

Sustainable Materials for Contemporary Architecture: A Review

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Abstract

The sustainability materials in the construction industry are crucial for fostering a more effective economy marked by reduced energy, waste, and pollution, lower emissions, improved safety of residents in public and residents through boosting interior air quality, increased job opportunities, and a more equitable wealth distribution. The objective of this study is to conduct an in-depth examination of sustainable construction materials by analyzing the challenges, barriers, prospects, motivations, and choices related to perceptions from different stakeholders. The evaluation procedure consisted of examining documents that were published in three reputable scientific databases, which included review articles, conference proceedings, and journal papers. This study presents an extensive examination of the most recent advancements, limitations, and future possibilities of more than forty sustainable construction materials. It was found that the selection of building materials considers their physical, chemical, and mechanical characteristics, as well as the financial capabilities of the clients. It was also asserted that the utilization of sustainable materials depends on their functional, technical, and climatic considerations, as well as the natural disaster vulnerabilities unique to the area. Various challenges and opportunities related to sustainable construction materials, such as technical, economic, and sociocultural barriers, were recognized. It is crucial to underscore the active participation of governments, industry, academia, and interdisciplinary collaborations in promoting and implementing sustainable materials. The outcome of this research offers a valuable point of reference for different stakeholders, such as professionals, government officials, clients, policymakers, scholars, and individuals responsible for making decisions, and proposes recommendations based on the relevant previous research.

Keywords: Construction industry, sustainable materials, green building, bamboo, greenhouse gases

INTRODUCTION

The negative impact of construction activities on the environment and society is significant, even though the construction industry has been instrumental in fostering economic development in countries. Worldwide, the construction industry accounts for approximately 40% of granite, stone, and natural sand, 25% of planks, roughly 40% of the world's energy, and approximately 16% of annual water consumption [1]. The construction of buildings has a major impact on the diminution of natural resources and leads to the production of a substantial volume of building and demolition waste. The manufacturing processes used to produce certain construction materials have a substantial impact on the emission of greenhouse gases, including carbon dioxide into the atmosphere. Concerted efforts to minimize the emission of GHG gases to mitigate negative

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environmental effects have been reported by many researchers. Roy et al. (2024) [2] and Dixit et al. (2012) [3] extensively investigated the energy requirements related to the manufacturing and processing of diverse building materials as well as the resulting CO₂ emissions and their environmental effects.

The utilization of concrete and steel is crucial in the construction industry because of their flexibility and strength. Benhelal et al. (2012) [4] and Shen et al. (2015) [5] estimated that the global production of cement in 2019 was approximately 4.4 billion tons, constituting 8% of total carbon emissions worldwide. Meyer (2008) [6] stated that the global annual production of concrete was approximately ten (10) billion tons. About one metric ton of carbon dioxide is emitted into the atmosphere per metric ton of Portland cement produced. Globally, the cement sector is estimated to be responsible for around 7% of the overall CO₂ emissions Iqbal and Swapnil (2017) [7]. Marut et al. (2017) [8] reported that the construction industry ranks second in terms of raw material consumption, with the food-processing industry taking the lead as the largest consumer. Building construction relies heavily on materials, as they are fundamental constituents [9]. These materials must be sustainable [9]. Progression of eco-friendly materials capable of fulfilling building standards while minimizing material consumption and energy usage is crucial [10]. Increasing global awareness of environmental issues and climate change has further intensified the demand for eco-friendly building materials [11].

In view of climate change, many researchers have focused their attention on environmental conservation, and sustainable construction holds a crucial position in alleviating resource scarcity, reducing waste, and minimizing inefficiencies, and is pivotal in the effort to curb greenhouse gas (GHG) emissions [12]. Striving towards a more sustainable future relied heavily on the selection of eco-friendly construction materials [13]. Researchers have explored sustainable construction materials, emphasizing their environmental advantages and potential to transform the industry. From innovative recycled products to state-of-the-art natural resources, prepare to uncover the finest eco-friendly choices that will lead to a greener and more sustainable construction sector.

Charef and Lu (2021) [14] highlighted considerable obstacles faced by the construction sector in achieving sustainability. Collaboration among professionals holds great significance, as it guarantees the effective implementation of green materials in the industry. Traditionally, earth bricks, concrete, and wood have been used in construction. Balaras et al. (2005) [15] opined that the life cycle of sustainable materials is important in impacting the environment and human health and can be determined by factors such as contamination and functionality. Presently, there has been a change in the material selection process, emphasizing that the prioritization of the functionality and performance criteria of green materials over cost and aesthetics is crucial [16].

