

The Application of Green Building Materials – A Systematic Review

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Abstract— *The use of sustainable materials is a component of sustainable development. The world has become increasingly globalized, and it is evident that in order to handle the enormous environmental pressure that human activity is placing on the planet, sustainable solutions must be proposed and implemented as soon as possible. This change is not only conceivable, but also necessary. Sustainability in building construction is currently a top focus due to the numerous benefits it provides. Because the worldwide trend is to-ward sustainability, sustainable building construction is critical in the construction business. Many environmental challenges are arising as a result of massive urbanization activity. Material efficiency, water efficiency, energy efficiency, indoor air quality efficiency, waste reduction, and sustainable site planning are all components of green building. A systematic examination of the available literature on the benefits of employing green materials in sustainable building was used to undertake this quantitative research technique. Meta-analysis was used to collect and analyze data. Green Building is a building that incorporates environmental considerations into every stage of design with the goals of protecting occupant health, improving workforce productivity, using natural resources wisely, and reducing environmental impact. Green buildings provide better health for building occupants due to enhanced interior quality, the development of more energy efficient products, and the use of fewer natural resources for the enjoyment and welfare of building tenants, as well as to safeguard the ecosystem, according to the findings. According to the findings of this study, the benefits of green construction should inspire clients, consultants, and contractors to invest in green buildings. Building with sustainable materials will reduce pollution while also improving the current condition of environmental challenges. This paper provides stakeholders, from designers to occupiers, with a cohesive overview of the sustainability concept and its beneficial role for future generations in order to grow this issue by increasing scientific information transmission from a technical-engineering perspective.*

Keywords— *Benefits, Energy consumption, Green Materials, Material efficiency, Sustainable Buildings, Sustainability.*

I. INTRODUCTION

The current status of the planet is pretty concerning. Particularly in regard to the issue of global warming caused by human activities such as industry and the usage of non-environmentally friendly materials. All of this contributes to global warming, which is hazardous to the environment. One option is to lessen the impact of global warming by using the notion of Sustainable Design [5]. People today are concerned about the extensive direct effects of industrialization on the environment, such as building and construction directions, materials, and designs. Energy, raw materials, water, and even waste items are among the resources under concern. The necessity to meet building needs and regulations such as accessibility, security, health, and productivity is a common unique difficulty encountered by building specialists, designers, or owners. The most significant requirement is to be environmentally conscious. Economic expansion is currently a significant challenge to sustainable design; however the approach adopted must be environmentally friendly by assuring conservation. People will wish to optimize a balance of financial, ecological, communal, and human benefits while still meeting the stated objective of proper infrastructure or facility, primarily in terms of comfort, productivity, and safety. A building has an impact on its surroundings, which contributes to global warming [4]. Taking the most groundwater and squandering water are required so that the groundwater surface recedes. A variety of waste impacts the ecosystem, including garbage, contaminated water, and household waste. It also contributes to greenhouse gas emissions, primarily through warmth from the AC machine. It

also has a negative influence on users, such as disrupting health and decreasing activity efficiency. Furthermore, as building begins, it contributes to a variety of negative environmental effects, including waste materials, noise, smoke, and dust, among other things [1]. Several architectural specialists and other experts developed and implemented answers to these problems, beginning with how to produce some recycled materials, design a house to grow, and build a structure that is light and fast. Adopting the notion of green building becomes one of the primary options for achieving environmental balance. Ecobrick is a sustainable material application in which recycled bottle debris and plastic waste are blended to make various modules [5] [11]. At first look, it appears that creating sustainable materials is simple and can help to mitigate the effects of global warming. Materials are made from resources that are either renewable or nonrenewable. Because the earth's capacity is finite, resource reduction is critical for our world's sustainable development. Sustainable development has been defined as development that meets the requirements of the present without harming future generations' ability to meet their own needs. It was understood to bring together humanity's development demands, environmental protection and conservation, and the ability of future generations to meet their own needs. Sustainability necessitates balancing environmental, social equality, and economic concerns.

Environmental problems stem from the world's over usage of commodities and energy. Materials have provided benefits and conveniences to human life, but they also impose a wide range of environmental responsibilities at every stage of production. The extraction, production, and use of ever-

increasing volumes of material resources--the majority of which are finite--will eventually have significant environmental implications [4]. The ramifications of existing economic patterns, our continuous existence with environmentally unsustainable materials, had influenced the potential of climate change. The crises heighten the stakes for innovative materials solutions. Sustainable materials are now thought to be a solution for an integrated strategy to managing material life cycles in order to achieve both economic efficiency and environmental viability [10][7]. These materials' qualities, performance, and composition all contribute significantly to reduced environmental impact, from cutting carbon emissions to making better use of the earth's scarce resources. Sustainable materials are materials that fit within the limits of a sustainable materials system, where the material must be appropriate for the system and the system must be appropriate for the material in order to be sustainable. As a result, it is critical to analyze how material progress might contribute to the establishment of a sustainable society. The ability of the planet; air, water, and land, as well as many forms of environmental challenges produced by our current patterns and rates of resource usage, is currently the critical materials issue we are facing. There is no way to completely eliminate all environmental problems. In many places of the world, there are numerous obstacles to sustainable development, including environmental degradation [14] [2].

II. BUILDING MATERIALS THAT ARE ENVIRONMENTALLY FRIENDLY

TABLE 1. Criteria commonly used to define sustainable materials

S/No.	Criteria
1	Recyclability of building materials and the demolished building
2	Thermal efficiency
4	Financial viability
5	Transport costs and environmental impact
6	Locally produced and sourced materials
7	Occupant needs and health considerations

Sustainable construction materials are those that have overall higher performance in terms of the predefined criteria shown in table 1. These materials are associated with resource sustainability, particularly rare resources (17). Most green professional builders would recommend that their clients install alternative waste water systems or solar energy systems. Other well-known materials include rainwater harvesting systems, compost toilets, radiation barriers, toxicant terminators or controllers, and environmentally friendly concretes. Environmentally sensitive buildings should be incorporated into designs and technical advances for a better and more sustainable future. Bridge designs that have been inventive in the last two decades have had a significant impact on the need to maintain the environment through the aspect of beauty. Similar qualities can be found in green framework products and materials [13] [8]. Recyclability or reusability of building materials derived from increasingly depleting resources, such as asserted tile flooring, bamboo flooring, wool matting, strawboard, and cotton ball safety (formed from denim scrap). The use of renewable materials decreases the usage and fatigue of limited harsh materials,

boosts durability, and reduces the amount of radioactive radiation generated by the component. When selecting a building material for product or project development, a variety of aspects must be examined to determine the material's sustainability. These materials must be derived from renewable resources rather than nonrenewable resources. The environmental impact of the chosen material must be considered across the entire life-cycle of the project, not only in the near term. Going "green" is not a passing fad. Many people are becoming champions for sustainable products because they benefit from them in a variety of ways. The following are the most prevalent sustainable materials utilized in today's various industries [4].

