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Design And Life Cycle Assessment Of Green Building & Its Material Using Bim

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Abstract
The construction industry's substantial environmental footprint underscores the urgent need for sustainable building practices. This research investigates the integration of Building Information Modelling (BIM) and Life Cycle Assessment (LCA) methodologies to enhance environmental performance in construction. Key findings reveal that early implementation of green metrics in building design is crucial for combating climate change. Through a case study on a residential building in Indore, India, utilizing Autodesk, Revit software, the study demonstrates the viability of green building materials and energy-efficient strategies. Comparative cost analysis highlights the economic and environmental benefits of green construction practices, despite initial investment challenges. Results indicate a potential 21% reduction in energy consumption and a 20% decrease in life cycle costs for energy-efficient buildings. Moreover, renewable energy generation equipment, such as solar panels, offers significant long-term savings and environmental benefits. This research underscores the importance of comprehensive cost analysis and the role of BIM in optimizing sustainable construction practices. By prioritizing energy efficiency and resource conservation, stakeholders can effectively address global energy and climate challenges while promoting environmentally friendly building designs.
Keywords: *Building Information Modelling (BIM), green building, sustainable construction, energy efficiency, cost analysis.*

INTRODUCTION

The construction industry significantly contributes to environmental degradation, accounting for approximately 30%–40% of the global environmental burden through extensive resource consumption and CO_2 emissions. As the depletion of natural resources and non-renewable energy intensifies due to construction activities, the early adoption of environmentally responsible strategies in building design becomes critical in mitigating the effects of climate change. Life Cycle Assessment (LCA) has emerged as a robust analytical framework for quantifying the environmental impacts and resource utilization associated with a building throughout its lifecycle. The extraction of data from Building Information Modelling (BIM) files enables accurate and comprehensive LCA calculations, allowing for systematic evaluation and comparison of the environmental performance of various building components and design alternatives. The integration of BIM and LCA during the early design stages significantly improves data accessibility and supports the development of sustainable construction practices by enhancing environmental performance metrics. Despite contributing 13% to global GDP, the construction industry faces challenges as a major resource consumer and waste producer, necessitating sustainable approaches. Regulatory measures and voluntary certifications promote sustainable building practices, prompting the integration of advanced techniques like BIM and LCA. Globally, buildings consume a substantial share of final energy and emit greenhouse gases, emphasizing the importance of energy efficiency. BIM-based simulations facilitate energy analysis and retrofitting strategies, reducing reliance on mechanical systems.While building construction fulfils human needs, it poses both positive and negative impacts throughout its lifecycle, notably in energy, water, and material resource consumption. Buildings consume up to 40% of total end-use energy worldwide, with developed countries heavily reliant on the building sector. With over 50% potential for energy savings, the building sector emerges as a key player in addressing global energy and climate challenges. "Going Green" has

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gained popularity, yet affordability remains a concern. Addressing this global issue requires detailed strategies for accessible green construction practices.In summary, integrating BIM and LCA methodologies into building design offers promising solutions to mitigate the environmental impact of the construction industry. By prioritizing energy efficiency, waste reduction, and sustainability objectives, stakeholders can optimize building designs to meet global energy and climate challenges effectively.

PROPOSED METHODOLOGY

This paper presents a comprehensive investigation into the life cycle assessment (LCA) of residential buildings, employing Autodesk Revit software as a primary tool. The methodology involves a systematic literature review to identify pertinent information on green building materials and related journals. Subsequently, leveraging Autodesk Revit version 2024, an architectural model of a residential structure is generated based on a detailed case study. Following the creation of the building model, simulations are conducted to evaluate the energy requirements and material usage throughout the building's life cycle. Furthermore, utilizing Autodesk Revit and Microsoft Excel, a comparative cost analysis is conducted between conventional and green building materials and energy consumption patterns. This comparative study sheds light on the economic viability and environmental impact of integrating green building practices into residential construction projects. Through a rigorous methodology, this research contributes to a deeper understanding of the benefits associated with sustainable building practices, providing valuable insights for industry practitioners, policymakers, and researchers alike.

