International Journal of Research in Engineering, Science and Management
Volume 5, Issue 5, May 2022
https://www.ijresm.com | ISSN (Online): 2581-5792

Sustainable Construction Materials – An Indispensable Resource for Effective Construction Management

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***Abstract*: Sustainable building materials can reduce the damage to non-renewable resources and the degradation of the environment. Chemical, physical and mechanical properties of materials and an appropriate design are accountable for the physical strength of a structure. Green buildings should be designed such that the sustainable materials used are the same or better than the conventional materials. In order to compare both sustainable materials and conventional materials, methodology of collecting sets of prices of sustainable as well as conventional materials for a given project and to do a quantity survey and check them for durability, life cycle, maintenance cost and carbon footprints identification has to be adopted. Although just selecting sustainable construction materials is not enough, there is more to it than just sustainable construction materials, and that is sustainable construction management. Here, it deals with efficient design, selection of sustainable materials, analysis of construction materials, and the environmental impact of the materials, which grants more efficiency in smooth completion of the project. Many research communities worldwide have discovered different sustainable building materials to meet the norms and standards required today for a complete functional structure. To achieve this, selection of building materials and the construction management practices must have integrity at all times to get the utmost benefit out of it. Therefore, the selection of construction materials that have minimum environmental impact which are beneficial for sustainable development.**

***Keywords*: Construction management, carbon footprints, green buildings, life assessment, quantity surveying, sustainable materials, sustainable development.**

1. Introduction

A green building is defined as the high-performance building which uses less water, energy, generates less waste, maintains indoor air quality for the occupants and uses efficient building materials [6]. The construction enterprise performs a chief function inside the social-budget improvement of a nation. Nowadays, construction must excel in four subjects – Social aspects, Economy, Technology, and Sustainability. As an essential branch of the ecological environment, ecological building materials can coordinate with the ecological environment [1]. Buildings have an excellent effect on the environment, roughly 40% of natural resources are extracted in industrialized nations, and preoccupying 70% of power and 12% of potable water, which produces 45% to 65% of the waste disposed of in our landfills. These are accountable for various dangerous emissions, accounting for 30% of greenhouse gases because of their operation, and a further 18% prompted circuitously via way of means of cloth oppression and distribution. 40% of the untreated and unrefined stone, gravel, and sand used globally and 25% of the natural timber are used in building production. There is interdependency in each aspect of construction management mentioned above and there can be no compromise on any of the subsequent apart from raw materials. In this case, selecting sustainable raw materials has many advantages like cost efficiency, availability, energy conservation, environment friendly. The sustainable development uses locally available building materials which are energy efficient and durable [7]. Hence selecting sustainable raw materials in construction management creates openings for flexibility in other aspects of management. This then further results in effective construction management. Sustainability implies the provision of more efficient services that maintain public health and welfare, cost-effective, and reduce negative environmental impacts, presently and in the future [11].

A. Scope and Objectives

To ensure that we are satisfying the need of this project, few and following are the objectives to execute while the direction of this project and our areas are confined to the following scope:

- Structures with respect to guidelines given by IGBC (Indian Green Building Council) will be designed and constructed.
- The guidelines which have been given by IGBC as per how a particular structure has to be constructed will be referred to ensure that the structure meets the required standards.
- Quantity Survey of the traditional construction materials like Cement, Sand, Aggregates, Concrete, Bricks/Blocks, Flooring tiles, Reinforced steel bars

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Table 1
Cost comparison and replacement for conventional construction materials