1. Bamboo



Source: Pexels

Bamboo is regarded as one of the most environmentally friendly building materials. It grows at an exceedingly fast rate, with some growing up to 900mm tall in 24 hours. It spreads and grows without needing to be replanted after harvest. Bamboo is a perennial plant that grows on all continents except Europe and Antarctica. It also has a high strength-to-weight ratio, stronger overall strength than concrete and brick, and a very long lifespan. As a result, it is the finest option for flooring and cabinetry. Unfortunately, bamboo must be treated in order to fight insects and decay.

Bamboo contains starch, which attracts insects, and it may expand and split after absorbing water if left untreated [3] [5].

2. Recycled Plastic



Firms are making concrete using recycled plastic and other ground-up rubbish rather than finding, mining, and milling new building components. Instead of adding to plastic pollution by filling landfills, this strategy minimizes greenhouse gas emissions while giving plastic rubbish a new use. Polymeric timbers are made from a combination of recycled and virgin plastic and are used to make fences, picnic tables, and other constructions while protecting trees. Two-liter bottle plastic can be spun into fiber and used to produce carpets. Cable pipes, roofs, flooring, PVC manholes, and PVC windows can all be made from recycled plastic. Recycled plastic is a durable and long-lasting material with great sound absorption properties. In the long run, making this green circle out of what we currently have will significantly reduce waste [18] [4].

3. Precast Concrete Slabs



Source: engineeringnews.co.za

Because they are weather durable, precast concrete slabs are used for walls and building facades, while others can be used for floors and flat roofs. Concrete is an excellent building material for controlling heat within a structure, and it is very inexpensive. Precast concrete slabs are more environmentally friendly than many other types of concrete since they require less energy to manufacture and construct. Precast concrete can also cure in a controlled environment rather than being exposed to a variety of unfavorable weather conditions when curing on a construction site. As a result, precast concrete

slabs minimize concrete fissures and structural faults, as well as demolition [17] [16].

4. Solar Panels



Source: alternative-energy-sources.co.za

Solar panels are becoming more common on roofs and in yards as technology progresses and designs become more visually appealing. Using solar panel tiles or mounted structures, a home can reduce its dependency on nonrenewable energy [11].

5. Newspaper wood



Source: vij5.nl/en

Did you know that the cycle can be reversed and paper can be converted back into "wood"? Newspaper wood is created by compressing old newspapers and glue into thin layers until

the texture resembles wood grain. How cool is that? What most of us consider recyclable rubbish is given new life through the up cycling process. It extends the life of paper on a whole new level by using less energy to change its condition for new use [13] [15].

6. Rammed Earth building



Source: murchisonrammedearth.com.au

It is a technology that has been employed for hundreds of years throughout human civilization and has a very lengthy lifespan. By compacting natural materials such as chalk, earth, gravel, or lime, it is a typical and cost-effective method of making sturdy foundations, floors, and walls. When forcefully pressed in wooden forms, it produces walls with a comparable feel to concrete. The use of rebar or bamboo in rammed earth buildings makes them safer or fortified. Mechanical tamping can significantly reduce the amount of labor necessary to build strong barriers. Rammed earth walls and floors can be used as thermal storage, allowing the sun to warm them throughout the day and slowly re-release the heat during the cooler evenings [7] [18].

7. Straw Bales



Source: hay-bale-wallpaper

It is yet another environmentally friendly building material that can be utilized as a framing material. They have strong insulating qualities and can be used as a soundproofing material. It can also be used as a fill material between columns and in beam a framework because it does not allow air to pass

through and has some fire resistant capabilities. Straw may be simply gathered and replanted with minimum environmental impact. Making straw into bales has a negligible impact. They can also be installed on walls, attics, and ceilings to help cool the house in the summer and warm it up in the winter. From sourcing to energy efficiency, straw-bale constructions are a sustainable building approach. Straw can be crushed and manufactured into ceiling and wall panels for insulated cladding in homes, in addition to bales. Compressed straw has numerous environmental advantages, including the fact that it is 100% recyclable and biodegradable. When straw panels approach the end of their long life cycle, they can be mulched and used as compost in gardens, or they can be recycled back into panels and reused [1] [10].



Building with hay-bale roof
Source: earth-heaven.com

8. Hemp Crete blocks



Source: theconstructor.org

It is a concrete-like material made from the hemp plant's woody inner fibers. The fibers are bonded with lime to form strong and light concrete-like formations. Because hemp concrete blocks are lightweight, they require significantly less energy to transport. Hempcrete is strong, has excellent thermal and acoustic insulation, and is fire resistant. Furthermore, its most important sustainable attribute is that it is CO₂ negative, which means that it absorbs more CO₂ than it emits. Hemp is a rapidly developing and renewable resource. Hempcrete is a permeable material that does not shrink when dried, thus there are no fracture lines. Although hemp Crete is not as robust as concrete, it is fire-resistant, pest-resistant, and a good insulator [2] [9].

9. Smart Glass Windows



Source: smartglassvip.com

In recent years, a major trend in sustainability has been the use of large windows to let in more natural light while reducing the demand for electric lighting. The benefits of this construction method cannot be oversold, but the benefits can be improved by using smart glass for the windows. The thermal properties of an innovative material known as "smart glass" change depending on how heat and air conditioning are applied within the residence [11] [14].

10. Mud bricks



Source: acs.edu.au

Traditional brick production is an energy-intensive process that entails the use of fossil fuels and the release of enormous amounts of greenhouse gases into the atmosphere. Mud brick is an environmentally friendly alternative to standard bricks that uses significantly less energy and chemical additives during manufacturing. When compared to regular bricks, this material has a near-zero carbon footprint (depending on shipping) and takes half the time to make [1] [2].

