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Construction Materials for Sustainable Environment in Residential Buildings

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Abstract

This paper delves into the concept of eco-structure construction, particularly in India's rapidly growing population and urbanisation. It addresses the substantial energy consumption of buildings, which accounts for up to forty per cent of total energy usage, emphasizing the urgency to create sustainable environments. The study explores sustainable building practices, focusing on resource efficiency, waste reduction, and improved living conditions. It discusses the benefits of sustainable architecture, including improved indoor environment quality, water conservation, enhanced health outcomes, and reduced strain on shared resources. Additionally, the paper outlines the scope of environmental sustainability and the components of sustainable and green building design, highlighting the holistic approach required for effective environmental conservation and human well-being. Also, this research advocates for a paradigm shift towards eco-friendly building materials and methods to create a healthier and more sustainable future. Low-carbon and recycled materials: Using recycled aggregates, fly ash, and low-carbon concrete reduces greenhouse emissions and enhances durability in residential buildings. Biodegradable and bio-based materials: Materials like bamboo, hemp Crete, and mycelium offer renewable, biodegradable options with strong insulation properties, suitable for non-load-bearing applications. Energy-efficient insulation: Phase Change Materials (PCMs) and Insulating Concrete Forms (ICFs) provide superior thermal comfort, reducing energy needs for heating and cooling. Locally sourced and earth-based materials: Region-specific materials, like rammed earth and adobe, minimize transport emissions and naturally regulate indoor temperatures. Green roofing and vegetation integration: Green roofs and walls enhance insulation, support biodiversity, and manage stormwater, creating a sustainable urban ecosystem. Lifecycle Assessment (LCA): Lifecycle analysis tools identify low-impact materials, guiding sustainable choices based on overall environmental cost and durability. Innovative materials: Grapheme-enhanced concrete and 3D-printed materials reduce resource use while improving strength, insulation, and waste minimization in residential structures.

Major Findings: *These findings emphasize a shift toward materials that balance environmental impact with performance in residential construction. Sustainable construction materials focus on reducing carbon emissions, increasing energy efficiency, and ensuring longevity.*

Keywords: *Cost Analysis, Construction Techniques, Environmental Conservation, Green Building Design, Sustainability, Sustainable Architecture*

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1.0 Introduction

The earth's state is swiftly degrading and will become grave if individuals do not adopt environmentally friendly practices. Eco-structure construction is a long-standing idea and common practice for improved living. With 159,1 million inhabitants and rapid urbanization and population growth, India faces a grave problem. Up to forty per cent of the total energy level is consumed by buildings and structures. In the era of increasing temperatures and climate change, there is a need to focus on establishing a safe environment, which is one of the most essential and widely discussed topics worldwide. However, the evaluation of new construction is limited to performance considerations from the start of planning through the construction finish. Actual efficiency during occupancy depends on what was accomplished regarding enhanced structure and design quality, as verified by final inspection and commissioning, the standard of m leadership, maintenance and operation practices, and the building users' actions. Sustainability environments in residential buildings provide the necessary performance for building throughout the structure's life cycle while reducing the use of resources that are not renewable and natural loads to water, air, and land. Nevertheless, the evaluation of new construction is limited to performance considerations from the initial design through the construction finish.

1.1 Sustainable Building

A construction is environmentally sustainable if it requires a smaller amount of water, improves its energy efficiency, conserves natural resources, produces less waste, and offers better spaces for those living there than a traditional structure. Simply put, Sustainable Building is the development and running of a building that is mindful of the environment. And for numerous valid factors, ecological building has grown more widespread. The idea of encouraging sustainable and ecological construction concepts has assumed a prominent position in the real estate sector due to the current paradigm shift.

A sustainable building results from a design philosophy that focuses on boosting the effectiveness of resource use (e.g., energy, water, and materials) while reducing impacts on human health and the environment



Figure 1. Sustainability of sustainable building.

throughout the building's lifecycle. This is accomplished through more effective sitting, planning, building, operation, maintenance, and removal. Commonly, sustainable buildings are constructed and maintained to minimize the general effect of construction on people and the environment by effectively using electricity, water, and other resources, and other assets; safeguarding the health of tenants and enhancing worker efficiency; and decreasing waste, pollutants, and damage to the environment.

1.2 Benefits of Sustainable Building

1.2.1 The Rising Popularity of Sustainable Architecture

With humanity's growing concern for the planet, it should come as no surprise that Sustainability Architecture continues to gain appeal, and you might be wondering what green design is. From homes to corporate amenities, planners are uncovering new environmentally friendly construction techniques to preserve the environment and reduce their environmental impact. Below are ten advantages of sustainability constructing and ecological constructing procedures, as well as how this architecture movement can safeguard generations to come:

1.2.2 *Improved Indoor Environment: Quality of Life*

It is no mystery that our environment significantly affects our well-being and standard of living. Over the years, architects and planners worldwide have taken enormous strides toward creating environmentally friendly designs that can profoundly impact the occupants of structures and significantly reduce their adverse effects on the environment. From design components such as increased illumination sources, climatic conditions, comfortable characteristics, and better air quality, the well-being, levels of stress, and general level of life of residents in environmentally friendly buildings have benefited significantly.

1.2.3 *Saving Water: Reduce, Reuse, Replenish*

Water conservation is a different visible advantage associated with environmentally friendly construction. According to studies, environmentally friendly construction can not only decrease water pollution using freshwater-efficient utility fittings, but it may additionally decrease the strain on common water supplies. By implementing specially designed water purification structures, the reuse of water and alternative water sources (such as precipitation) is made possible. These advances preserve this vital resource of nature and safeguard future pure water supplies.

