An Analysis on Low Cost and Energy Efficient Materials for Sustainable Housing

V. Nandhini[1], D. Ambika[2], V. Sampath Kumar[3], S. Dhinu Priya[4], G. Poovizhi [5] and V. Santha Rubini [6]

PG Scholars [1,4,5,6] , Assistant Professors [2,3]

Abstract

One of the necessities of human beings is suitable housing. At current, there are millions of people without an appropriate roof over their heads. The world requires environmentally friendly, sustainable housing of low cost to afford to house for the millions of impoverished peoples. Housing construction should tame the existing method of conventional construction, which is affluent and has meager thermal performance and ignores the substantial environmental impact of high embodied energy of the building process. Consequently, there is a requirement for developing better low-cost sustainable building techniques. In this paper, an eco-friendly residential building and low-cost building are identified, and the materials used in those buildings are identified. The cost of each material is collected, and it helps to know the low cost and energy-efficient materials for construction. Few green building materials are also identified, which can be used for sustainable housing.

Keywords: *Eco-friendly material, Energy-efficient material, Low cost and Sustainable housing.*

I. Introduction

Sustainability can be defined as meeting the requirements of the present without compromising the requirements of future generations. Sustainable housing has the prospective to provide superior quality housing at a value that is reasonable both in long and short term. Thus, sustainable housing targets environmental, economic, and social sustainability from design to the execution phase and also result in reasonable and environmentally less damage housing. Bamboo is considered as one of the new rising materials which have extraordinary financial potential. Bamboo has been customarily utilized in India, Latin America, Philippine, and China for a hundred so years. It has been used as auxiliary individuals in short-length footbridge, low-ascent houses, long-range rooftop, and development stages. Additionally, it is likewise abused in erection, design, destruction, and common works. The proportion of rigidity to the thickness of bamboo is multiple times higher than that of steel [1]. The utilization of nearby materials in the various segments of working can help for low salary bunches. It was seen that with the utilization of innovation and reuse of waste material as a building material, the expense of development could be limited to a degree. The reuse of waste material like rice husk, fly debris, and so forth as a building material and the filler chunk can be utilized as an option in contrast to ordinary piece the expense of development can be decreased [2]. The utilization of locally accessible or created constructing materials for housing can lessen the structures sway on the earth. It emphasis around five gatherings of building materials, for example, bamboo, compressed earth blocks, and interlocking blocks of reused materials, which are the promising structure materials for low-cost housing development. It introduces a test for the improvement of maintainable structure materials [3]. Low-cost housing is an idea that manages compelling costing and the systems which help in diminishing the cost development using faraway accessible materials. The cost of decrease is accomplished by choice of progressively proficient material or by an improved structure. Focal points of low-cost building materials are contamination, counteractive action, and reducing energy consumption [4]. The requirement for moderate and sustainable housing preconditions essential for manageable urban arranging and sustainable housing, economical structure materials for low-cost housing, and parts of social sustainability are considered. The utilization of reasonable and locally appropriate structure materials, for example, wood, bamboo, adobe bricks, and compressed earth blocks, can be exceptionally encouraging for concerning sustainability [5]. Structures were probably the biggest buyer of vitality and materials, and subsequently, they are likewise perhaps the biggest supporter of negative natural effects. The blended Assessment Method and National Environmental Database, NMD approaches were utilized to dissect the natural effects of building materials, as their shadow costs. It has been recognized that the natural effect of a structure is, to a great extent, affected by the material decisions made at the early plan phase of the undertaking. It has been demonstrated that it is conceivable to diminish the natural effects of building materials even on account of a cautiously planned low vitality building [6]. Six waste materials in our everyday lives were blended in with the gypsum powder and allo-chroic powder to make thermochromic face blocks. Allochroic confronted blocks can be applied to both inside and outside dividers of various kinds of structures [7].