11. Terrazzo



This is a mosaic flooring type in which little bits of marble or granite are embedded in polished concrete or epoxy resin. Terrazzo floors, when properly maintained, can endure up to 40 years without losing their luster. The original terrazzo was put in cement and was inspired by the work of 20th-century Italian artists. Today, epoxy resin is used to make 90% of terrazzo floors. Terrazzo & Marble Supply Company creates 'forever flooring' from its proprietary epoxy, which includes materials such as brass, aluminum, and zinc, as well as recycled glass, beer bottles, marbles, and porcelain. A terrazzo floor may be more expensive than carpets, but carpets must be replaced. Terrazzo floors, on the other hand, have a lifespan of more than four decades, making them a sustainable building material. Furthermore, before pouring terrazzo, you can use the color of your choice to create the floor of your desire. It creates easy-to-clean floors that can also be used in high-traffic areas like as schools, airports, and stadiums [16] [17].

12. Recycled Tires



Rubber tires were not recycled until recently, and they clogged landfills. Fortunately, researchers discovered that the rubber found in tires provides durability, flexibility, and insulation, all of which are crucial features in construction materials. Some Earth ship homes, which are environmentally conscious, employ recycled tires packed with sandbags as insulation. Others are working on techniques to create rubber masonry blocks from recycled tires that can be used to build new structures. This is a sustainable method of keeping tires out of landfills. It is a recyclable substance that can be used to create home insulation [13] [15].

13. Reclaimed, Recycled or Sustainable Wood



Source: woodguide.com

This is the most commonly used building material for a reason. It is aesthetically pleasing, easy to operate, and brings nature indoors. Reclaimed or recycled wood has a far lower environmental impact than new timber harvesting. However, if you are purchasing new wood, it is critical that you acquire it from a sustainably managed forest. It is also a terrific material for natural-looking floors or exposed beams. It's no surprise that it's become one of the most popular materials in eco-friendly architecture [3] [12].

14. Plant-Based Polyurethane Rigid Foam



Source: byhyu.com

Rigid foam has been used as an excellent insulator for homes and commercial structures for several decades. However, a critical ingredient in the initial generation of stiff foam was discovered to be environmentally hazardous. This is where rigid foam's newer, eco-friendly equivalent comes in handy. Plant-based polyurethane rigid foam is made from bamboo, hemp, and kelp and is excellent for wall insulation. This increased rigidity is also beneficial to furniture and even surfboards. It safeguards against mold and bugs. It has a longer lifespan than other types of traditional insulation. It is an excellent thermal insulation that saves energy and money on cooling and heating [1] [12].

15. Cob



The odd organic-looking dwellings are formed of cob, a mixture of subsoil, water, fibrous organic material (typically longer straw), and, in some cases, lime. Did you realize the oldest known cob structure dates back over 10,000 years? The

housing crisis, combined with climate change, certainly made us consider alternatives. Aside from being environmentally beneficial, cob is a natural material that is really easy to work with, and its texture allows to create designs of any types. It acts as natural insulation and is extremely energy efficient. Cob dwellings don't need much heating [1] [4].

16. Pollution-Absorbing Bricks



Source: civilwale.com

With growing environmental concerns, one of the most challenging problems to handle is air pollution. While other environmentally friendly building materials help to minimize CO2 emissions, pollution-absorbing brick works to offset emissions. While pollution-absorbing bricks are uncommon in modern construction, this futuristic material has the potential to be a sustainable, air-filtering alternative to earth brick. It's a self-contained ventilation system. It is a novel approach to greener building materials and techniques. This technology can help growing cities supply better air to their citizens [6] [7].

17. Composite Roofing Shingles



Source: roofingcalc.com

Constant maintenance, management, and replacement of construction materials necessitate a significant investment in resources. As a result, common roof tile types like asphalt shingles and wood shakes that constantly rise and crack can become energy drains because they allow air and moisture to enter and exit the property. Composite roofing shingles are a superior choice since they retain the natural appearance of more traditional materials while requiring less maintenance [6] [10].

18. 3D-Printed Concrete



Source: researchgate.com

We all know that concrete is a construction material that isn't going away anytime soon. While there are a few potential concrete alternatives, there are also techniques to make concrete production more sustainable. 3D printing is one example. 3D-printed concrete allows contractors to digitally create any shape and "print" it with concrete. It saves time, energy, and money. The capacity to print on demand eliminates waste. Save energy and money on material transportation [15] [17].

19. Natural or Recycled Carpeting



Source: outandaboutcarpets.co.uk

Many carpeting goods are created from synthetic fibers derived from chemicals, however natural fiber carpets such as wool, sea grass, coir, jute, and sisal are also available. Salvage yards may also carry fairly worn carpeting from demolition projects [2] [5].

20. Sheep's Wool

Sheep's wool is an excellent substitute for chemical-laden insulation. It insulates the home just as well as traditional insulation while using less energy to produce. Sheep's wool can help you save energy and soundproof your home. Sheep's wool is a completely natural and environmentally beneficial material that can be swiftly regrown. Wool is most recognized for its use in warm, cozy blankets and sweaters. It is also an excellent house insulator, with its fibres generating millions of tiny air pockets that trap air. Wool is commonly found in the ceiling, walls, and attics. It does not decay as quickly as other insulating materials such as straw, and when compared to some natural insulators such as cotton, sheep's wool is more common, easier to harvest, and regenerates quickly.

Unfortunately, it is not the least expensive insulator. It must also be treated to keep insects at bay and fungi from growing. Depending on the chemicals employed, this treatment may make sheep's wool less eco-friendly [1].

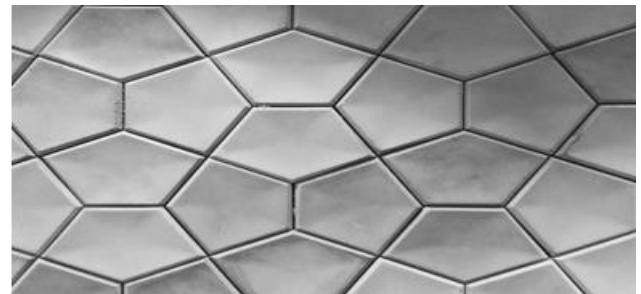


Source: pixabay.com



Sheep wool incorporated in the ceiling

21. Ash Crete



Source: beyondhomes.ca

Ash Crete is a concrete alternative that largely relies on recovered fly ash. Fly ash is combined with lime and water to create a strong and durable material similar to traditional cement. The use of fly ash in Ashcrete makes it an environmentally favorable alternative because it can replace cement, resulting in lower CO2 emissions. Furthermore, high-volume fly ash concrete can replace 25% of the cement. When compared to typical concrete, further advantages of fly ash include less bleeding, higher concrete strength, and reduced shrinkage [10] [13].

22. Low-VOC Paint



Source: kraudelpainting.co.au

VOC stands for Volatile Organic Compounds and refers to organic substances that can outgas into the atmosphere, such as formaldehyde. VOCs are responsible for the disagreeable

odor of oil-based paints. Low-VOC paints contain a lower proportion of these chemical molecules [1] [2].