1.2.4 *Enhanced Health: Eco-Friendly for Life*

Dwelling in an environmentally friendly structure may prolong your life. According to research, various health advantages accrue to occupants of green buildings due to the use of eco-friendly building materials. Sustainability Buildings, for instance, eschew the use of materials that may contain VOCs, volatile organic compounds, or plastic by-products known to emit noxious vapours and toxins into the environment. These hazardous substances are associated with breathing problems, allergies, and other health conditions and, in severe instances, a higher likelihood of developing cancer.

1.2.5 *Reducing the Strain: Shared Resources, Increased Efficiency*

Our local common assets are in jeopardy due to our planet's growing populace (particularly in big cities worldwide) and the increased demand. Vital sources such as energy and water are being preserved due to innovations, environmentally friendly procedures, and technological advances created by inventive builders all over the globe. By enhancing efficacy, green buildings can reduce the ecological impact on these assets, allowing them to be conserved for future generations.

1.2.6 *Reduced Operational Cost and Maintenance: Traditional vs. Green*

One of the biggest benefits of Sustainability buildings is their reduced expenses for upkeep, which results from specially engineered architectural components that reduce energy consumption and aid in lowering the price of water and energy for each resident. This economic building may spare homeowners and businesses a fortune. Although the initial cost for building proprietors to construct such buildings may be more expensive than conventional non-green construction, the expense grows significantly over time.

1.2.7 *Energy-Efficient: Non-Renewable vs. Natural Resources*

As a green building designer, energy conservation is a fundamental goal. Creating buildings that draw their energy from organic materials – including sunlight, wind, and water – is highly advantageous for the environment because it protects the natural world from the contamination caused by fossil fuels (such as gasoline and coal).

1.3 Scope of Environmental Sustainability

Environmental sustainability will be one of the primary worries of all nations. Sustainability issues regarding ecological systems, habitats, and the planet are of the highest priority. The use of environmentally friendly techniques incorporating systems of biology, biotechnology instruments, and techniques can influence the subsequent growth of the natural world while preserving its long-term viability.

1.4 Components of Sustainable and Green Building Design

Sustainable and green building design encompasses a holistic approach towards environmental conservation

and human well-being. Six primary criteria, as outlined by the EPA, serve as benchmarks for evaluating the eco-friendliness and viability of such structures. Energy efficiency and renewable energy integration are fundamental, emphasizing resource conservation from design to operation, including the utilization of renewable energy sources like solar panels. Water efficiency is equally crucial, spanning from construction practices to water usage in the building's operation, particularly for landscaping. Environmentally preferable building materials, such as reused steel and recycled products, minimise resource consumption and emissions. Waste reduction strategies extend beyond occupancy waste to encompass debris from construction and future demolition, emphasizing pollution minimization. Toxicity reduction involves substituting hazardous materials with safer alternatives, enhancing indoor air quality and occupants' health. Finally, indoor air quality is optimised using renewable materials like bamboo, which not only sequester carbon but also improve oxygen production, underscoring the interconnectedness of sustainability, health, and environmental stewardship in building design.

1.5 Sustainable and Green Building Projects Have Many Benefits but Also Face Some Challenges

1.5.1 Benefits

Protecting the planet: Reduce reliance on non-renewable resources, like coal and oil.
Reduce waste: Produce less waste and toxic gases.
Improve health: Promote healthier living by improving indoor air quality and occupant health.
Reduce costs: Lower maintenance costs and operating costs.
Boost the economy: The construction industry is an economic driver.
Improve sustainability: Use eco-friendly materials and renewable energy sources.

1.5.2 Challenges

Cost: Green construction methods can be more expensive than traditional methods.
Time: There can be a time lag between setting out to use sustainable methods and doing so.
Adoption: There can be a lack of customer awareness and a skilled workforce.
Policy: There can be inadequate policy implementation.
Green buildings are designed to use energy, water, and resources efficiently to reduce their environmental impact.

2.0 Literature Review

Thong Jia Wen *et al.*,[1] Implementing Industrial Building System (IBS) in housing construction aims to create greener structures in Iskandar Malaysia. A comparative Life Cycle Analysis (LCA) between IBS and traditional methods evaluates their environmental impact during assembly. The study models assembly stages using Gabi 6.0 and conducts a sensitivity analysis to assess presumptions' effects on results, crucial for promoting sustainable growth amidst rapid urbanization. Tarja Hakkinen *et al.*,[2] sustainable construction faces managerial and procedural challenges rather than technological limitations. Lack of client understanding, resistance to innovation, and procurement inefficiencies hinder adoption. Overcoming these obstacles requires identifying decision-making stages, new roles, and effective communication strategies, crucial for advancing environmentally friendly practices. Peter O. Akadiri *et al.*,[3] an analytical framework promotes sustainability principles in construction, integrating resource conservation, cost efficiency, and design aesthetics. The framework emphasizes social, environmental, and economic balance, reshaping construction professionals' decision-making processes towards long-term viability and environmental stewardship. David R. Riley *et al.*,[4] prefabrication methods are gaining importance in sustainable construction due to their environmental benefits. A survey-based study identifies 33 Sustainable Performance Criteria (SPC) and categorizes them into economic, social, and environmental dimensions. The findings underscore the growing significance of environmental considerations in selecting building techniques, which are vital for fostering sustainability in construction. Johnny Kwok Wai Wong *et al.*,[5] green Building Information Modeling (BIM) research focuses mainly on sustainability during the design and construction phases. Future research should prioritize developing comprehensive BIM tools for sustainability tracking throughout a building's lifecycle, integrating