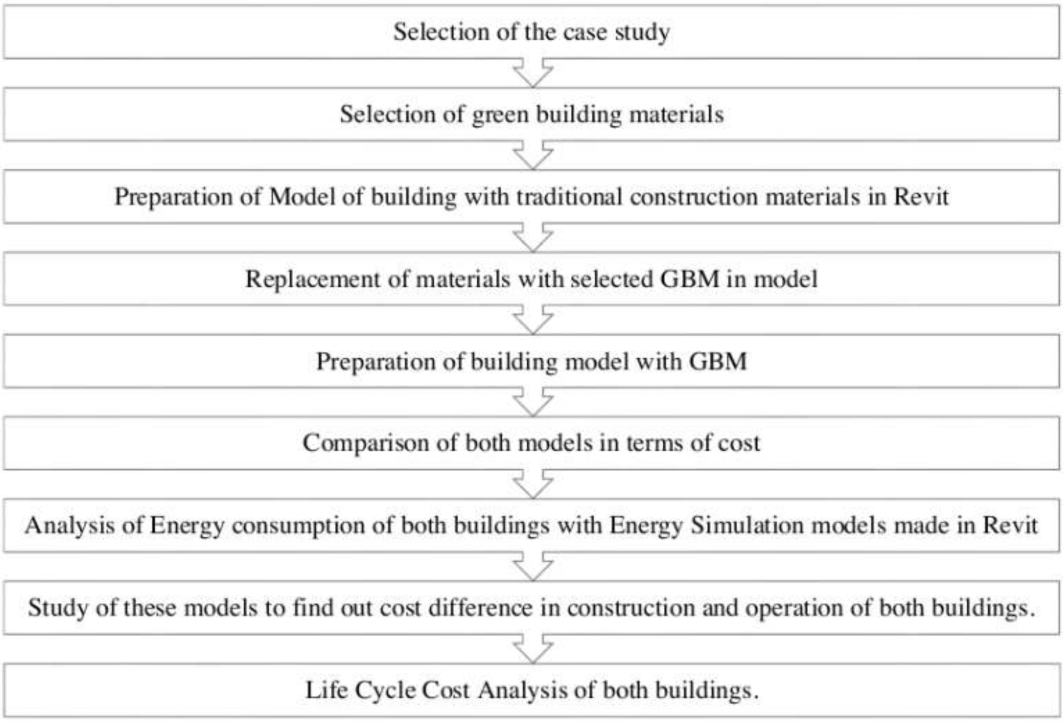

Figure 2.1 Research Methodology Chart

GREEN BUILDING PARAMETERS

Site selection

The project focuses on a residential building in Indore, initially constructed using traditional materials, into a more sustainable and energy-efficient structure. The selected site is a G+4 storied building with a plot area of 2000 sq. ft., featuring residential units and ground-floor shops. The first step involves finalizing the transition to green building materials to replace the conventional ones. This shift aims to enhance the building's sustainability and reduce its environmental impact. Additionally, the installation of energy-generating equipment, particularly solar panels, is prioritized to decrease reliance on non-renewable energy sources, aligning with renewable energy objectives. Furthermore, implementing a proper water harvesting system is deemed essential to optimize water efficiency within the building. By capturing and utilizing rainwater effectively, the building can reduce its water consumption and reliance on external water sources. Overall, these measures contribute to the building's eco-friendliness, resource efficiency, and alignment with contemporary sustainability standards.