23. Sand Crete blocks



Sand Crete is comparable to conventional concrete in composition, but instead of the usual aggregate used in cement manufacturing, Sand Crete is made with natural sands and fine river stone. Sand crete minimizes greenhouse gas emissions during production by requiring less Portland cement [7] [9].

24. Reclaimed or Recycled Steel



Source: turbofuture.com

Steel can be used in place of wood for framing, boosting a structure's resistance to earthquakes and severe winds. A 200-square-metres house requires roughly 54 trees to build, while a recycled steel structure requires only the steel equivalent of six discarded vehicles. Steel is 100% recyclable, reducing the environmental effect of new building greatly. The recycled metal is long-lasting material that does not need constant replacements. It does not burn or warp, making it ideal for roofing, building facades, and structural support. Furthermore, repurposed steel is resistant to water and pests. Steel also makes structures more resistant to severe winds and earthquakes [6] [11].

25. Grass Crete



Source: indiamart.com

Grass Crete is a composite material composed of finely crushed rock, water, and grass or turf. It is frequently used in driveways, walkways, parking lots, and other surfaces as an alternative to tarmac. The mixture is spread on a compacted sub-base and then covered with gravel or turf layers. Because

Grass Crete is porous, rainwater may drain through it and vegetation can develop around it [4] [10].

26. Stone



Stone is derived organically from the soil and is used for both construction and home furnishings. When used in construction projects, stone is long-lasting and low-maintenance, and its versatility results in little to no waste. Because it is a naturally occurring material, it frequently does not require factory manufacture, reducing CO2 emissions. It is a long-term investment that will not need to be replaced. It is recyclable and can be used in other projects or to make roadbeds with minimal to no waste [9] [12].

27. Linoleum Flooring



Linoleum is a more environmentally friendly option than vinyl tiles and sheet flooring. Linoleum is created by combining linseed oil resins with wood and cork particles. Linoleum is also simple to recycle. Linoleum can even be composted if it is free of adhesives [1].

28. Timber-Crete

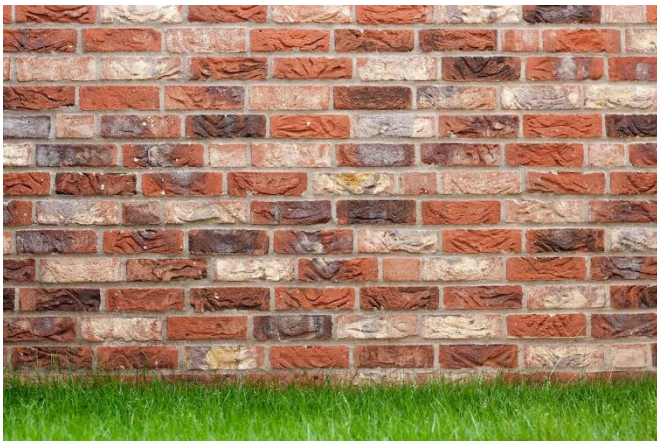




Source: buildabroad.org

This is an intriguing building material composed of sawdust and concrete. It is lighter than concrete and has a lower carbon footprint. Sawdust reuses a waste product while also replacing some of the energy-intensive components of regular concrete. Timber concrete can also be shaped into classic shapes such as pavers, bricks, and blocks [7].

29. Adobe Brick



Adobe brick has been used for ages and is popular in the Middle East and the Americas. Adobe is a clay-straw combination used to manufacture bricks for the construction of houses and other constructions. The fundamental advantage of adobe is that it uses naturally occurring earth resources and requires less energy to make. It has natural insulating characteristics that keep indoor temperatures stable, resulting in cheaper energy bills and a lower carbon footprint. Adobe is completely recyclable, leaving no garbage behind. It is made from earth-friendly materials [10].

30. Cordwood



Source: <https://en.wikipedia.org>



Image source by Zahraa Ali Hammood

Cordwood is a wall-building technique that employs stacked small logs that resemble firewood in shape. To hold things together, cob or mortar is utilized between the wooden logs. The cordwood technique is commonly used in homes and gives the overall building a rustic cottage appearance. Cordwood provides natural insulation and can be made from locally available materials, saving energy and money on shipping. It is inexpensive and simple to build. It saves time and energy when building a house. The cob-wood mixture restricts heat transfer, resulting in lower energy use [9].

31. Ferrock



Source: a3511.wordpress.com

It is a relatively new substance that employs recycled materials such as steel dust from the steel industry or ferrous rock left over from industrial processes that would otherwise be disposed of in a landfill. It creates a concrete-like building material that is stronger than concrete. It holds and absorbs carbon dioxide during the drying and hardening process. As a result, ferrock is carbon neutral and emits much less CO₂ than traditional concrete. It may be mixed and poured to create driveways, staircases, walkways, and other buildings, making it a viable alternative to cement. Some researchers claim ferrock is more weather resistant than concrete. Ferrock is an extremely hard and resilient material that is utilized for marine applications such as constructions exposed to seawater. It's five times stronger than Portland cement. It weighs 10 to 25% less than a brick-built structure. The actual Ferrock development process is highly sustainable [4] [5] [1].

32. Plant-based Polyurethane Rigid Foam



Source: lindenindustries.com

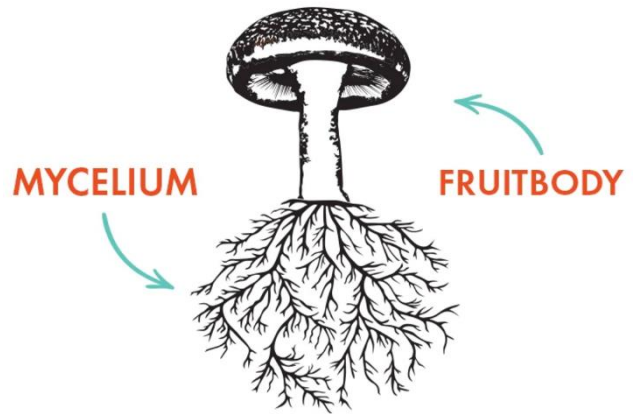
Although rigid foam is a common insulation material, it is not the most environmentally friendly. In contrast, plant-based polyurethane rigid foam is manufactured from bamboo, kelp, and hemp. Its plant-based composition makes it a more responsible option for individuals concerned about environmental protection. Don't be concerned if you're worried about the effect it might have on your health. Plant-based polyurethane rigid foam is a suitable choice for those who are chemically sensitive and protects against mold and pests. This material can be used for more than just insulation. It can also be found in furniture and surfboards [13].