reduce, reuse, and recycle principles to enhance carbon reduction management. F. Asdrubali *et al.*,[6] a comparison between LEED (US) and ITACA (Italy) evaluation systems highlights their approaches to assessing environmental impact. Despite differences in weighting factors, both systems yield correlated scores, suggesting their suitability for evaluating building sustainability across different contexts. Abraham Mwasha *et al.*,[7] identifying sustainability energy performance indices is crucial for assessing long-term sustainability in building envelopes. The study emphasizes the importance of selecting appropriate performance indicators and models to accurately evaluate sustainability, essential for promoting environmentally friendly construction practices. Milad Samari *et al.,*[8] sustainable construction growth in Malaysia faces barriers like funding constraints and market challenges. Government intervention is crucial for overcoming these barriers and promoting green building initiatives, highlighting the need for policy support and stakeholder collaboration. Xinying Cao *et al.*,[9] prefabricated construction demonstrates environmental advantages over conventional methods, with reduced resource depletion and environmental damage. Despite government support, evaluating the ecological impact of prefabrication techniques is essential for ensuring sustainable development and informed decision-making in construction. Xining Yanga *et al.*,[10] integrating Building Information Modeling (BIM) with Life Cycle Assessment (LCA) facilitates environmentally friendly planning in China's construction sector. BIM-enabled LCA enables detailed evaluation of a building's environmental sustainability, enhancing decision-making and promoting sustainable building design practices.

Shaikha Alsanad[11], Kuwait's construction sector faces challenges in adopting sustainable practices due to a lack of knowledge and insufficient regulations. Efforts to promote sustainable construction require government initiatives, regulations, and public awareness campaigns, essential for overcoming barriers and advancing environmentally friendly building practices. Tao Huang *et al.*,[12] Predictions indicate a decline in building materials demand and CO_2 emissions, emphasizing the importance of extending building lifespans and improving material recycling. Sustainable construction practices can significantly reduce environmental impact and resource consumption, essential for mitigating adverse environmental effects in China's construction sector. Milena Medineckiene *et al.*,[13] a multi-criteria evaluation approach compares construction options for single-family dwellings based on environmental, economic, and social criteria. The study highlights the importance of considering holistic impacts on humans and the environment when selecting building materials and methods, essential for promoting sustainable construction practices. Gian Andrea Blengini *et al.,*[14] Life cycle evaluation of a low-energy home in Italy highlights its environmental benefits compared to conventional structures. The study emphasizes the importance of evaluating building performance holistically, considering economic, social, and environmental factors to promote sustainable construction practices. Alexander Passer *et al.*.[15] assessing the environmental impact of construction materials and technological processes is crucial for sustainable building design. Life cycle evaluations reveal opportunities to optimize energy usage and reduce CO_2 emissions, vital for advancing environmentally friendly construction practices. Ahmad Jrade *et al.*,[16] Integrating Building Information Modeling (BIM) with Life Cycle Assessment (LCA) facilitates environmentally friendly design and evaluation of building projects. The proposed model streamlines sustainability assessment during the planning phase, essential for promoting sustainable building practices. Luís Bragança *et al.,*[17] Evaluating the sustainability of residential buildings involves complex considerations of environmental, economic, and social factors. The study discusses methods for assessing sustainability in building projects, emphasizing the need for comprehensive approaches to promote environmentally friendly construction practices. Edmundas Kazimieras Zavadskas *et al.,*[18] Multiple-criteria decision-making techniques show promise for supporting sustainable choices in construction. The review highlights the increasing use of these methods in environmental decision-making, essential for promoting environmentally friendly practices in the construction industry. Yong Han Ahn *et al.*,[19] Drivers for environmentally friendly buildings include energy preservation and pollution reduction, while barriers include cost concerns and resistance to change. Identifying and addressing these factors is crucial for promoting sustainable practices and

advancing environmental policies in the construction sector.

3.0 Methodology

The methodology section will outline the systematic approach used to study construction materials for sustainable development in residential buildings. It will detail the data collection methods, analysis techniques, and tools employed to evaluate the environmental impact, durability, and efficiency of different materials. This section will also describe the flowchart illustrating the sequential steps followed in the study, ensuring a structured and comprehensive investigation.

Table 1. Material comparison

Criteria	Autoclave Aerated ConcreteBlock	Red Bricks
Cost	Usually higher than redbricks	Generally lower cost
Eco-friendliness	Environmentally friendly	Less environmentally friendly
Weight	Lightweight	Heavier
Straightness	Precise and uniform	May have variations in straightness
Insulation properties	Excellent thermal and sound insulation	Moderate insulation properties
Construction speed	Faster installation	Slower installation
Durability	Durable and resistant to pests	Less durable
Energy efficiency	Good energy efficiency	Lower energy efficiency