Conventional Materials	Rate (Rupees)	Sustainable Materials (Replacement)	Rate (Rupees)
Cement	₹330 /- bag of 50 kg	Fly ash cement	Fly ash ₹350/- bag of 50 kg
Sand	₹3,300 /-cu. m.	Sand	₹3,300 /- cu. m.
Aggregate	₹ 580/- ton	Reclaimed aggregates	Recycled Concrete Aggregate at ₹420 /- ton
Reinforcements	₹55 /- kg	Reclaimed steel	Recycled steel - ₹47 /- kg
Stirrups	₹55 /- kg	Recycled steel	Recycled steel - ₹47 /- kg
Plaster interior	₹670 /- bag of 25 kg	Clay plaster	Building supply stores – as low as ₹600 /- 25 kg bag Online – as high as ₹550 /- 25 kg bag plus shipping
Plaster exterior	₹4,900 /- metric ton	Gypsum plaster	₹6,000 /- metric ton
Bricks	₹3,090/- Cubic meter	AAC Block	₹3,400 /- Cubic meter
Paint exterior	₹480 /- litre	Non-VOC paint	₹370 /- litre
Paint interior	₹480 /- litre	Non-VOC paint	₹370 /- litre
Windows and openings	₹3,500 /- unit	Insulated Glass and recycled wood	₹3,500 /- unit
Lightings	₹125 /- unit	Low watt led	₹190/- unit
Plumbing fittings	₹50 to ₹700 /- fitting	PPR fittings	₹200 /- fitting
Flooring	Ceramic tiles ₹480 /- meter square	Terrazzo	₹250 /- meter square

will be carried out.

- Alternate sustainable construction materials will be found out to replace the traditional construction materials, those sustainable materials will be checked for various requirements.
- Traditional construction materials and sustainable construction materials will be compared in terms of their strength, durability, affordability, ease of application, effects on the environment, ease of availability, maintenance cost, resistance against climatic changes, duration of construction, availability of workers required for construction.
- After the detailed comparison, if a particular sustainable construction material is equivalent or better than the traditional construction material then it will be used for construction.

2. Data Collection

A. Sustainable Construction Materials

1) Sustainable construction materials used for interior and exterior work

- Polyurethane rigid foam sheets
- Cork sheets
- Rammed earth wall
- Terrazzo tiles/blocks
- Sheep wool
- Reclaimed wood
- Recycled plastic
- Mycelium blocks

2) Modern sustainable construction materials

- Ashcrete blocks
- Hempcrete blocks
- Ferrock blocks
- Timbercrete [10]
- Reclaimed steel bars
- Precast concrete slabs
- Cement made out of plastic

3) Traditional sustainable construction materials

- Bamboo
- Straw bales [12]
- Thatched roof

B. Life assessment of Conventional and Sustainable Construction Materials

1. Cement – Cement has a three-month shelf life.
2. Concrete – Concrete should endure up to 100 years if properly cared for in big-scale constructions such as skyscrapers.
3. Ceramic tiles – Ceramic tiles may not have the same longevity as porcelain tiles as ceramic tiles last between 3 to 20 years under normal circumstances.
4. Wood – If 100-year-old wood ash is repaired and cared for properly, it has the potential to last another 100 years.
5. Glass – Glass has a lengthy life lifetime, generally reaching 25 years.
6. Plaster of Paris – A POP fake ceiling may easily survive for 15-20 years if there is no external damage.
7. Plastics – Life expectancy of plastic materials is 400-500 years.
8. Steel – The average life span is estimated 15 to 20 years for Structural Steel structures.
9. Carbon Fibre – Carbon fibre parts are expected to survive for more than 50 years, according to experts.
10. Rigid foam – Rigid foam insulation has a lifespan of 100 years or more due to its hardness and water resistance.
11. Earth clay – Brick structures are designed to survive 100 years or more, according to the International Association of Certified Home Inspectors (IACHI).
12. Autoclaves Aerated Concrete Blocks – According to AAC-India, AAC blocks have a life expectancy of over 100 years.
13. Bricks – Bricks are designed to survive generations. The typical lifespan of a brick structure is believed to be more than 100 years.

14. Ashcrete – Ashcrete has a shelf life of 5months.
15. Hempcrete – Hempcrete has a life span of more than 100 years.
16. Ferrock – Ferrock has a long life as it has 100 years' life expectancy.

3. Methodology

A. Site Selection Report

- Name of Construction firm – Gurudutt Developers.
- Name of Project – Sarvoday Apex (2 Towers) (G+15).
- Locality – Kalyan Station.
- Date of visit – 30/9/2021.
- Objective of visit – To know about the materials required for construction.
- Proprietor – Praful Shah.
- Site Engineer – Bhushan Kadam.
- Land cost – ₹2,500/- Sq. Ft.
- Cost of construction – ₹2,000/- Sq. Ft.