33. Clay Brick



Clay brick is a natural material created from water and earth's clay. It is completely recyclable, environmentally beneficial, and does not emit any dangerous compounds when disposed of in a landfill. Clay brick is a low-energy material. In the summer, it keeps a house cooler, while in the winter, it traps heat for a longer amount of time [17].

34. Mycelium



Source: <https://fungi.com>

It is a naturally occurring building material. Mycelium is a naturally occurring unicellular creature that is found in the root system of fungi and mushrooms. It might be encouraged to develop in molds or forms made of a composite of various natural materials, such as ground-up straw. It is then air-dried to form lightweight and durable bricks or other shapes [6]. Mycelium, when combined with pasteurized sawdust, may be shaped into practically any shape and utilized as a remarkably strong building material. There is the possibility of producing strong and lightweight bricks and construction components with unusual shapes. The mushroom-based building material can resist high temperatures, offering it an organic and compostable alternative to traditional building materials such as insulation, Styrofoam, and even concrete. Mycelium is an extremely durable, environmentally friendly substance that is resistant to water, mold, and fire [11] [10].

35. Enviroboard



Enviroboard Installation
Source: georgehill-timber.co.uk

Enviroboard is a fireproof board composed of magnesium, sawdust, and fiber cloth. These boards are commonly used for wall and roof lining, as well as underlayment systems. Because of their water resistance, environmentally friendly fire board products are stronger than ordinary boards and do not deform with time. They do not emit additional carbon

emissions because to its green manufacture - natural drying and curing process.

Enviroboards are a versatile and long-lasting product that may be utilized in a wide range of building and restoration projects [2].

36. Cork



Image source by Jonathan Borba

Cork, like bamboo, grows quite quickly. It can also be harvested from a living tree, which continues to grow and produce more cork (tree bark). Cork is manufactured from the cork oak tree, which is a highly renewable and environmentally favorable resource. When you open that delicious bottle of wine, remember that there is a better destination for cork than the landfill. Cork is a tough substance that is resistant to moisture and liquids (thus the wine) [2]. It may absorb vibration due to its structure. Cork harvesting can assist to combat global warming. Cork is durable, flexible, and returns to its original shape even after prolonged strain. Because of its durability and resistance to wear, it is commonly used in floor tiles. It also absorbs noise well, making it ideal for insulation sheets, and its high shock absorption capabilities make it ideal for sub-flooring [1]. It can also be used as a thermal insulator because it burns cleanly and does not emit hazardous fumes when burned. Cork does not absorb water or rot since it is essentially impermeable. Unfortunately, it can only be obtained from the Mediterranean, making exporting it somewhat expensive. Fortunately, it is extremely light, requiring less energy and emissions to transport [6].

III. THREE PILLARS OF SUSTAINABILITY AND THEIR INTERRELATIONSHIPS

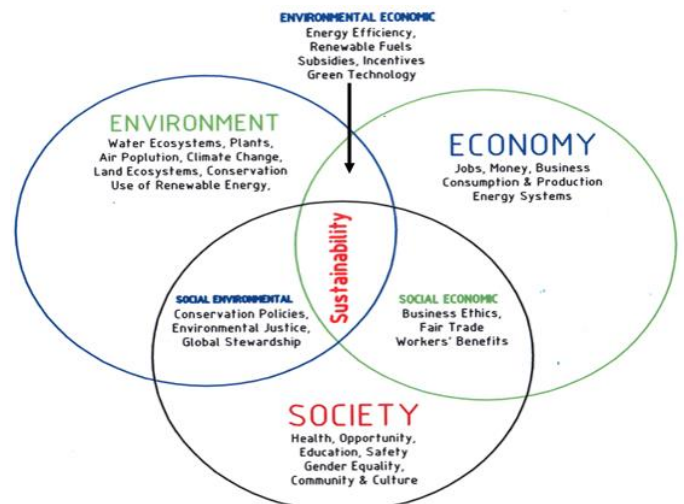


Fig. 1: Simple Venn diagram of Sustainable Development Theory (created by the author)

Sustainable development is the sweet spot where personal, social, environmental, and economic requirements can all be met without compromising one another [11]. For example, a company is sustainable if it is:

- Profitable and growing
- caring about its employees by paying fair wages, providing benefits, and providing education
- caring about the local community and society at large by supporting local charities
- caring about the environment through sustainable product design and green technologies.

This is due to the fact that sustainable development is at the crossroads of human, social, economic, and environmental sustainability. Let us now look more closely at the various sorts of sustainable development pillars.

Environmental, social, and economic issues influence and constrain a sustainable economy. In other words, economic progress, social equity, and environmental preservation are all essential for long-term development [14]. Sustainability is built of three pillars, as seen in figure above: the economy, society, and the environment. Profit, people, and planet are some vernacular terms for these themes. Urbanization is accelerating in both developed and developing countries, resulting in a slew of environmental, social, and psychological issues that must be addressed. This problem occurs as a result of the continued population growth and the resulting requirement for homes. However, in order to increase efficiency in the building industry, cutting-edge materials must be used. Despite this, the construction industry has experienced various challenges, including a lack of funds, statutory constraints, and unsustainable implementation [10]. This has motivated the urge to discover a solution to the difficulties and challenges of the study area. There are several approaches to using sustainable materials [10] [11]. This is especially visible in the context of challenges to social, environmental, and economic sustainability [1]. The

sustainable management of any growth is focused on addressing three critical areas that enable people living today to have access to justice and equal rights [8]. Current actions must not bankrupt future generations, and environmental degradation must be reduced or eradicated [12]. Furthermore, participants in the debate said that sustainable implementation should include a transition process in which resource exploitation, technical development direction, and institutional adjustments are made to meet future as well as present needs [2].

A. *Environment*

Environmental sustainability seeks to improve human well-being and long-term sustainability through environmental preservation and more efficient use of natural resources. Environmental protection is usually included during the development process [12]. It entails incorporating the environmental variable with an ecological approach in each of the various sectorial policies and actions, such as conserving and restoring damaged ecosystems and natural spaces, reducing waste production and its hazards, and assisting in the prevention and resolution of global environmental problems. The ability of human attempts to coexist with the preservation of ecosystems and biodiversity is defined as sustainability [15] [4].