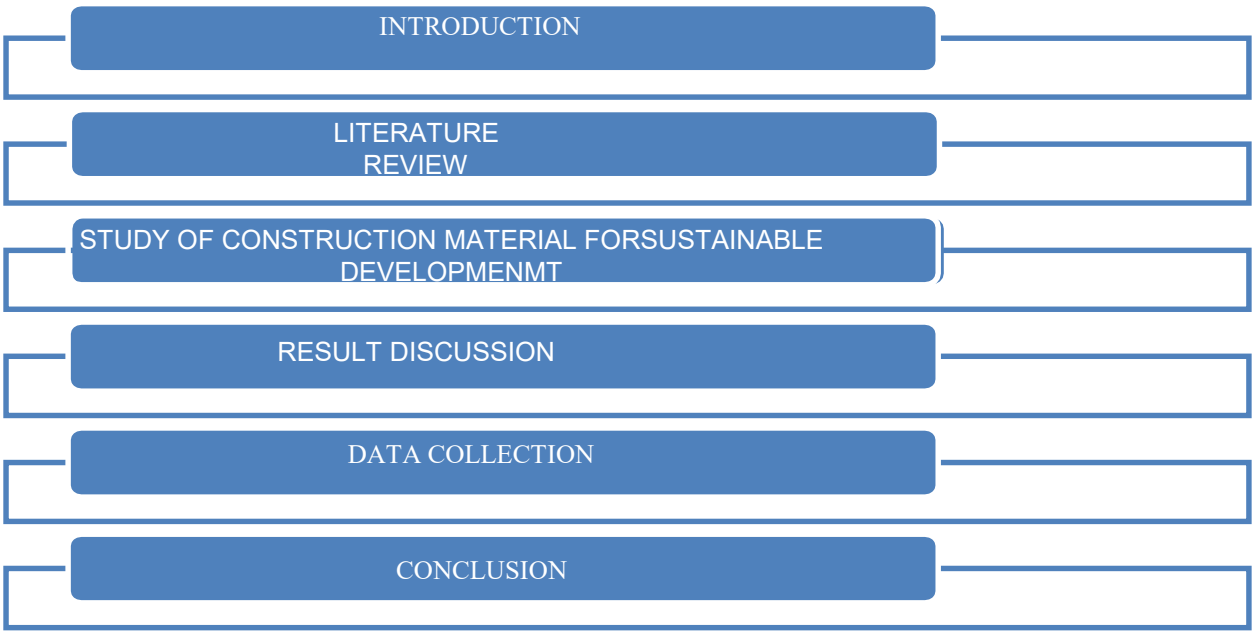


Figure 2. Research methodology.

Table 2. Fly ash and ordinary Portland cement

Properties	Fly Ash	Ordinary Portland Cement (OPC)
Composition	Waste products from coal-fired power plants	The mixture of limestone, clay, andgypsum
Environmental Impact	Reduces carbon emissions and landfill waste	High carbon emissions during production
Strength	Generally lower strength comparedto OPC	Higher strength and initial settingtime
Durability	Enhances long-term durability ofconcrete	Provides good durability properties

4.0 Case Study

N B Bhalchandra Akashvan



Figure 3. 3rd eye view of the actual site.

4.1 Site Details

- Name of site: N B Bhalchandra Akashvan.
- Location of site: Punawale, Pune - 411035, Maharashtra.
- A G+21 proposed building.
- Owner and Developer: Nandkumar Bhalchandra Bhondve.
- Architect: Samarth Chintamani Properties.
- Cost of project: 64.4 Lakhs per Flat Onwards.
- Structural Engineer: JW consultant.
- Builder: N B Bhondve Group.
- Area: 2.29 Acres
- The residential building has No of Towers: 1, Towers No. of Floors: 21 Floors, No. of Units: 317 Units.
- This project is based on a sustainable structure.
- Present condition of the project: under construction.
- Possession March 2025.

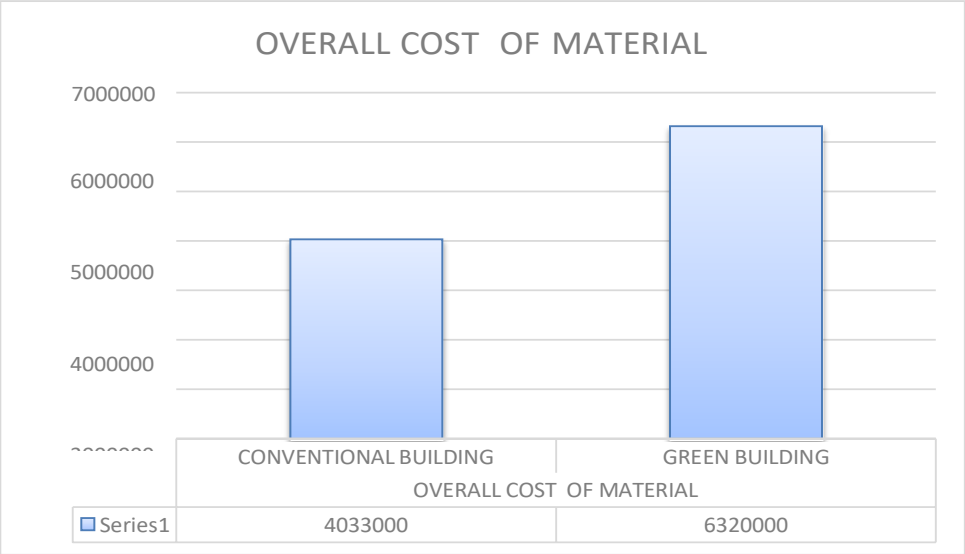
5.0 Results and Discussion

5.1 Graph Analysis

The graph illustrates a comparison of overall material costs between conventional and green buildings. Green building materials show a higher cost at $6,320,000

Table 3. The overall cost of material

The overall cost of material	
Conventional building	Green building
4033000	6320000



Graph 1. The overall cost of material.

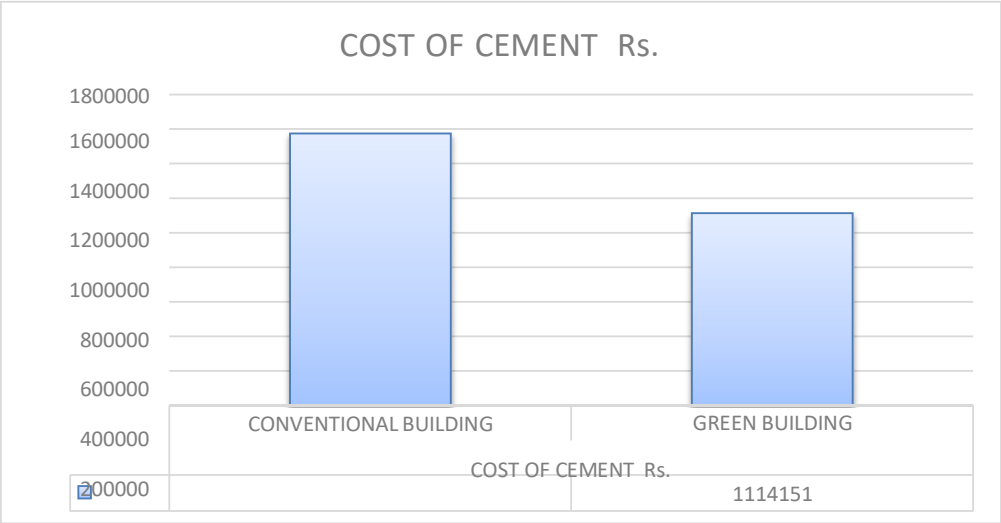
compared to $4,033,000 for conventional buildings, indicating the initial investment required for sustainable construction practices.