Various reusing assets, for example, fallen leaves, recouped iron powder, wood chips, supply residue, and so forth., were the utilizable waste materials. Three waste materials, for example, wood chips, concrete, and waste paper were blended in with gypsum and broke down in thermochromic material, and it is made into blocks. The warm radiation of daylight can be consumed by the blocks to change the tint. These allochroic blocks can be applied to the outer dividers of structures [8]. Soil, reeds, stones, natural timber, sun-dried adobe blocks were the zero-vitality building materials. Lime, fired mud blocks, lime-pozzolana concrete were the medium-vitality building materials. Aluminum, glass, steel, portland concrete, nano-materials, plastics, and so forth were the high-vitality building materials [9]. Vitality utilization in the private and tertiary areas was particularly high. Vitality protection measures were produced for recently built structures and structures under renovation. To move toward the possibility of flexible structures vitality, water, land, and material protection, together with ecological stacking and the characteristics of the indoor and outside situations, were considered [10]. High-density wool insulation in all dividers to give warm solace. Testing minimal effort building materials that can give basic, warm, and vitality effectiveness and landing at indoor warm solace limits dependent on the inhabitant's inclinations in nearby climatic conditions [11]. Cellular blocks are the selective masonry work units utilized in building development ventures for its colossal quality and toughness [12]. Marble squanders can be utilized to produce feasible green composite materials for development applications. Marble squander has been investigated for conceivable usage, consequently, it helps in forestalling the natural issues, for example, dumping and contamination. Marble muck eco- blocks have the most reduced water ingestion [13]. Energy preservation measures can viably cause a few reserve prudence in energy and take into consideration its stability [14]. The inclusion of solar passive into the structure prompts a decrease in energy utilization of building which at last lessens the CO_2 emanations and aides in sustainable advancement [15]. The mud block wall structure with a south bronze-insightful glass window is energy redeemable from the minimum heat improvement [16]. The heat, sound, and fire adsorbing glass-fleece separators are excellent in numerous regards, but their structure crumples in the fire [17]. The manageable solution for reused Construction and destruction squanders including reused concrete aggregates and reused marble as elective development materials have become a worldwide pattern these days [18]. Cost decrease of the thermal protection materials can be accomplished by utilizing common materials and squanders as a piece of the primary framework, which will likewise contribute to the decrease of CO_2 discharge [19]. Natural locally accessible materials are favored over present-day materials. These included materials like a block that were privately made. The decision of these materials stemmed out from the need to utilize negligible energy [20]. Most of the resources expected to construct houses for all are non-renewable. These issues inspire the need to heed the advancement of materials that outcome in lower development costs and insignificant expenses to nature [21]. Individuals need houses that are appealing, having more life expectancy, bigger space territory, natural inviting and less expensive. In this manner, low-cost houses and minimal effort houses are expected to satisfy the requirement. The nearby accessible materials and innovation fill a need for low pay individuals [22]. The houses can be built by utilizing customary and locally accessible crude materials of bamboo, reeds, stick, rattans, willow, timber and leaves of some specific trees, and has been intended to suit the conventional living propensities for neighborhood individuals and keep up their socio-social legacy [23]. Many developing and developed nations see economical housing improvement as excessively expensive for low - center pays family units [24]. All materials should be environmentally friendly, renewable and efficient [25]. All the naturally available materials are exhausting which has made it obligatory that we pick materials and development frameworks that need minimum energy for its implementation [26]. Natural fiber fortified polymer composites have risen as a potential ecologically cordial and financially savvy option in contrast to manufactured fiber strengthened composites [27]. Using plastics for minimal effort development has suggestions for supportable waste administration and satisfactory housing [28]. Net-zero energy structures have substantially maximum costs [29]. Bamboo items have properties that are practically identical to or outperform that of timber-based and timber items [30].

II. Material Identification

A. Green Building Material

Green building materials are comprised of renewable rather than nonrenewable material. Green materials are environmentally accountable because impacts are examined over the lifespan of the product. Construction actions worldwide consume 3 billion tons of raw materials every year or 40 percent of total universal use. Utilizing green building materials and products stimulates the conservation of declining nonrenewable resources internationally. Also, incorporating green building materials into building projects can help in decreasing the environmental impacts associated with the extraction, transportation, processing, installation, recycling, reuse, and disposal of building industry source materials.

Some of the green building materials are clay, mud, sand, wood, stone, bamboo, cork, abode bricks

which are made up of clay, sand, and straw and mud and lime, rammed earth, cob, straw, earth plasters, areca, casuarina, reused wood pillars and door, reused bricks, Porotherm hollow block, Mangalore tiles, mud, and coconut fiber are used for plastering, Mangalore tiles and coconut shells are used as filler material, terra cotta, Athangudi tiles, linseed oil and natural Colouring Agent for painting and kurudi blocks.

B. Materials Used

For this study, I have taken three buildings that were constructed using eco-friendly, low cost, and green materials.

a) Low Cost and Eco – Friendly Residential Building

The residential building which I have chosen for the study is located at Dharapuram with a total built-up area of 1664 sq.ft. Materials used for the construction of low cost and eco-friendly residential building is porotherm hollow block, Mangalore tile, Athangudi tile, plus door and UPVC. The eco-friendly residential building is shown in Figure 1.