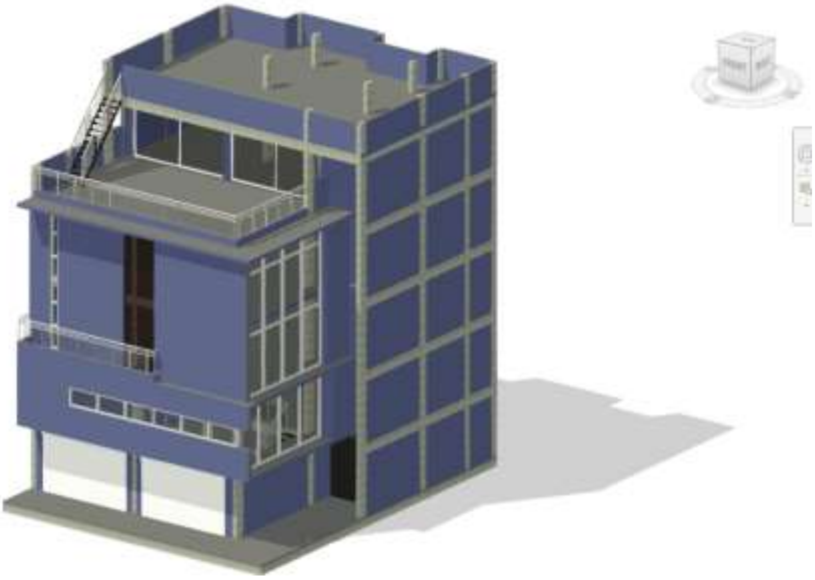

Figure 3.1 G+4 Residential building selected as a case study

GREEN BUILDING MATERIALS

ACC BLOCKS:

Autoclaved Aerated Concrete (AAC) blocks are low-maintenance, precast building units known for their exceptional thermal insulation, lightweight characteristics, and structural durability. Owing to their superior heat-insulating properties, AAC blocks effectively minimize the ingress of external heat and help maintain interior thermal comfort, leading to substantial reductions in air conditioning energy demands—typically up to 25%. In addition to thermal benefits, the use of AAC blocks results in decreased structural loads, thereby reducing the requirements for foundation depth, structural steel reinforcement, and mortar consumption.AAC blocks are composed of environmentally sustainable materials, including quartz sand, calcined gypsum, lime, Portland cement, water, and aluminium powder. The introduction of aluminium generates hydrogen during the manufacturing process, forming uniformly distributed air voids that contribute to the material's low density and thermal performance.

With a weight approximately 50% lower and a size up to ten times greater than conventional clay bricks, AAC blocks offer ease in handling, cutting, and shaping, which enhances construction efficiency. These characteristics collectively make AAC blocks a sustainable and energy-efficient solution for modern building practices, aligning with green construction goals.

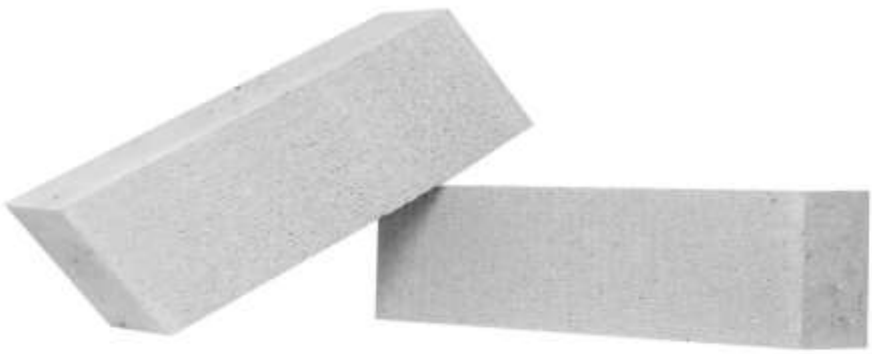

Figure 3.2 ACC Blocks

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CERAMIC TILES:

Ceramic Tiles play a significant role in green construction due to their sustainability attributes. Firstly, they are often crafted from recycled materials or renewable resources, lessening their environmental footprintCeramic tiles contribute to energy efficiency through their inherent reflective properties, which reduce the reliance on artificial lighting and cooling systems. Additionally, they typically exhibit low emissions of volatile organic compounds (VOCs), thereby supporting improved indoor air quality. From a water conservation perspective, ceramic tiles are engineered to require minimal water during both manufacturing and installation processes, enhancing their suitability for sustainable building applications.

Figure 3.3 Ceramic tiling Revit Autodesk image

RICE HUSK ASH:

Rice husk ash concrete is a type of building material made by mixing rice husk ash, a leftover from burning rice husks, with concrete. It helps make buildings stronger and more durable because the ash reacts with certain compounds to strengthen the concrete. This type of concrete is considered "green" because it's environmentally friendly. Using rice husk ash reduces the need for traditional cement, which produces a lot of carbon dioxide during manufacturing. By reusing rice husk ash, we also solve the problem of disposing of this agricultural waste, which can be tricky. Additionally, buildings made with this concrete can save energy because they provide better insulation, keeping them cooler in summer and warmer in winter. Overall, rice husk ash concrete is a smart choice for construction because it's good for the environment, makes buildings stronger, and can help save energy and money in the long run. For gain of a design strength of concrete only 20% of total cement replaced by RHA.