Cost of Cement Rs.

The graph illustrates the cost of cement in conventiona l and green buildings. In comparison, conventional building cement costs approximately Rs. 1,559,950, whereas green building cement costs about Rs. 1,114,151, indicating a considerable cost reduction in green construction practices.

Table 4. Cost of cement Rs

The cost of cement is Rs.	
Conventional building	**Green building**
1559950	1114151



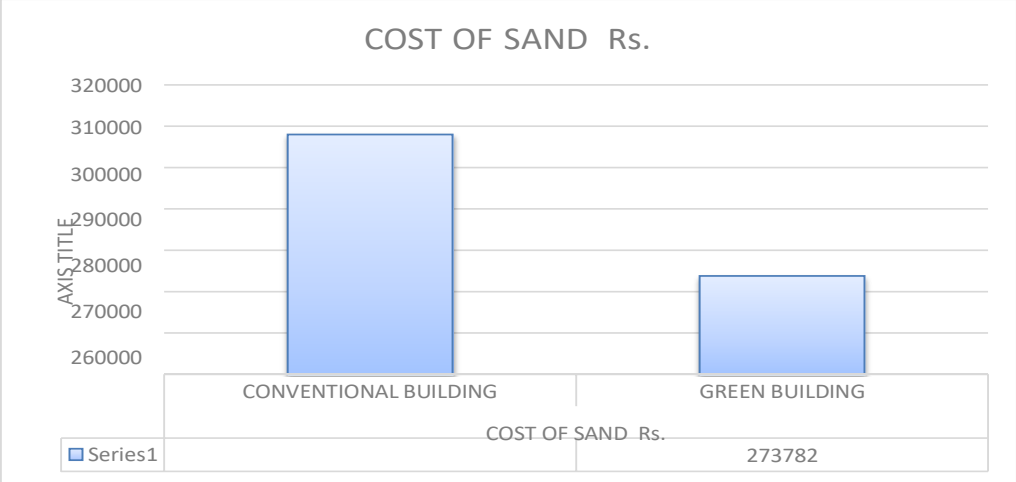
Graph 2. The cost of cement is Rs.

Cost of Sand Rs.

The graph depicts the cost of sand in both conventional and green buildings, with both types costing Rs. 273,782. This suggests that the expense for sand remains consistent throughout conventional and green construction practices.

Table 5. The cost of Sand is Rs.

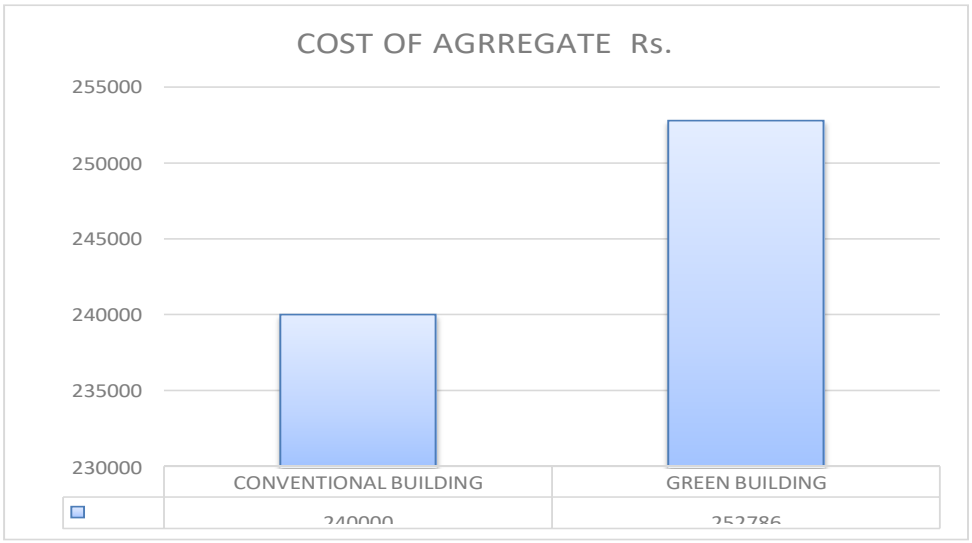
The cost of sand is Rs.	
Conventional building	**Green building**
273782	273782



Graph 3. The cost of sand is Rs.

Cost of Aggregate Rs.

In comparison between conventional and green buildings, the cost of aggregate differs slightly. In conventional construction, it's Rs. 240,000, while in green buildings, it's slightly higher at Rs. 252,786. This indicates a marginal increase in aggregate costs for green building projects.



Graph 4. Cost of aggregate Rs.

Table 6. Cost of aggregate Rs.