Figure 1. Ecofriendly Residential Building

1) Porotherm Hollow Block

Porotherm smart bricks are 60% lightweight than ordinary walling material. The structural cost is saved due to the reduction in dead load. Faster construction can be achieved by using these blocks. The handling of this block is secure, and it has excellent insulation of 45% better compared to conventional walling material. It provides a cooler temperature inside the building. The block is coated with waterproof polish to avoid the formation of fungus. The coating has to be done for 15 years once, and so the maintenance cost was very less. Porotherm Hollow block is shown in Figure 2.

Figure 2. Porotherm Hollow Block

2) Mangalore Tile

Mangalore tile provides excellent waterproofing in regions of rains quite frequent. It is corrosion-resistant, and it has greater longevity when compared to other materials. Mangalore tile is shown in Figure 3.

Figure 3. Mangalore Tile

3) Athangudi Tile

Athangudi tile is a modest composition of cement, sand, stone aggregate, ferrous oxides. The head surface of the tile was patterned with glazing, and it can be manufactured in anyplace. Athangudi tiles are easy to install, durable for decades, and financially affordable. Athangudi tile is shown in Figure 4.

Figure 4. Athangudi Tile

4) Plus Doors

Doors are made up of recycled wood which decreases the demand for reclaimed lumber. Also it can reduces the landfill waste. Plus door is shown in Figure 5.

Figure 5. Plus Doors

5) UPVC Windows

Windows are made up of UPVC. Windows with different dimensions were used for the purpose of ventilation and lighting that is 40% for lighting and 60% for ventilation. UPVC window is shown in Figure 6.

Figure 6. UPVC Windows

6) Filler Slab

The use of filler slabs reduces 30 to 40 % of total construction cost. It does not need plastering, weathering course, and reinforcement. Filler slab is shown in Figure 7.

Figure 7. Filler Slab

b) Laurie Baker Low- Cost Housing

India's housing issue can be resolved only by using locally available resources. In the location of Laurie Baker's low-cost housing, mud is the material that is obtainable locally in plenty, which can be used for bulk housing construction. Distant from its easy obtainability, other benefits of mud are that it costs less and consumes lesser energy. Laurie Baker revealed a concealed heritage in the local home-grown style of architecture and to use only local materials which is instantaneously available to make structurally stable buildings that could manage with local climatic conditions.

The materials used for construction are abode brick, terra cotta tiles, jallis, bamboo, Mangalore tiles, and coconut shells.

1) Abode Brick

Abode bricks are fabricated with mud and lime. It is fireproof, non-toxic building material, durable and it provides adequate thermal mass to buildings. The abode brick slab is shown in Figure 8

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Figure 8. Abode Brick

2) Terra Cotta Tiles

Terra cotta tiles absorb, store and discharges heat very effectively, make the building intramural warmer in winter and cooler in summer. It makes the interior environment further comfortable and also decreases the energy demand and allied carbon emissions. Even a 15 mm clay plaster coating will have a substantial insulating effect. Terra cotta tile slab is shown in Figure 9.

Figure 9. Terra Cotta Tiles

3) Filler Slab

In filler slab, Mangalore tiles and coconut shells are used as filler material. It can reduce 30 to 40 % of construction costs and also the use of reinforcement in the building. Filler slab is shown in Figure 10.

Figure 10. Filler Slab

4) Jallis

Jallis are used for light and ventilation instead of windows. It is a local and waste material. Jalli is shown in Figure 11.

Figure 11. Jallis

5) Bamboo

Bamboo has higher tensile strength, less weight, easy to use, cost-effective, and it does not cause any danger to health. Bamboo is shown in Figure 12.

Figure 12. Bamboo

C. Auroville Earth Institute Technology

Auroville Earth Institute targets making widespread use of raw earth as the primary building material, thus energy-saving, sustainable, and eco-friendly. It focused on reducing the use of cement, steel, and reinforced cement concrete in constructing a building.

Materials used in Auroville institute for construction is compressed stabilized earth blocks, thatch, wooden rafters, and bamboo mat.

1) Compressed Stabilized Earth Blocks

The raw soil is stabilized for a compressed earth block is marginally moistened, decanted into a steel press, and then compressed either with the motorized press or a manual. Compressed Earth Blocks can be compressed in several different sizes and shapes. Compressed Stabilized Earth Blocks are energy-efficient, inexpensive, eco-friendly, soundproof, toxin-free, and resistant to fire and pests. It decreases deforestation because there is no necessity for the burning of brick. The carbon emissions are 12.5 times lesser than country fired brick, and embodied energy is 10.7 times smaller than country fired brick. The strength is greater than the country fired bricks.