The incorporation of rice husk ash (RHA) significantly influences the properties of concrete, contributing to its sustainability and performance. RHA serves as a vital component in the development of green concrete due to its pozzolanic characteristics and eco-friendly nature. Its addition reduces the heat of hydration, thereby mitigating drying shrinkage and enhancing the overall durability of the concrete mix. Furthermore, RHA improves the concrete's resistance to chemical attacks, particularly against chlorides and sulphates, making it more suitable for aggressive environmental conditions.

Figure 3.4 Rice husk

VEDIC PLASTER

Vedic plaster, refers to a traditional method of plastering walls that has its roots in ancient Indian architectural practices, particularly from the Vedic period. This technique involves using natural materials such as gypsum, clay, lime, and cow dung to create a durable and breathable surface for walls and ceilings. Vedic plastering typically involves several layers of different materials, each serving a specific purpose. The result is a smooth, aesthetically pleasing surface that is also environmentally friendly and promotes good indoor air quality due to its breathable nature.

Unlike cement plaster, Vedic plaster does not release carbon dioxide. Its eco-friendly product is made entirely of natural resources; no chemicals are added during the production process. The qualities that cow dung provides are what make this product what it is. Unmatched qualities include radiation-proof quality, a natural air purifier, a thermal insulator that allows for a temperature differential of ten to fifteen degrees, pollution control measures, and more that are hard to find in other sources. A mixture's 20–22% cow dung makes a significant contribution to the plaster's manufacture. It is therefore valuable from an economic and social standpoint. Additional advantages include improved health, less water use, decreased moisture, a source of positive energy, an indirect increase in the usefulness of cows, an increase in their economic value, and protection against.

Figure 3.5 Vedic plaster

VEDIC PLASTER		
PROPERTIES	**SPECIFICATION**	**Results**
Setting time initial minute	IS: 2542 (Part I/Sec 3) - 1978	10
Setting time final minute	IS: 2542 (Part I/Sec 3) - 1978	50
flexural Strength Mpa (28 days)	BSEN:1015(pt.18)	5.6
compressive strength Mpa (28 days)	IS: 2542 (Part I/Sec 5) - 1978	32
Appearance		Off white
pH		9.4
dry bulk Density at 20 °C	IS: 2542 (Part I/Sec 12) - 1978	750 kg/cm³
dry set Density at 20 °C	IS: 2542 (Part I/Sec 5) - 1978	1260 kg/cm³
CO2 remove per 25 kg		5.40 kg
Shielding efficiency	(IEEE 299:2006).	32 decibels of attenuation at 900 Megahertz (MHz).
washability		Washable

finish		natural matte
protection against		High frequency radiation & low frequency electric field.
TVOCs (Volatile Organic Compounds)	ASTM D3960	free of VOC emissions
Odor		odourless
Flashpoint		Non-flammable

Table 3.1 Vedic Plaster Properties

SOLAR PANELS:

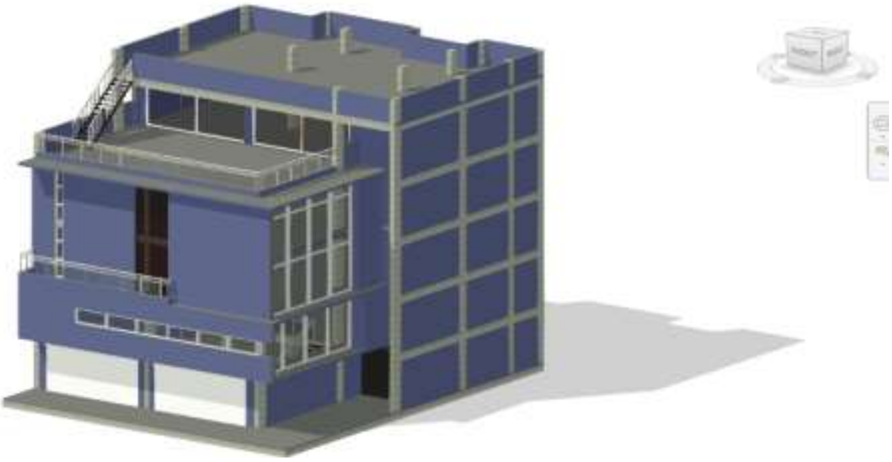
Solar panels are like special boxes that catch sunlight and turn it into electricity. They use tiny parts called solar cells, usually made from silicon, which make electricity when sunlight hits them. In green buildings, solar panels are super helpful. They use sunlight, a renewable energy source, so we do not have to rely on dirty fossil fuels that run out. Plus, they make electricity right where it is needed, cutting down on bills. Since they do not need much fixing and do not make any pollution, they are great for the environment. Solar panels also keep things stable by protecting against sudden changes in energy prices and supplies. Even though they can cost a lot at first, they save a ton of money in the long run by lowering electricity bills. Plus, they create jobs in the renewable energy field, helping local communities. So, putting solar panels on green buildings is not just smart, it is also good for saving money, keeping things clean, and looking after the planet. Solar Panels Investing in rooftop solutions leads to great savings, while protecting the environment. Tata Power Solar offers solar rooftop for home. Save and Earn from your idle rooftop space. Tata solar power is one of the leading companies in solar power generation in India. Tata solar power provides rooftop solar panels with various varieties based on area available. Central government also provides subsidies for provision of solar panels.

Particulars	Description
Tata solar Panel	12 nos modules of 540 watts each
Tata solar grid inverter	6 kw
Soler Accessories	Solar GI Structure 6kw, MC4 Connector, Array Junction Box, AC Distribution Box, 70 nos Fasteners, Solar Cable (Appx 70 Meter), AC Cable (Appx 30 Meter), Cable Tie, Conduit Pipe, Earthing Kit, Lighting Arrestor
Space required	400 sq. feet.
Generate	720 Unit monthly
Price	Rs. 370,000

Table 3.2 Solar Panel description

RESULTS AND DISCUSSIONS:

This study aims to compare the construction costs between a conventional building and a green building. A G+4 residential building was chosen as the subject of analysis. Initially, a model of the building using traditional construction materials was developed, providing detailed volumetric data for each building element. This volumetric data facilitated the estimation of material quantities required for construction. Subsequently, a second model utilizing green building materials was constructed using the same methodology based on volumetric analysis.



Following the establishment of both models, the total cost of traditional materials that could potentially be replaced by green building materials was computed. Simultaneously, the cost associated with acquiring the necessary green building materials was determined.

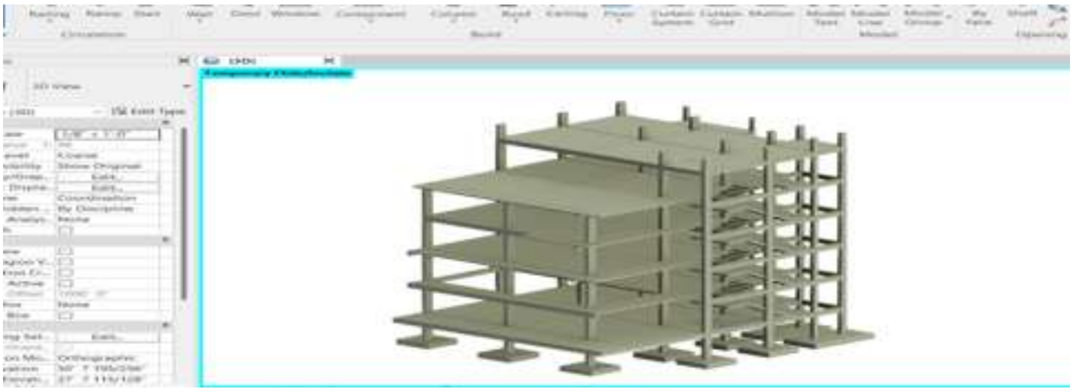


Figure 4.1 Structural Model

Figure 4.2 Architectural Model

Cost Required for traditional materials						
s.no.	**Materials**	**Quantity**	**unit**	**Rate**	**per**	**Amount**
1	Concrete (C+S+A)	183	cu.m	3800	cu.m	694260
2	Steel					
	6mm	593	kg	48	kg	28464
	8mm	2,260.00	kg	54	kg	122040
	10mm	7,823.00	kg	58	kg	453734
	12mm	7,328.00	kg	58	kg	425024
	16mm	731	kg	68	kg	49708
3	Red brick	64,473.00	nos	9	nos	580257
4	Plaster	2,077.00	sq.m	194	sq.m	402354
5	Tiles	650.00	sq.m	598	sq.m	388700
6	Doors					