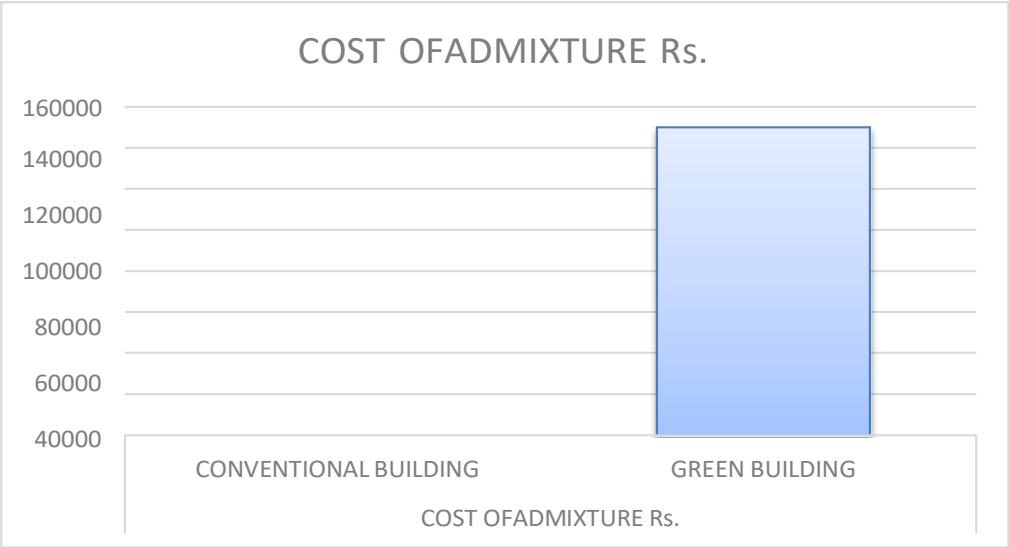
Cost of aggregate Rs.	
Conventional building	**Green building**
240000	252786

Cost of Admixture Rs.

The graph shows the cost of admixture in conventional and green buildings. In conventional construction, it's Rs. 1,559,950, whereas in green buildings, it's Rs. 1,114,151, indicating a significant cost reduction in green building projects.

Table 7. Cost of admixture Rs

Cost of admixture Rs.	
Conventional building	**Green building**
1559950	1114151



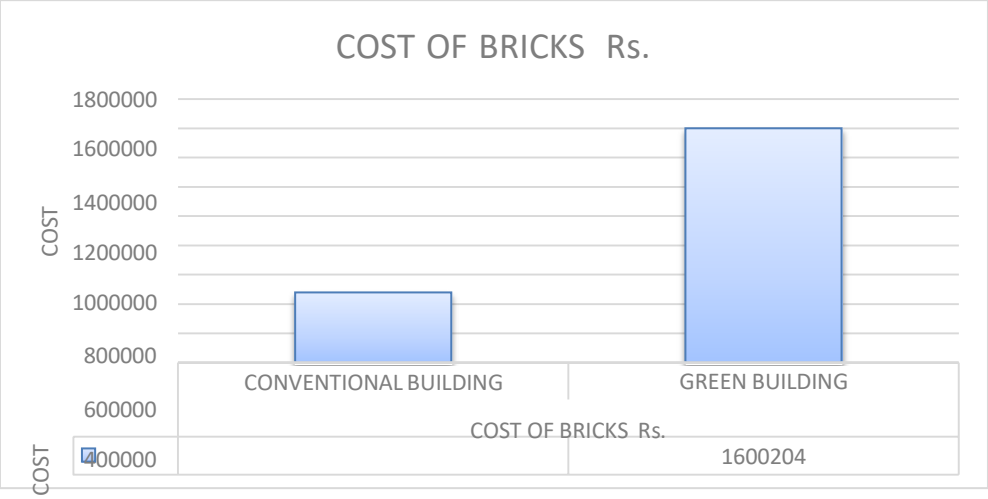
Graph 5. Cost of admixture Rs.

Cost of Bricks Rs

The graph shows the cost of bricks in conventional and green buildings. In conventional construction, it's Rs. 480,000, while in green buildings, it's Rs. 1,600,204, reflecting a substantial increase in cost for green building projects.

Table 8. Cost of bricks Rs

The cost of bricks is Rs.	
Conventional building	**Green building**
480000	1600204



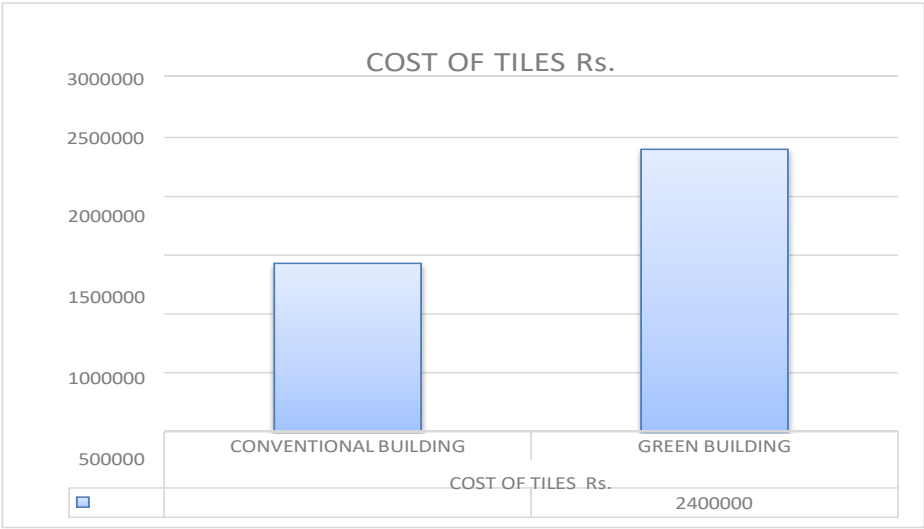
Graph 6. The cost of bricks is Rs.

Cost of Tiles Rs

The graph shows a comparison of tile costs between conventional and green buildings. In conventional construction, the cost is Rs. 1,430,000, whereas in green buildings, it's Rs. 2,400,000, indicating a significant difference favouring conventional construction in terms of cost.

Table 9. The cost of tiles is Rs.