2) Thatch

Thatch is a natural insulator and natural weather-resistant material. The air pockets inside a thatch roof insulate the building in both cold and warm weather. Thatch is shown in Figure 13

A. Brick

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Figure 13. Thatch

3) Wooden Rafters

Timber is a flexible and versatile material. It is economical, eco-friendly, durable, and energy-efficient material.

4) Bamboo Mat

Bamboo mat is eco-friendly and economical, and it is an alternative to concrete or metal. The bamboo roof is natural and eco-friendly, and its roofing sheets are much flexible.

III. Cost Comparison of Green Material over Conventional Material

Cost comparison of brick, floor tile, roof tile, and rafters are shown in table 1, 2, 3, and 4.

Table 1. Cost Comparison of Brick

Green Materials	Size (cm)	Cost (Rs.)	Conventional Material	Size (cm)	Cost (Rs.)
Porotherm Brick	40 x 20 x 15	48 per piece	Red Brick	19 x 9 x 9	7 per piece
Compressed Stabilised Earth Blocks (CSEB)	30 x 15 x 9	28 per unit	Solid Concrete Block	39 x 19 x 14	50 per piece

B. Floor Tile

Table 2. Cost Comparison of Floor Tile

Green Materials	Cost (Rs.)	Conventional Material	Cost (Rs.)
Athangudi Tiles	55 Per sq.ft	Vitrified Floor Tile	70 Per sq.ft
Terra Cotta Tiles	30 Per sq.ft		

C. Roof Tile

Table 3. Cost Comparison of Roof Tile

Green Material	Size (inches)	Cost (Rs.)	Conventional Material	Size (inches)	Cost (Rs.)
Mangalore Tiles	10 x 16	30 Per Piece	Cement Roofing Tile	12 x 16	45 Per Piece

D. Rafters

Table 4. Cost Comparison of Rafters

Material	Cost (Rs.)	Conventional Material	Cost (Rs.)
Wooden Rafters	50 per sq.ft	Mild Steel	150 Per sq. ft

IV. Barriers of Using Green Materials

The obstacles that are observed in the site for implementation of green materials are the lack of technical skills to construct a building using green building materials, the lack of training and education about the use of green building materials in construction, the lack of awareness and knowledge among stakeholders.

V. Star Rated Materials

A. Bamboo

Bamboo is considered as one of the star rated material because it is a renewable, strong, and sustainable building material. Green rating systems in India (GRIHA / LEED) help in encouraging the use of bamboo as construction material by stimulating the building professionals to use bamboo related building materials. IGBC affords 4 points for hastily renewable building material in the building.

B. Terra Cotta Tiles

Terra cotta tiles are a sustainable and energy-efficient selection for building construction. It is long-lasting which life expectancy of over a hundred years. Tiles also do not require maintenance, protecting the environment from harsh chemical cleaners and landfills. It is recyclable and reusable for prospect construction.

C. Straw Bales

Strawbale was considered as a star-rated material because of its durability, resistance to burning, pest infestation, and high insulation. The building built of the straw bale has been certified as a LEED Gold building by the U.S. Green Building Council.

VI. Alternate Green Building Materials for Sustainable Construction

Some of the green alternatives for the building material that can have a lower impact on the environment at a low cost and helps in achieving sustainable housing are identified.

A. Bamboo

Bamboo can be used as a reinforcement as an alternative to steel. It has been extensively used as a conservative building material and is attaining additional focus due to its potential for eco-friendly value in green construction. Bamboo provides more oxygen and absorbs more carbon dioxide, which is very superlative in combating global climate change.

The advantages of bamboo a green building material are it has greater tensile strength than steel. The fire resistance competency of bamboo to resist fire is very high. The elasticity of bamboo is extensively preferred in earthquake-prone regions due to its elastic nature. The weight of bamboo is less, and so it can be easily displaced and installed, which makes transportation and construction easier. It does not affect human health like asbestos and cement, and they are cost-effective.

B. Palm Tree

Palm trees are used as a building material for rafters, house walls, and roofing. It can be used as a column in construction. The palm tree is the strongest of tree species, and it can persevere for several years. It is hard, durable, and heavy and is greatly valued for construction.

C. Clay Bags

Clay helps the bags mold firmly around the barbed wire, enhancing the tensile strength of the walls. Sand, gravel, and stone dust can sustain during flood conditions better but may need extraordinary bracing during construction.