García and colleagues (2018) [17] created eco-friendly construction systems that replaced conventional steel and concrete elements with wooden components. Prefabricated structures offer the advantages of waste reduction and the possibility of reusing components in different buildings owing to their flexibility and secure disassembly. This technique can be exemplified by the construction of buildings using mechanical fastening rather than chemical fastening. This approach allows for easier disassembly, reduces the risk of component damage, and reduces material pollution [17]. Wooden structures have lower carbon dioxide emissions throughout their life cycle than concrete structures. It is also essential to concentrate on reducing the ecological effect of transporting the components of prefabricated structures over long distances, as this may outweigh the advantages of adopting prefabrication in construction. Abimaje and Baba (2019) [18] suggested that for construction material to be deemed sustainable, it must exhibit characteristics such as eco-friendliness, cost-effectiveness, adaptability, and longevity. Timber, as an alternative construction material, can sequester CO₂ rather than emit it, unlike aluminum, concrete, and steel, which do not sequester CO₂ and instead release much higher quantities into the atmosphere [19].

CHALLENGES AND BARRIERS TO THE ADOPTION OF SUSTAINABLE MATERIALS

The utilization of sustainable materials in the construction industry can result in a wide array of benefits. However, the acceptance and utilization of such materials encounter obstacles. Inadequate expertise creates a significant barrier to the integration and development of sustainable materials in the construction industry. Construction professionals, as emphasized by Oyewole et al. (2021) [20] tend to be cautious and conservative when recommending and adopting sustainable materials. Professionals in this sector often lack the necessary information regarding cutting-edge sustainable materials. Engineers and architects leading sustainability efforts may have a narrow understanding of this topic [21].

The perceived advantages of adopting sustainable construction are below average, and the industry remains unaware of its significance [22]. Moreover, concerns regarding the high costs associated with green materials impede their development and adoption in the construction field. The obstacles stem from rising investment costs, prolonged payback periods, client uncertainties regarding project viability, insufficient understanding of life cycle expenses, and restricted availability of financial resources. The perceived expense of participating in sustainable construction hinders adoption. Many researchers have suggested that green building projects incur additional costs compared with traditional buildings, ranging from 1% to 10% [23]. This additional cost could primarily be due to the inclusion of green materials and efficient mechanical systems, which are both costly and complex, as well as an extended design process.

Challenges exist in developing countries when it comes to implementing green buildings owing to the limited availability of green materials and experts. The exorbitant expenses associated with the construction of environmentally friendly buildings further complicate this situation. The absence of legislation, incentives, policies, standards, and government assistance serves as an additional obstacle to the advancement and implementation of sustainable materials within the construction sector in these countries [24, 25]. Therefore, it is crucial to establish policies that aid the training of skilled labor and enhance access to green building materials. Azhgaliyeva and Rahut (2022) [23] suggested that government strategies should aim to encourage the development of environmentally friendly buildings encompassing regulations, tax breaks, financial assistance, loans, government funding, and well-thought-out blueprints.

Consumers' lack of interest in sustainable construction poses challenges to the adoption of eco-friendly materials. According to research conducted by Dzokoto and Dadzie (2013) [26]. The lack of knowledge about sustainable materials poses significant obstacles to the implementation of sustainable construction practices [27]. It was emphasized that there is a shortage of sustainable building materials, a lack of tools for evaluating the performance of green materials, and the absence of exemplary demonstration projects are all connected to knowledge about sustainable materials. Davies Davies (2017) [28] underscored the significance of obtaining precise and abundant information on past sustainable construction endeavors to facilitate upcoming projects. The lack of historical data has been highlighted as a major obstacle to sustainable construction in developing countries. Ogunkah and Yang (2017) [29] highlighted the significance of client preferences and requirements for the use of sustainable materials in the construction sector. They also highlight how cultural beliefs and resistance to change can hinder the adoption of specific construction materials, potentially leading to the limited use of green construction materials. Djokoto et al. (2014) [30] further revealed that the cultural context within a community can significantly impact the reception of new ideas. Often, transitioning from familiar to unfamiliar can present challenges, resulting in a lack of progress due to unfavorable conditions. The clients' lack of enthusiasm for green buildings has contributed to the low implementation of eco-friendly materials. According to research conducted by Dzokoto and Dadzie [42], the adoption of sustainable construction encounters notable obstacles because of inadequate comprehension of sustainable materials. This study highlights that the scarcity of environmentally friendly construction materials, the absence of proper assessment tools for green materials, and the dearth of successful projects all result from a lack of knowledge about sustainable materials.

