both thermal protection and rain because of their slope design. Compared to the embodied energy in reinforced cement concrete construction using cement and steel the embodied energy of locally available clayey bricks and tiles is very less. The only factor which reduces the impact of materials is the measurable amount of fly ash present in the Portland Pozzolana Cement used for construction. Even then construction with the minimum usage of cement through exposed brick construction and mud plastering helps in reducing a considerable amount of energy as the cost of transportation of materials is also a significant factor accountable for its embodied energy. Apart from the vernacular approach advanced materials such as natural fibre-based composite panels should also be adopted for improving sustainability. Also, maximum reuse of waste materials such as old wooden windows, doors, frames, and furniture should be integrated into the construction. The clayey tiles for roofing can reduce the cost and embodied energy of the building to a reduced value to improve the impact of the building over the exploitation of natural resources. Regionally available random rubble masonry engineered materials with recycled components, rubber, lignocellulose materials, bamboo products, and materials from agricultural or other forms of waste can also be used in developing low-energy materials (Adrina & Dagmar, 2021).

5.3 Energy

Energy accounts for 18 % of the green rating assessment. Nearly 35 % of the factors responsible for reducing energy consumption are followed as per the assessment for green building rating. To reduce energy wastage low energy consuming devices are to be installed primarily for refrigeration and air conditioning. The energy rating of these devices should be at least above 3-star and a 5-star rating is ideal for maximum reduction in consumption of energy by the devices.

The installation of solar water heaters, as well as solar panels, will improve the clean and renewable energy usage of the building. More efficient solar panels based on the average monthly consumption should be designed and also the water heaters installed should be able to satisfy the daily hot water requirement of the building residents. The lighting power density of the lights in the building is also a factor that affects the energy assessment in rating. So, this should be maintained minimum by reducing the number of points. By the installation of a biogas plant, the consumption of liquefied petroleum thereby conserves a sufficient amount of energy in cooking. Adopting public transport system and electric vehicles also helps in improving the green building rating of the residential project. During the electrification of a project, we should allocate a facility for fast charging required for electric vehicles to improve the green building rating.(Choudhary et al., 2021)

By adopting advanced and innovative technologies to improve the sustainability of the building we can achieve a measurable improvement in the points required for the green building rating based on SVA GRIHA. The architectural and energy factors influencing rating can be increased up to 16 points by adopting the recommendations for improving sustainability and reducing the environmental impact. This can be attained by adopting minimalism in the design.

The utilisation of low-energy materials and vernacular architecture which promotes localized procurement of materials results in a drastic transformation of acquiring criteria points to twice the initial value. The newly changed list of points acquired by sub-factors in green building is mentioned in table 8.

After adopting the improvement measures all the subgroups were able to satisfy the minimum point criteria with a total of 36 points. This increase in points by a value above 50 % of the initial sum was achieved by making variations in 2 subgroups only which depict the importance of those groups in determining the green building rating of the proposed residential building based on the SVAGRIHA system for assessment.

Table 8. Improved Subgroup Points

Sub-Group	Improved Points
Landscape	3
Architecture & Energy	16
Water & waste	6
Materials	8
Lifestyle	1
Innovation	2
Total	36

Thus, by implementing the advancements proposed above in this article to improve the technology and methods of building construction in the fields of materials, architectural design, and energy consumption the proposed residential building becomes eligible for receiving a 3-star as per SVA GRIHA green building assessment system. So proper planning before the implementation of construction is necessary for developing a green building as the methods of converting a residential building into a green building after construction are passive measures that are not sustainable.

6. RESULTS

As per the SVAGRIHA Assessment, the green building rating of the proposed building has a significant dependency on the materials, energy, and architecture of the proposed design. The initially proposed residential building acquired 21 points from all the criteria involved. After undertaking improvement measures for the sub groups which failed to achieve the minimum points required the green building rating of the residential building qualified the minimum range for all the sub groups thereby making the project eligible for assessment and thus received a 3-star rating with total criterion points of 36 from all the 14 criteria.

7. CONCLUSION

From the study, it’s clear that the green building rating of a building can be enhanced by making required amendments in the materials used for construction design and architectural variation to improve the utility and sustainability of the building and the reduction of energy consumption in the building using efficient devices and technologies to harvest renewable energy sources.

As per the research, there is an increase of more than 50% of the initial rating parameters by adopting sustainable practices in various criteria. The green building rating can be regarded as a passive assessment tool for measuring sustainability based on the parameters involved in the system. The study proves that the measures that are taken to improve the energy, materials, and design of the proposed residential building helped in making the project sustainable.

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