	Roller Shutter door	19.00	sq.m	3755	sq.m	71400
	Door 30"X84"	16.00	sq.m	2700	sq.m	43200
	Door 36"X80"	4.00	sq.m	2700	sq.m	10800
	Door 48"X84"	13.00	sq.m	2700	sq.m	35100
	Sliding glass door	19.05	sq.m	6500	sq.m	123825
7	windows					
	windows louvers 16"X36"	3.72	sq.m	3765	sq.m	14005
	windows louvers 24"X36"	2.79	sq.m	3765	sq.m	10504
8	Glass panels	43.2	sq.m	3765	sq.m	162648
9	Iron + Aluminium louvers	501	r.m	195	r.m	97695
10	Energy generator equipment's					0
Total Cost						3713718

Table 4.1 Cost Required for traditional materials

Cost Required for green building material						
s.no.	**Materials**	**Quantity**	**unit**	**Rate**	**per**	**Amount**
1	Rice Husk Concrete (C+RHA+S+A)	183	cu.m	4000	cu.m	732000
2	Steel					
	6mm	593	kg	48	kg	28464
	8mm	2,260.00	kg	54	kg	122040
	10mm	7,823.00	kg	58	kg	453734
	12mm	7,328.00	kg	58	kg	425024
	16mm	731	kg	68	kg	49708
	Total Reduced steel cost					1025022
3	ACC block	9,210.00	nos	55	nos	506550
4	Vedic Plaster	2,077.00	sq.m	250	sq.m	519250
5	Ceramic tiles	650.00	sq.m	700	sq.m	455000
6	Door					
	Roller Shutter door	19.00	sq.m	3755	sq.m	71400
	Door 30"X84"	16.00	sq.m	2700	sq.m	43200
	Door 36"X80"	4.00	sq.m	2700	sq.m	10800
	Door 48"X84"	13.00	sq.m	2700	sq.m	35100
	Sliding glass door	19.05	sq.m	6500	sq.m	123825
7	windows					
	windows louvers 16"X36"	3.72	sq.m	3765	sq.m	14005
	windows louvers 24"X36"	2.79	sq.m	3765	sq.m	10504
8	Doble Glass panels	43.2	sq.m	4400	sq.m	190080
9	Iron + Aluminium louvers	501	m	195	m	97695
10	Energy generator equipment (Soler Panels)	38	sq.m			370000
Total cost						4204431

Table 4.2 Cost Required for Green Building materials

The research delineates that the traditional building materials, potentially replaceable by their green counterparts, incur a total cost of INR 37.13 lakhs. In contrast, the acquisition of green

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building materials accrues to INR 42.04 lakhs, augmented by an auxiliary expense of approximately INR 3.70 lakhs for energy generation equipment.
In a comparative analysis, the green building approach entails an incremental cost of INR 4.90 lakhs over the traditional building methodology, encompassing both material procurement and energy generation equipment expenses.

Cost Comparison			
Materials	**Cost**	**Materials**	**Change cost**
Concrete (C+S+A)	694260	Rice Husk Concrete (C+RHA+S+A)	732000
Steel	1078970	Reduced Steel	1025022
Red brick	580257	ACC Block	506550
Plaster	402354	Vedic Plaster	519250
Tiles	388700	Ceramic tiles	455000
Doors	284325	Door	284325
windows	24509	windows	24509
Glass panels	162648	Doble Glass panels	190080
Iron + Aluminium louvers	97695	Iron + Aluminium louvers	97695
Energy generator equipment's	0	Energy generator equipment (Soler Panels)	370000
	3713718		4204431