Natural resource exploitation is maintained at existing levels without exceeding the carrying capacity limit or damaging the essential attributes of the resource. It attempts to prevent the depletion of finite, difficult, or slowly regenerable resources, as well as the generation of waste and harmful pollutants [15]. Many businesses are working to decrease their carbon footprints, packaging waste, water usage, and other environmental effects. These actions can benefit both the environment and the economy. Reducing the use of packing materials, for example, can cut spending and enhance fuel economy [11].

B. *Society*

The goal of social sustainability is to ensure society's well-being, cohesiveness, equality, and development through establishing inclusive infrastructure through sustainable urban design, as well as products and services that benefit the community as a whole [15]. The concept of social license is linked to the social pillar. A sustainable business must have the acceptance and support of its employees, stakeholders, and the community in which it operates. The methods used to gain and keep such support vary, but it ultimately boils down to treating employees fairly and being a good neighbor and community member, both locally and globally. Businesses might refocus on employee retention and engagement strategies. These can include more responsive perks such as improved maternity and family benefits, flexible scheduling, and opportunities for education and growth. Companies have established a range of methods for giving back to the community, including as fundraising, sponsorship, scholarships, and investment in local public programs [2] [3]. The social pillar of sustainability, one of the three principles, focuses on peace, enhancing social interactions, inclusivity, and equality. Some of the key variables leading to the

achievement of the social sustainable development goals (SDG) are the preservation of regional culture (cultural sustainability) and the promotion of honesty and reciprocity within the local community. Sustainability provides a solution to the need to improve overall population quality of life, seek social cohesiveness (intra-generational equality), and protect natural resources and environmental quality for future generations (inter-generational equity) [3]. This is founded on the ability to defend shared interests via democratic and non-exclusive channels, as well as the preservation of the social and cultural network [7] [9]. This should be accomplished through changing individual and societal attitudes and actions so that people care about one another and value social justice, education, health, peace, and tranquility, hence improving and protecting future generations' level of living [7].

C. *Economy*

Economic sustainability implies that a firm must be growing and lucrative in order to be sustainable; without profit, the organization would perish. Increasing economic value is an indirect indicator that the company is providing something useful and valuable to society [2]. This is the cornerstone of the free market: if your product is not valuable or there is already an abundance of it on the market, you will make little money from it. For these reasons, this pillar of sustainability is critical to attaining sustainable development and maintaining the long-term profitability and viability of the organization [4]. This evaluates sustainability from the standpoint of a consumer-driven culture, which considers nature's scarce resources as a source of income that prevents catastrophic tragedies. Sustainability should provide economic riches at the local, regional, and global levels in order to preserve the foundation of natural resources and their conservation. This will support financially viable and successful growth [7]. In order to survive, a company must be profitable. Profit, on the other hand, cannot overcome the other two pillars. In fact, the economic pillar is not concerned with profit at any cost. It all comes down to compliance, good governance, and risk management. Organizations can evaluate and agree on sustainability efforts after including the economic component (and accepting profit). The economic pillar acts as a check on the drastic steps that firms are sometimes forced to take, such as quitting fossil fuels or chemical fertilizers all at once rather than in stages. Economic sustainability is concerned with the efficient use of resources in order to increase profitability and generate economic growth in order to raise living standards. This should not be done at the expense of other aspects of sustainability; rather, there should be a collaborative effort to achieve prosperity while not negatively hurting individuals, society, or the environment [3].

IV. THE EFFECTS AND BENEFITS OF GREEN MATERIALS FOR SUSTAINABLE BUILDINGS

Following a discussion of the definition of the Green Economy, the following advantages and negative Aspects are discussed:

A. *The Negative Aspects*

Developing and maintaining low-carbon, zero-waste cities and infrastructure to improve our ecosystems is not a simple task. Scientists say we utilize more materials and resources, resulting in more harmful green-house gases, toxics, and non-biodegradable garbage than our world can handle. These man-made processes and activities will put strain on the ecosystem and the demands of future generations. The fundamental issue with materials and resources is the environmental impact caused by our existing patterns of use. Natural resources and raw materials, the interaction between production and consumption patterns, designing for sustainable products, waste production and emissions, and the present emphasis on energy and transportation efficiency are all challenges in the use of sustainable materials. The framework for sustainable material management (SMM) is also one of the problems. The ability to mix design, nature, and technology with the environment is the future framework for SMM. When it comes to the Green Economy, there are no significant downsides; yet, the concept faces several challenges [17] [15].

Transformation: First and foremost, our society requires a genuine makeover. Unfortunately, many businesses and communities are not prepared for this shift. Green Economy necessitates that businesses recognize and become conscious of their corporate social responsibility, embrace innovative practices, and reduce their environmental impact as much as feasible. This concept is still a long way from being a reality in many countries. Fortunately, groups have formed in many parts of the world to assist and accompany businesses in their transition to a green and sustainable corporate approach. Among these is the Sustainability Accounting Standards Board, an independent US organization that has been advocating sustainable companies to investors since 2011.

Transition to green economy: The transition to green economy in developing nations is a difficulty. They are confronted with growing environmental issues as well as widespread poverty. Adopting a viable green economic system in these areas is difficult and demands more extensive bio-economic analysis.

Natural Resource Scarcity: Future natural resource constraints may be severe. Natural resources, either renewable or non-renewable, are used to create materials. Resources are a "limited infinity" because, while they can be provided for an unlimited amount of time, their productivity is restricted [8]. The prediction of renewable resource depletion is worrisome, because human society is interwoven within the biosphere and relies on ecosystems for a stable supply of fundamental necessities such as water, energy, minerals, and agricultural land. As the world's population grows and the global economy expands, it is pretty fair to expect that global demand for basic resources will grow as well. Supply commodity/material demand creates market pressures to generate alternate materials and/or goods. At the same time, extraction of many non-renewable resources has reached or is approaching its peak.

The Best Design Obstacles: To achieve proper design, some evaluation indicators should be addressed while selecting materials for sustainable goods. A sustainable product is one that has as little environmental impact as possible during its life cycle. The extraction of raw materials, production,

consumption, and final recycling are all examples of sustainable elements of products. The energy consumption of materials during the forming process (forging and casting), the final treatment process (heat treatment and surface treatment), and the economic cost are also considered [14]. Material selection and specification are the most critical aspects to explore before using any materials to avoid non-toxic or non-durable materials [3].