The cost of tiles is Rs.	
Conventional building	Green building
1430000	2400000



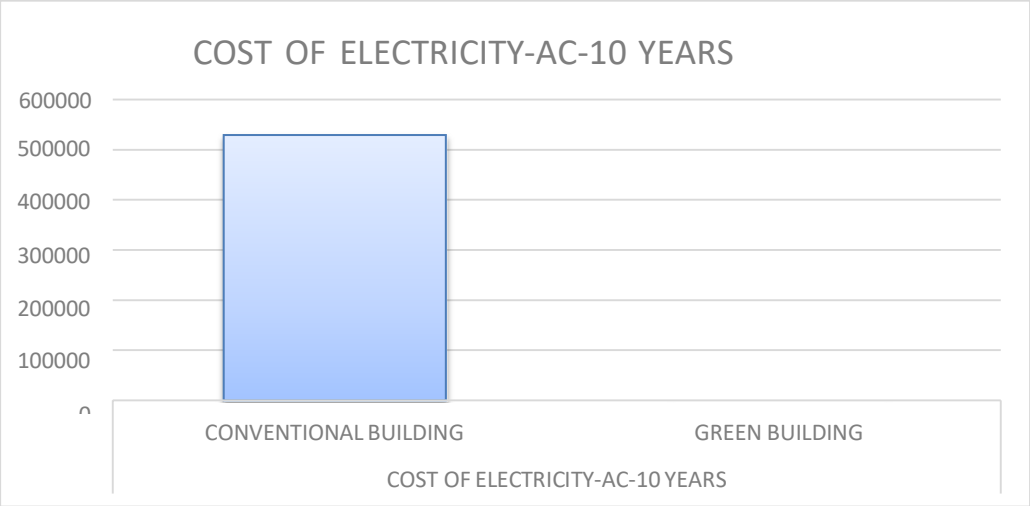
Graph 7. The cost of tiles is Rs.

Cost of Electricity-AC-10 Years

The graph shows a striking contrast in the cost of electricity for air conditioning over 10 years between conventional and green buildings. While conventional buildings incur Rs. 529,250, green buildings demonstrate zero costs, showcasing significant savings and environmental benefits in green construction.

Table 10. Cost of electricity-AC-10 years

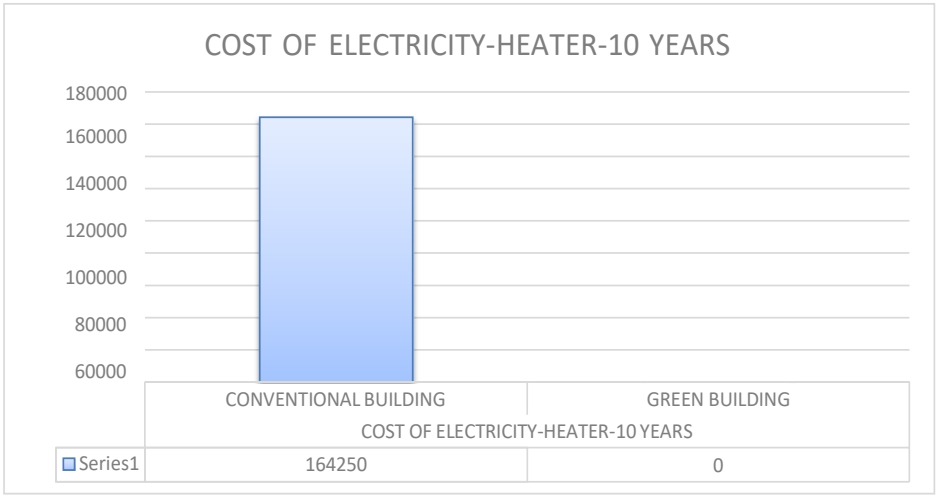
Cost of electricity-AC-10 years	
Conventional building	**Green building**
529250	0



Graph 8. Cost of electricity-AC-10 years.

Cost of Electricity-Heater-10 Years

The graph illustrates a notable disparity in electricity costs for heaters over 10 years between conventional and green buildings. In conventional structures, the expense amounts to Rs. 164,250, whereas green buildings register zero costs, underscoring substantial savings in energy consumption.



Graph 9. Cost of electricity-Heater-10 years.

Table 11. Cost of electricity-Heater-10 years

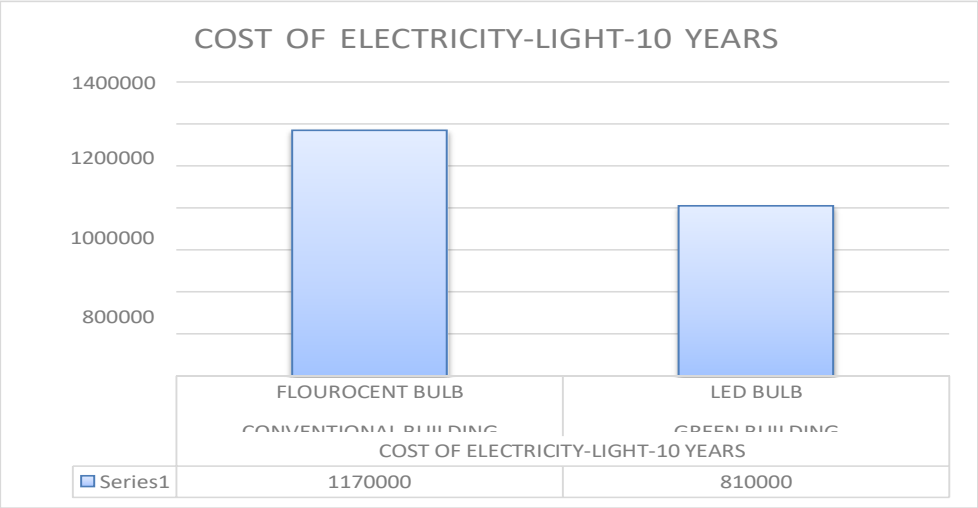
Cost of electricity-Heater-10 years	
Conventional building	**Green building**
164250	0

Cost of Electricity-Light-10 Years

The graph demonstrates the substantial contrast in electricity expenses for lighting over a decade between conventional and green buildings, specifically comparing fluorescent bulbs in conventional structures to LED bulbs in green buildings. Conventional buildings incur Rs. 1,170,000, whereas green buildings with LED bulbs register a reduced cost of Rs. 810,000, emphasizing the efficiency and cost-effectiveness of LED lighting.