The advantages of clay bags as a building material are the tensile strength of clay bags is the same as the function of reinforcing rods and rammed earth used in concrete structures mainly when they are combined

with four-point barbed wire. The durability of clay bag for construction was tested under the substantial wind, snow, and seismic circumstances at the California Institute of Earth Art and Architecture and has conceded all building code requirements. They can also be able to withstand magnitude 6 and 7 earthquakes, together with fire, hurricanes, and floods, and this durability makes it a practical alternative to conventional building materials.

D. Straw Bales

Strawbale can be used in its unprocessed state because it does not need extra processing, and it is quite inexpensive. By using straw bale, the building will undoubtedly provide very significant levels of insulation for climate change.

The straw bale is a low carbon and low impact building material. The energy efficiency of the straw bales exceeds that of contemporary construction. It efficiently holds the interior temperatures in even the coldest climates. Another main benefit is that clay and straw are profuse materials, making them available at low costs. Though straw might be a tremendous combustible material, the straw wall with clay finishing on both sides maintains a fire separation of 90 minutes, which prominently exceeds that of general residential construction. Lastly, at the end of building a life, the materials can be completely recycled back into the environment with slight to no impact.

E. Coconut Shell Tile

Coconut tile is prepared from reclaimed coconut shells, low- volatile organic compound resins, and sustainably harvested wood benefactor. Coconut shell is an innately anti- decomposition material having natural resin. Coconut mosaic tile is made by hand. It has magnificent performance, versatility, and durability.

The benefits of using coconut shell tile are waste produced can be reduced. Coco Tiles eliminate unwanted coconut shells from the waste stream. The coconuts are reaped for their eatable portions, leaving behind the shell. Till now, these shells have been thrown away or burned, adding to landfill waste or cause air pollution. Coconut tiles eliminate these shells from the waste and produce an exclusive decorative material. Resins and adhesives used are zero volatile organic compound types of glue and resins in the construction of coco wall panels, serving to reduce harmful pollutants in the ambient atmosphere.

F. Cactus Extract

The cactus extract increases the plasticity of the mortar, compressive strength, and workability of the concrete. The setting time of cement can be delayed due to the moisture-holding capacity of carbohydrates extant in the cactus.

G. Terra Cotta Tiles

Terracotta floor tiles are recognized for their toughness and durability. These tiles can tolerate abuse without splinter, chipping, or fading. It is flexible and can be sealed to increase its stain resistance and moisture features. The brown and earthy red color of the tiles provides it a natural look, increasing an aesthetic appeal to the house.

H. Porotherm Bricks

Porotherm hollow bricks peruse the benefits of natural clay. These are perforated hollow blocks that can be either vertically perforated or horizontally perforated. They are made up of natural substances and are empty inside, which makes them more efficient than the standard solid blocks and bricks. Porotherm brick weighs 60% lesser than conventional brick. The compressive strength of porotherm brick is more significant than 3.5 $N/mm^{2,}$ and its density is around 700-800 kg/m^3. It is conveniently lightweight and large blocks.

VII. Results and Discussion

The cost of Auram Press (Earth construction equipment) for the production of CSEB ranges from Rs.2,11,967 to Rs. 4,23,933. So, porotherm bricks can be used over other bricks because there was no initial cost, and the quantity of bricks used in construction gets reduced due to its larger dimension, and it does not need plastering and painting. The cost difference between Athangudi tile and Vitrified floor tile is Rs. 15 per sq.ft, which is nearly 27%, and the cost difference between Terra Cotta tile and Vitrified floor tile is Rs. 40 per sq.ft, which is almost 57%. The cost difference between Mangalore tile and cement roof tile is Rs.15 per piece, which is nearly 33%. The cost difference between the wooden rafter and mild steel rafter is Rs.100 per sq.ft, which is nearly 67 %.

VIII. Conclusion

Porotherm brick and Compressed Stabilised Earth Blocks wall houses are affordable low-cost dwellings. The use of these blocks does not need plastering and painting. It will not cause any harm to human health and the environment. The cost of construction gets reduced. Materials used for eco-friendly construction are Mangalore tiles, Terra cotta tiles, Athangudi tiles, Porotherm bricks, Compressed stabilized earth blocks, bamboo, wooden rafters, and thatch. The cost of these materials is compared and analyzed to identify the low-cost materials for the construction of low cost and energy-efficient buildings. Filler slab was used to reduce the cost of installation. This type of construction is sustainable and helps in decreasing

CO_2 emissions. Apart from these materials, few green building materials are identified as an alternative to existing conventional materials, and their benefits and drawbacks are studied.

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