From table 2, the total approximate cost of materials required for 15 floors is ₹ 62,115,010.

From table 3, the total approximate cost of materials required for 15 floors is ₹ 56,094,190.

For table 3,

Name of Project – Sarvoday Apex.

Location – Station Road, Kalyan (West) – 421301.

B. Green Building Certification

1) Process of LEED certification

The following are the primary phases in the LEED certification process:

1. Determine your desired degree of LEED certification you want.
2. Choose the appropriate LEED rating system based on USGBC recommendations.
3. Begin and register your project.
4. Submit your completed application along with information on the credits you earned for your building or project.

Table 2
Quantity surveying of conventional materials used

Item used in Construction	Approximate Quantity per floor	Approximate Quantity for 15 floors	Cost for 15 floors (in ₹)
Cement	1,500 bags	22,500 bags	7,425,000 ₹
Sand	3,600 cubic feet	54,000 cubic feet	5,045,700 ₹
Aggregates	2,700 cubic feet	40,500 cubic feet	234,900 ₹
Bricks	32,000 no's	480,000 no's	2,966,400 ₹
Reinforcements	41,038 kg	615,570 kg	33,856,350₹
Stirrups	200 kg	3,000 kg	165,000 ₹
Plaster interior	260 litres	3,900 litres	104,520 ₹
Plaster Exterior	210 litres	3,150 litres	97,040 ₹
Paint Interior	256 litres	3,840 litres	1,843,200 ₹
Paint Exterior	200 litres	3,000 litres	1,444,000 ₹
Flooring	560 no's of 2Ft. X 2Ft. Tiles	8,400 no's of 2Ft. X 2Ft. Tiles	15,480,000₹
Plumbing	56 no's of fittings	804 no's of fittings	281,400 ₹

Table 3
Quantity analysis of replaced materials with sustainable materials

Replaceable Items used in Construction	Approximate Quantity per floor	Approximate Quantity for 15 floors	Cost for 15 floors (in ₹)
Fly Ash Cement	1,500 bags	22,500 bags	7,875,000 ₹
Sand	3,600 cubic feet	54,000 cubic feet	5,045,700 ₹
Reclaimed aggregates	2,700 cubic feet	40,500 cubic feet	180,100 ₹
AAC blocks	32,000 no's	480,000 no's	3,264,000 ₹
Reclaimed steel	41,038 kg	615,570 kg	28,931,790₹
Recycled steel	200 kg	3,000 kg	141,000 ₹
Clay plaster	260 litres	3,900 litres	93,600 ₹
Gypsum plaster	210 litres	3,150 litres	108,900 ₹
Non-VOC paint	256 litres	3,840 litres	1,420,800 ₹
Non-VOC paint	200 litres	3,000 litres	1,110,000 ₹
Terrazzo	560 no's of 2Ft. X 2Ft. Tiles	8,400 no's of 2Ft. X 2Ft. Tiles	7,762,500 ₹
PPR fitting	56 no's of fittings	804 no's of fittings	160,800 ₹

Table 3
Comparison in cost of maintenance

Parameters	Maintenance cost per year of conventional building	Maintenance cost per year of sustainable building
Maintenance cost per Sq. Ft.	2.5 ₹	2 ₹
Area of 2BHK flat	1000 Sq. Ft.	1000 Sq. Ft.
Maintenance Cost per year	30,000 ₹	24,000 ₹
Total number of 2BHK flats	60	60
Total maintenance cost of 2BHK flats per year	1,800,000 ₹	1,440,000 ₹
Area of 3BHK flat	1495 Sq. Ft.	1495 Sq. Ft.
Maintenance cost per year	44,850 ₹	35,880 ₹
Total number of 3BHK flats	30	30
Total maintenance cost of 3BHK per year	1,345,500 ₹	1,076,400 ₹
Total maintenance cost of building per year	3,145,500 ₹	2,516,400 ₹

5. To begin your LEED certification, you must pay a fixed certification cost as well as a registration fee.
6. Your application is evaluated based on the number of points earned in each area.
7. Certification is given based on the level you have attained.