Table 12. Cost of electricity-Light-10 years

Cost of electricity-light-10 years	
Conventional building	**Green building**
Fluorescent bulb	Led bulb
1170000	810000



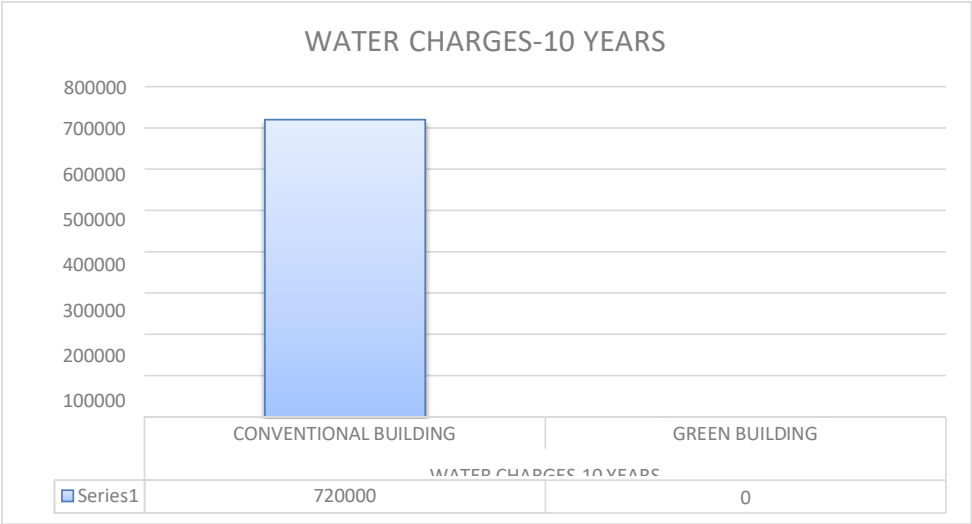
Graph 10. Cost of electricity-Light-10 years.

Water Charges-10 Years

The graph illustrates a significant disparity in water charges over ten years between conventional and green buildings. While conventional buildings accumulate water charges amounting to Rs. 720,000 green buildings incur no water charges, showcasing the efficiency and sustainability of green building practices.

Table 13. Water charges-10 years

Water charges-10 years	
Conventional building	**Green building**
720000	0



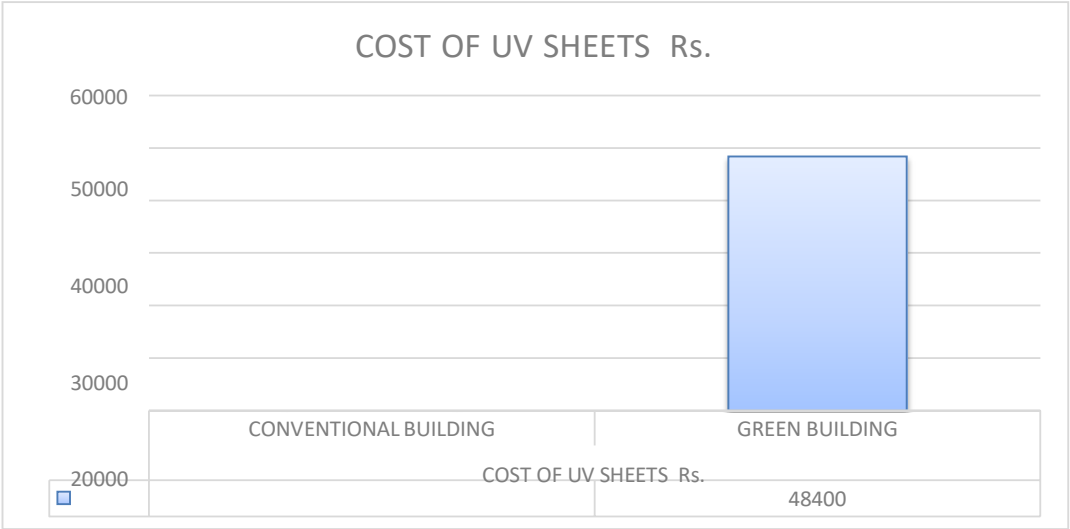
Graph 11. Water charges-10 years.

Cost of UV Sheet Rs

The graph demonstrates a contrast in the cost of UV sheets between conventional and green buildings. While conventional buildings do not incur any cost for UV sheets, green buildings invest Rs. 48,400, indicating a proactive approach towards environmental sustainability and energy efficiency.

Table 14. The cost of the UV sheet Rs

The cost of UV sheets is Rs.	
Conventional building	**Green building**
0	48400



Graph 12. The cost of the UV sheet is Rs.

6.0 Rate Analysis

Sr. No.	Material	Conventional building	Green building
1	Cement	1559950	1114151
2	Sand	480000	1600204
3	Bricks	480000	1600204
4	Tiles	1430000	2400000

7.0 Conclusion

In conclusion, this study highlights the significant benefits and challenges associated with sustainable and green building projects. While initial construction costs may be higher due to specialized materials and features, the long-term savings in energy consumption prove to be substantial. Green buildings not only offer financial benefits over time but also contribute to environmental conservation and improved quality of life for occupants. Additionally, the marketing advantage of green building components adds to the overall profitability of the project. The success of green building initiatives relies on commitment from all stakeholders, including clients, users, designers, and contractors, to prioritize sustainability and incorporate green practices into every phase of the project. Moving forward, it is essential to continue exploring cost containment strategies and fostering a culture of sustainability to ensure the widespread adoption of green building principles in future construction endeavours.

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