Hazardous Materials and Production: Product manufacturing often incorporates chemical substances such as product blending, interfacial interaction of two chemical substances, cutting fluids during machining, cleaning aids, and paint. Building materials, interior furnishings, surface treatments, paints, coatings, and consumer products have all been proven to generate volatile organic compounds (VOCs) and so contribute to the presence of indoor air pollutants [6] [9]. As we spend more time indoors, we are confronted with the issue of indoor air quality and its health repercussions, which are directly related to the products we use. Aside from dangerous compounds in manufacturing, the manufacture of steel, glass, aluminium, and paper requires a lot of electricity, which produces carbon dioxide (CO₂), which contributes to global warming [9]. Changing weather patterns, the effects of climate change, rising sea levels, and flooding will not only disrupt agriculture, but will also cause more sickness and ill health in humans [3].

Life-cycles of Materials: Addressing billions of people's development needs by enabling education and eco-economic development of dramatically more eco-efficient solutions, lives, and behaviour. Many businesses are realizing that they can save money by encapsulating important technical procedures and treating problem materials more efficiently [3]. This evolution is now leading to a rediscovery of the product life-cycle. Using a life cycle perspective can assist in identifying opportunities and leading to long-term solutions to lessen environmental effect. Material life-cycle activities comprise all material-related operations such as extraction, transportation, production, consumption, product usage, reuse, recycling, and disposal. All of these steps will have an environmental impact, which is primarily due to the materials utilized in each stage [9]. Extraction activities increase local demand for water and electricity and pollute surface and ground waters; additionally, mining frequently causes mobilization of elements that are released to the environment from soil and rocks or from the minerals themselves (e.g., release of sulphur-containing substances in brown-coal mining, causing acidification of ground water) [14] [13].

B. The Benefits

The simple description of Green Economy explains how its adoption helps both businesses and society. Nonetheless, we've decided to highlight the four most immediate advantages of this concept [16]:

- Cost and production reductions, resulting in more responsible raw material use and more efficient energy consumption;
- Waste reduction through recycling and reuse of products that have reached the end of their life cycle;

- Job creation (e.g. project managers, consultants, installers, coordinators, etc.);
- Increased sales of products that address environmental challenges and respect the environment.
- Reduce energy usage; • reduce greenhouse gas emissions and trash generation over a product's complete life cycle;
- Reduce natural resource use by boosting resource efficiency; and
- Ensure biodiversity protection.

V. EFFECTS AND BENEFITS OF GREEN MATERIALS TO THE ENVIRONMENT

The supply of fossil fuels is shrinking by the day. With numerous contentious concerns affecting environmental degradation arising on a daily basis, such as global climate change, resource security, and reliance on energy sources. Sustainable measures necessitate the use of renewable energy sources in all utilities, particularly infrastructure [14]. Today, initiatives to safeguard the environment are visible, such as the global debate by international delegates in Copenhagen to battle climate change-causing factors such as gas emissions and greenhouse gas pollution. Another advantage of green designs is that they conserve water [1]. Water is becoming increasingly scarce; therefore a sustainable building should feature on-site conservation techniques such as harvesting, storage, efficient utilization, reuse, and recycling measures to reduce waste. The materials have also minimized negative impacts on human health, contributing to worker and user safety, lowering liability measures, resulting in lower insurance costs for owners, lowering resource disposal costs, and aiding in the achievement of environmental goals. There is also improved indoor quality of the atmosphere for the user, allowing for more production or comfort. Natural illumination should be used in sustainable buildings due to proper ventilation and great moisture control. Such constructions have methods of avoiding the use of materials that emit emissions, as well as appraisals for elements that can neutralize "chemical, biological, or radiological attacks" [3].

VI. EFFECTS AND BENEFITS OF GREEN MATERIALS TO THE SOCIETY

Thermal comfort: The benefit of building inhabitants is also associated with warm extravagance, which is made up of different interconnected elements of temperature and humidity. This has included wide, scholarly consideration to put on and also review the warm extravagant effort in green filling in as distinct and typical structures. The social benefits of sustainable design are linked to improved quality of life, health, and well-being [18]. These advantages can be enjoyed at various levels, including buildings, communities, and society as a whole. The major focus of many researches in sustainability development is on comfort, health, and satisfaction. Despite the fact that these outcomes are clearly related, they have separate scholarly backgrounds and use different approaches. Epidemiologists and public health specialists deal with health issues. Researchers with competence in building science and physiology study comfort, whereas environmental and experimental psychologists study

well-being and psychosocial processes. This section's study unifies findings from these several fields, with a focus on studies that analyze the health, comfort, and well-being outcomes associated with the presence or absence of sustainable building components [18] [3].

The social benefits of sustainable design at the community or societal level include knowledge transmission, improved environmental quality, neighborhood rehabilitation, and reduced health risks from pollutants connected with building energy usage. Although more study on the benefits of sustainable design features to building occupants has been undertaken, interest in the community benefits of sustainable design is developing, and some possible areas of value to the Federal government are highlighted at the end of this section. The building environment can have an impact on the residents' quality of life in both positive and bad ways. Illness, absenteeism, weariness, discomfort, stress, and diversions are some of the negative consequences of poor indoor air quality, thermal conditioning, lighting, and certain components of interior space design (e.g., materials selections, furniture, and personnel densities). Often, reducing these issues through sustainable design enhances health and performance. Improved indoor air quality and enhanced personal temperature and ventilation control have significant positive impacts. Buildings should have features and attributes that provide good psychological and social experiences in addition to decreasing hazards and discomforts. Although there has been less research on health-promoting environments, emerging evidence indicates that certain sustainable building features, such as increased personal control over indoor environmental conditions, access to daylight and views, and connection to nature, are likely to produce positive states of well-being and health. Security is another emerging social concern affecting buildings [3].

VII. GREEN MATERIALS' ECONOMIC EFFECTS AND BENEFITS

When most people hear the word "green building," they immediately think of the environment. It means fewer materials, less pollution, and more environmentally responsible behaviors. These structures have appeared at a time when more individuals are emphasizing the need of conserving their surroundings. However, while some people are focused on sustainable design, they may have completely ignored the other benefits. Green construction includes economic advantages in addition to environmental advantages [18] [3].

Less energy usage: Electricity is used in buildings. Lights, heating and cooling, water, and technology are all required. All of these items require energy, therefore electricity is widely used in business buildings. Recycled building materials contribute significantly to environmental conservation and waste reduction. Installing well-insulated windows, ceilings, and walls can aid in preventing energy waste. Furthermore, the use of solar heaters, insulated air-conditioning pipes, and photovoltaic panels can improve the energy efficiency and environmental friendliness of buildings.

More jobs: All occupations necessitate skilled people, and green building is no exception. While construction requires workers who understand how to use the correct tools and designs for specific reasons, its subsectors also require experienced tradespeople to follow guidelines. Structures that are accredited for Leadership in Energy and Environmental Design must fulfill particular requirements, but they can't if people don't know what those are or how to meet them. Green construction need personnel with that understanding, and fortunately, the practice is attracting an increasing number of people to the field.