Buildings and homes are given up to 110 points based on a point scoring system that is generally divided into categories – from basic sustainable design to a framework that uses the least amount of energy possible, which also reflects the level or extent of green building construction methods and sustainable construction materials incorporated in the project. The more points obtained, the higher the level of LEED certification. According to the USGBC, there are four levels of LEED certification:

- LEED Certified: – 40 to 49 points.
- LEED Silver: – 50 to 59 points.
- LEED Gold: – 70 to 79 points.
- LEED Platinum: – 80+ points.

2) Process of IGBC certification

The following are the primary phases in the IGBC certification process:

1. First step is to registers in IGBC to gain access of the essential papers, formats, critical communications and information.
2. After registration, the project team may begin producing documentation and computations to meet necessary requirements and credit submission criteria.
3. After reviewing all of the project team's documentation and specifications, IGBC assigns a final rating to the project.

The rating levels are as follows:

- Certified: – Best Practices.
- Silver: – Outstanding Practices.
- Gold: – National Performance.
- Platinum: – Global/International Excellence.

IGBC allows project paperwork to be provided in two stages.

- Initial Document Submission.
- Final Document Submission.

4. Outcomes and Results

A. Cost, Quality, Maintenance of Sustainable Construction Materials

- On comparing the initial costs of both sustainable as well as conventional building materials, the short-term costs of the conventional building materials are lower than that of sustainable construction materials.
- Although the short-term costs do not justify the long-term costs of the sustainable construction materials, which are substantially lower than that of conventional building materials.
- The Qualities of sustainable construction materials was found out to be better than conventional building materials in durability and life cycle assessment.
- The Quality of sustainable construction materials are equal to or better than their replaced conventional building materials.
- In the maintenance cost comparison, the maintenance cost of a conventional building is substantially higher than that of a sustainable building.

Table 4
Carbon footprints of conventional and sustainable construction materials

Materials	Carbon footprints identification
Cement	900 kg of CO_2 are generated for the composition of every ton of cement, accounting for 88% of the emissions.
Concrete	In 2019, the specified mix value for concrete was 72.5 kg CO_2/- ton. The CO_2 emissions from concrete + reinforcement is 80.2 kg CO_2/ton, a 15% decrease (from 94.7 kg CO_2/- ton) from the first year of reporting in 2009.
Glass	The CO_2 emissions from flat glass manufacturing are 3.08 kg CO_2/- kg.
Wool	By dry weight, wood contains around 50% carbon that would otherwise be discharged back into the atmosphere.
Plastic	(LDPE or PET, polyethylene) has a carbon footprint of roughly 6 kg CO_2/- kilograms of plastic. Plastic shopping bag of almost 1 kg emits around 33 grams of CO_2
Ceramic	CO_2 emissions in the ceramic tile industry reached 180000 ton/- year. Spray drying generates 26% of total CO_2 emissions, whereas the burning process emits 57%.
Steel	In 2020, every metric ton of steel produced resulted in 1.85 metric tons of CO_2 being discharged into the sky.
Rigid foam insulation	900 kg of CO_2 are generated for the composition of every ton of cement, accounting for 88% of the emissions.
Carbon Fibre	According to the study, overall greenhouse gas (GHG) emissions for virgin carbon fibre amount 29.45 metric tonnes CO_2/- tonne of CF, compared to 4.65 metric tonnes CO_2/- tonne RCF generated via recycled Ferro carbons manufacture.
Hempcrete	Hempcrete is 0.2 – 2.0 MPa and 280 kg of CO_2/m3 during its lifetime.
AAC Blocks	One square foot of carpet emits 1.5 kg of CO_2.
Gypsum plaster	The CO_2e figure excludes the biogenic carbon dioxide emissions and sequestered carbon. CO_2e g/kg - 243.2 CO_2 fossil g/kg - 230 CH4 g/kg- 0.47 N2O g/kg - 4.7 x 10-3 CO_2 uptake g/kg - 0
Earth Clay	Using sun-dried bricks instead of burnt bricks can save up to 5907 kg CO_2e (in CO_2 emissions) and 5305 MJ of embodied energy for every 1000 bricks produced.
Ferrock	Ferrock generates carbon dioxide during manufacturing, but the amazing part about this material is that it absorbs CO_2 as it hardens.
Bricks	The average carbon footprint of bricks created is estimated to be 195 g CO_2/- kg of burnt brick and 162 g CO_2/- kg of fired brick, depending on whether CO_2 emissions from biofuel burning and raw material transportation are included or removed.
Terrazzo	Terrazzo medium grain tiles are LEED approved and include up to 80% waste recycled content from the marble and stone industry.
Ashcrete	The quantity of CO_2 emitted during the production of a percentage of fly ash is still over 90% less than that created during the production of the same proportion of cement.