Table 4.3 Cost comparison of materials

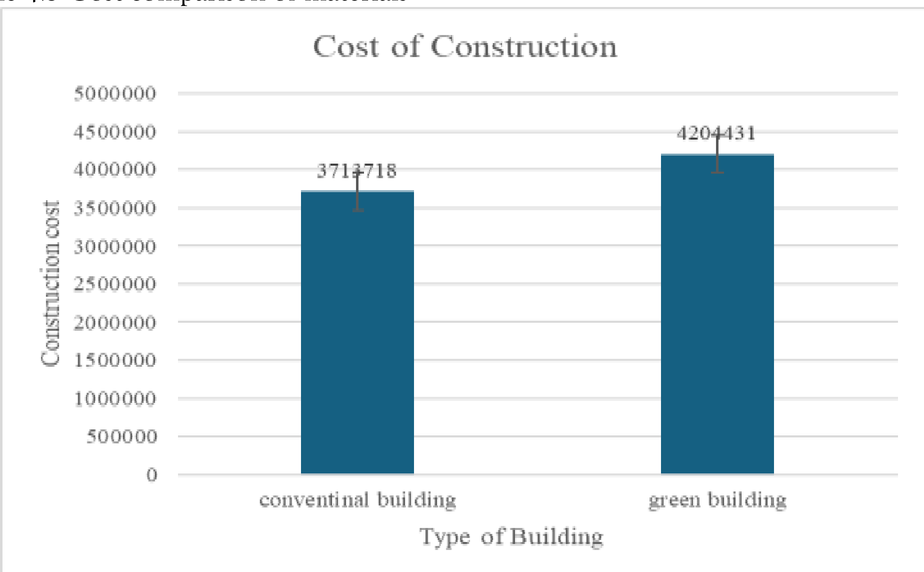

Figure 4.4 Cost Compression

In this phase, a thorough analysis of the building was conducted utilizing Revit software, facilitating both structural and energy assessments through Revit Insight. Employing simulation techniques within Revit, all building components were scrutinized based on their respective characteristics

Figure 4.5 Conventional Building Energy Model

The initial energy simulation model yielded an estimated electricity expenditure of approximately 5.51 USD per square meter annually, considering a total building area of 429 square meters. The conventional building model indicated a total energy consumption of 134 kilowatt-hours per square meter per year, amounting to 57,486 kilowatt-hours annually.

Conversely, the simulation model for the green building projected an electricity cost of around 5.20 USD per square meter annually, with the same building area of 429 square meters. This model demonstrated a reduced energy demand of 125 kilowatt-hours per square meter per year, totalling 53,625 kilowatt-hours annually.

Figure 4.6 Green Building Energy Model

Comparing the two models, it was determined that employing green building materials could potentially conserve approximately 3,861 kilowatt-hours of energy.Upon comprehensive examination of all energy simulation models, it was concluded that the annual energy expenditure for a traditional material building amounted to 197,358 INR, whereas the cost associated with

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energy consumption in a green building was reduced to 186,333 INR. Consequently, an approximate savings of 11,025 INR was achieved through the utilization of green building practices. Renewable energy generation equipment plays a crucial role in mitigating the costs associated with energy consumption throughout the life cycle of a building.
According to data from Tata Solar Power, a 400-square-foot installation of solar panels yields an average monthly output of 720 units, translating to 8,640 kWh per year.
This solar energy generation results in a cost savings of INR 28,062 annually. Upon subtracting the solar energy expenses from the total energy costs of the green building, the residual annual external energy requirement for powering the building is approximately INR 156,271 per year.
From all these studies, we come to result that by using these green building materials and energy generation devices we need 15 years to recover extra cost require during construction. Also, In 30 years, Green Building benefits nearly INR 8.62 lakhs.