Lower operating costs: Green buildings employ energy-saving techniques to ensure that structures are as energy-efficient as feasible. These construction technologies, when paired with environmentally friendly practices, have the potential to considerably reduce energy bills.

Stronger economy: Green building has supported the US economy by creating millions of jobs and contributing hundreds of billions of dollars. This market is undeniably growing, with fast expansion in the green building sector expected over the next four years. While green construction has numerous environmental benefits, it also has numerous economic benefits. Businesses may cut costs, generate jobs, and help the economy by converting to environmentally friendly practices. Long-term usage is a feature shared by many sustainable products. The fact that you use a product for a longer period of time benefits not just the environment, but also your wallet. You may be tempted to buy "what's on sale," but investing in a long-term material product that can be utilized for many years is a wiser decision if you want to genuinely save money.

VIII. RESEARCH METHODOLOGY

The research method used in the study was a systematic review. Based on a comprehensive search and selection of literature on applied engineering concepts and optimal exploitation of renewable resources, the current manuscript filters and evaluates scientific publications on the use of sustainable materials in the context of sustainable development between 1980 and 2023, with the goal of enhancing the advancement and implementation of sustainable development, green design concepts, and circular economy features. To accomplish these objectives, huge and scientifically validated databases (e.g., Science Direct, Google Scholar, Web of Science, Springer Link, Pro-Quest, Wiley Online Library, and Nature) were searched using predefined methods connected with the Boolean and operator. Furthermore, the manuscripts chosen were of the article form and written entirely in English. A meta-analysis was used to examine and analyzed the findings.

IX. RESULTS AND CONCLUSION

Understanding the definition of sustainable materials and employing the life-cycle of materials approach correctly can lead to changes in product design, technical innovation that improves resource efficiency for improved waste management methods, and more effective regulations. Monitoring material consumption trends and becoming familiar with the life-cycle

of materials management provide information that may be utilized to determine how we can meet our material needs at acceptable economic and environmental costs. Sustainability and social fairness are critical variables in achieving human and environmental well-being. The use of green materials for sustainable buildings necessitates the implementation of operating and maintenance expenses during the design process. This eventually boosts production, reduces the use of precious resources, or reduces energy costs as a means of averting failures or optimizing maintenance requirements. They help cut building life cycle expenses and renovation expenditures. This paper will benefit people, communities, and the general public by making them aware of the advantages of adopting green construction materials for sustainable environmental development and management. Nowadays, energy sources are depleting quickly, and the usage of natural resources is increasing. Sustainable building materials must be designed and implemented correctly. Aside from that, it offers numerous advantages like as lowering carbon emissions, reducing global warming, and reducing waste materials and goods. This article indicates that the adoption of sustainable construction materials will increase energy efficiency, reduce hazardous waste generation, and safeguard the environment, hence reducing resource consumption and increasing recycling and reuse rates.

REFERENCES

- [1] Abdulrahman D. Alsulaili & Marwa F. Al-Matrouk & Rabab A. Al-Baghli & Amal F. Al-Enezi, 2020. "Environmental and economic benefits of applying green building concepts in Kuwait," Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, vol. 22(4), pages 3371-3387, April. Handle: RePEc:spr:endesu:v:22:y:2020:i:4:d:10.1007_s10668-019-00352-1
DOI: 10.1007/s10668-019-00352-1
- [2] Adeniyi* Shogo Musbau, Sarajul Fikri Mohamed^b, Kolawole Olayinka Rasak^c (2020). Socio-Economic Benefits of using Green Materials for the Construction of Low-Cost Buildings in Nigeria. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
- [3] Akwada, D. R., Akinlabi, E.T. (2016). economic, social and environmental assessment of bamboo for infrastructure development *infrastructure as a driver for economic growth and integration in African: what is the way forward? the International Conference on Infrastructure Development in Africa*
- [4] Alves A, Patiño Gómez J, Vojinovic Z, Sánchez A, Weesakul S. Combining Co-Benefits and Stakeholders Perceptions into Green Infrastructure Selection for Flood Risk Reduction. *Environments*. 2018; 5(2):29. <https://doi.org/10.3390/environments5020029>
- [5] Ametepey¹, S. O. and Ansah², S. K. (2014). Impacts of Construction Activities on the Environment: The case of Ghana. *Journal of Construction Project Management and Innovation* Vol. 4 (S1): 934-948.
- [6] Ashford, N. A., & Hall, R. P. (2011). The Importance of Regulation - Induced Innovation for Sustainable Development. *Sustainability*, 3(1), 270292. <https://doi.org/10.3390/su3010270>
- [7] Bamigboye G O et al (2019), Innovation in Construction Materials-A Review. IOP Conference Series: Materials Science and Engineering. 640 012070 doi:10.1088/1757-899X/640/1/012070
- [8] Barbosa, F., Woetzel, J., & Mischke, J. (2017). *Reinventing construction: A route of higher productivity*. McKinsey Global Institute.
- [9] Bungau, C.C.; Bungau, T.; Prada, I.F.; Prada, M.F. Green (2022). Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges. *Sustainability*, 14, 13121. <https://doi.org/10.3390/su142013121>

- [10] Cody Fithian and Andrea Sheets 2009 Green Building Materials. UTSoA - Seminar in Sustainable Architecture
- [11] Erik arnesson 2019 analysis of sustainable building materials, their possibilities and challenges
- [12] Ji, Shiva. (2016). Green Building Materials and their Common Use in Everyday Life. 10.13140/RG.2.1.1635.4323.
- [13] Ojo- Fafore, Elizabeth & Aigbavboa, Clinton & Ramaru, Pretty. (2018). Benefits of Green Buildings.
- [14] Prutha Patel and Anant Patel (2021). *IOP Conf. Ser.: Earth Environ. Sci.* **785** 012009
- [15] Rentz B. 2023. 20 Sustainable Building Materials for a Greener Future
- [16] Ries, Robert^Bilec, Melissa M.^Gokhan, Nuri Mehmet^Needy, Kim LaScola (2006). The economic benefits of green buildings a comprehensive case study.
- [17] Sheth Dr K N 2016. Sustainable building materials used in green buildings 9th international conference on engineering and business education (icebe) & 6th international conference on innovation and entrepreneurship (icie)
- [18] Shogo musbau adenyia*, sarajul fikri mohamedb, kolawole olayinka rasakc. socio-economic benefits of using green materials for the construction of low-cost buildings in Nigeria