B. Advantages of Green Building Certifications

The advantages of Green Building Certification are as follows:

- Exceptional resale value.
- Reduced operating costs.
- Tax concessions and funding possibilities.
- Structural benefits.
- Compliance rebates have been simplified.
- Higher rates of occupancy.
- Increased rental rates.
- Increased asset value and risk reduction.
- Tenant contentment.
- Possibilities for local and national recognition.
- Built to last.
- Governmental regulations are maintained.

C. Environmental, Economic and Social Benefits

- Improve and safeguard occupant health.
- Enrich and conserve biodiversity and ecosystems.
- Enhance your aesthetic characteristics.
- Natural resources can be preserved and restored.
- Raise the standard of living and monetary viable.
- Reusing building materials lowers operational costs which also boosts tenant productivity.
- Reduces liability.
- Alleviate the workload on local infrastructure and maintain a healthy lifestyle.
- Reduce toxic waste emissions, pollutions and environmental degradation.
- Reduce reliance on non – renewable sources such as fossil fuels.

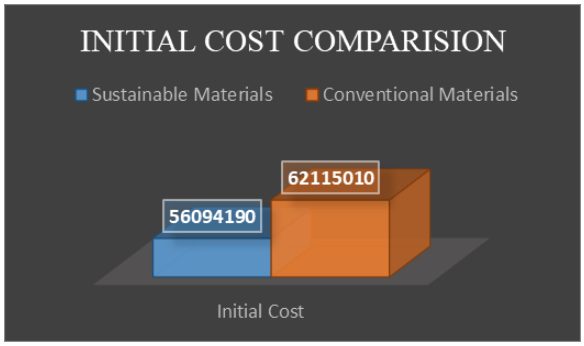

Fig. 1. Cost comparison of construction materials used on site

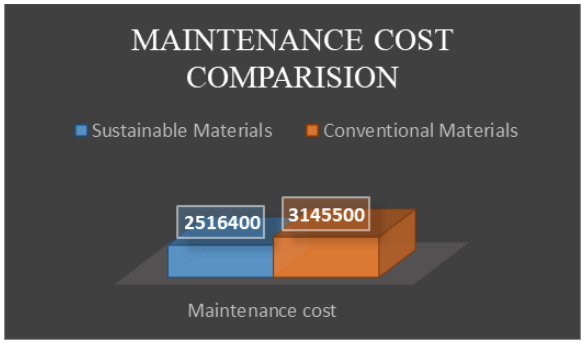

Fig. 2. Maintenance cost of construction materials

5. Conclusion

Sustainability is progressively turning into a key thought of building professionals, approach creators, and industry alike since the globe is moving towards zero-vitality construction [3]. Sustainable building materials are of high performance. Based on the above data processing, it can be seen that the building that has been implementing green building will release operational costs and environmental costs efficiently [4]. These usually come from renewable sources, or can be recycled easily. Such options are generally cheaper than conventional materials, but even when more expensive, they often generate energy savings for the property owner. Materials are the key to sustainability in the built environment and innovative new materials will allow architects and engineers to build structures that have greater value as they are more pleasing to use, live in or look at, healthier and much more sustainable [7]. At the same time, they maintain and sometimes exceeds building quality standards. The building sector is best placed to lower greenhouse emissions, when compared to other large emitters – according to the UN Environment Program. There's actually potential for the construction sector to act as a carbon sink in the future i.e., absorbing and storing carbon rather than releasing it into the atmosphere. Building with recycled steel, which keeps its properties even after being recycled multiple times where there's no loss of quality. And amazingly, 75% less energy is used every time that steel is repurposed as a building material.

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