Conventional building				
Life cycle	1 year	10 years	20 years	30 years
Life cycle energy consumption	134 kwh/m2/year	1340 kwh/m2/year	2,680 kwh/m2/year	4020 kwh/m2/year
Life cycle cost (INR)	197,358 INR	1,973,580 INR	3,947,160 INR	5,920,720 INR

Table 4.4 Life cycle of energy consumption and cost of the conventional building

Green building				
Life cycle	1 year	10 years	20 years	30 years
Life cycle energy consumption	125 kwh/m2/year	1250 kwh/m2/year	2,500 kwh/m2/year	3750 kwh/m2/year
Life cycle cost (INR)	156,271 INR	1,562,710 INR	3,125,420 INR	4,688,130 INR

Table 4.5 Life cycle of energy consumption and cost of the green building

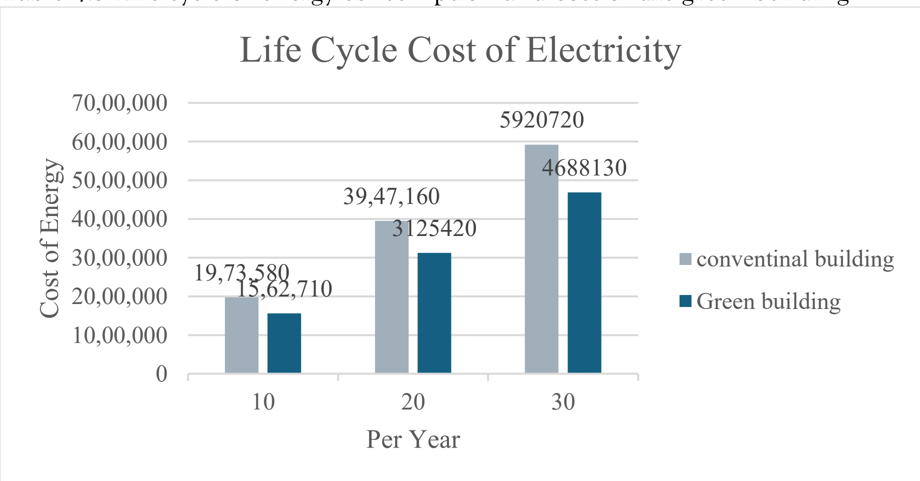

Fig 4.7 Green Building vs Conventional Building energy cost consumption

5. CONCLUSION

The utilization of Revit software in the current study demonstrates that quantities of materials can be efficiently prepared during the development of 3D models. This capability significantly reduces the time required for material quantification and component identification.

Building Information Modelling (BIM) facilitates a streamlined construction process yielding precise outcomes within reduced timeframes and costs. It offers project participants enhanced project visualization and enables pre-construction modifications, thus enhancing project accuracy and durability. BIM also optimizes scheduling and sequencing for construction phases, thereby mitigating risks. The insights derived from Life Cycle Assessment (LCA) research will empower designers, engineers, and building users to make informed decisions promoting sustainable development.The study reveals that the annual energy cost of a structure under base conditions amounts to Rs. 197,358. However, for buildings constructed using energy-efficient materials, the annual energy cost reduces to Rs. 156,271, marking a 21% decrease. Over a 30-year lifespan, a conventional building incurs a life cycle cost of Rs. 5,920,720, whereas an energy-efficient building's life cycle cost amounts to Rs. 4,688,130, indicating a 20% efficiency gain in total life cycle cost.In the base scenario, the annual electrical energy consumption of a building is approximately 57,486 kWh. By employing energy-efficient materials, the annual electrical energy consumption reduces to 44,985 kWh, representing a 22% efficiency improvement. Over the building's life cycle, electricity consumption decreases from 1,724,580 kWh to 1,349,550 kWh, constituting a 21% efficiency enhancement through the use of energy-efficient materials.

Green building construction typically incurs a 20% higher cost compared to conventional building construction due to material expenses. However, meticulous planning can optimize these costs, which can be recouped over the building's life cycle.Revit Autodesk emerges as a valuable tool for analysing building life cycles, aiding in planning, execution, and forecasting of construction projects.Green buildings contribute to reduced energy consumption throughout their life cycles, thereby offsetting the additional material costs incurred during construction. Renewable energy sources, such as solar and wind energy, play a pivotal role in energy consumption reduction.

The integration of green building practices and renewable energy generation equipment can yield energy savings of up to 35%, thereby mitigating carbon emissions and combating global warming. Green building practices significantly enhance indoor environmental quality; however, cost remains a crucial consideration for households with average incomes. Hence, comprehensive cost analysis is imperative for informed decision-making.

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