BENEFITS OF SUSTAINABLE MATERIALS

The primary advantage of incorporating sustainable materials in the construction sector is the promotion of environmental sustainability. However, construction professionals, as noted by Komolafe et al. (2018) [22] tended to be conservative in their approach to proposing and adopting sustainable materials. They contribute to enhancing indoor air quality; thus, the well-being and safety of the occupants of the building and the environment are well guaranteed. There is a reduction in greenhouse gas emissions and environmental pollution throughout the lifespan of the material. It enhances productivity and minimizes resource consumption. Energy usage in buildings and facilities can be reduced, leading to improved energy efficiency and operational effectiveness. This will lead to a substantial decrease in costs and waste, while also necessitating less upkeep because of the improved resistance to moisture. Additionally, longevity can be enhanced and maintenance needs reduced, ultimately boosting the resale value of the property and promoting greater energy and resource efficiency, thus achieving cost-effectiveness.

Utilizing local and regional materials effectively reduces the impact of transportation and supports local economies. This involves sourcing materials from nearby extractions, harvesting, and manufacturing locations. Encouraging both on-site and off-site recycling is crucial. On-site recycling is generally more sustainable, and planning for a designated recycling area within a building can help reduce landfill waste, material costs, energy consumption, and maintenance expenses [31]. The utilization of renewable resources, such as plant-based materials with a short harvesting period, helps conserve resources [32].

The utilization of recycled resources, including recovered and repaired materials, aids in waste reduction and lessens the need for new materials. This method effectively reduces the ecological footprint associated with extraction and processing activities [33]. Recycling content materials can be recycled from recycled content. Incorporating low-emitting materials is crucial for minimizing health issues related to indoor building materials, and construction site waste is sorted and recycled at waste management facilities. Adhering to local regulations ensures the proper handling of hazardous substances, thereby safeguarding the environment. Sustainable materials have the potential to improve energy efficiency and sustainability of existing structures when integrated into renovation and retrofitting projects. This can involve utilizing insulation made from recycled materials, incorporating reclaimed wood flooring, or upgrading windows using energy-efficient alternatives.

SUSTAINABLE MATERIALS SELECTION

Zhong et al. (2021) [34] emphasized in their studies the significance of sustainable materials in reducing energy intake during the construction and operation phases. Their research underscores the potential of utilizing environment-friendly materials to construct energy-efficient structures, thereby contributing to decarbonization efforts in the construction industry. Determining suitable principles for selecting and acquiring sustainable materials, establishing specific standards and evaluation criteria, validating performance, and evaluating the market preparedness and potential for meeting sustainable certification standards pose significant challenges [32]. According to Sirisalee et al. (2004) [35] and Giudice (2005) [36], a meticulous choice of appropriate green materials is imperative in the design phase. This not only helps in minimizing the environmental impact but also significantly impacts the lifespan of both the built environment and construction projects.

Guidelines

Sirisalee et al. (2004) [35] and Giudice et al. (2005) [36] proposed a range of standards, strategies, and instruments for evaluating and choosing sustainable materials, including cost-benefit analysis, index-based techniques, ranking techniques, and multicriteria decision-making. It is imperative to maintain material durability, flexibility, strength, disassembly, and adaptability without compromising. The process includes developing designs for various ceiling finishes and flooring options while ensuring optimal material utilization. Some recommended principles and resources for sustainable materials include the following.

Measurement

The validation of sustainable materials was examined using various criteria by Bredenoord (2016) [32]. in the respective studies.

- This factor takes into account the overall construction area.
- This parameter quantifies the quantity of construction waste diverted from landfills.
- This was employed to quantify the redirected construction debris. This criterion assesses the proportion of materials in a project that are reused, recycled, renewable, and locally sourced. It sets the highest emission thresholds for substances in accordance with global regulations.
- Environmental impact: This factor assesses and contrasts materials with minimal environmental impact for material selection.

Verification

The verification methods and tools to be adopted are determined by the specific goals and scope of sustainable criteria undertaken Here are some examples of verification methods:

1. Life Cycle Assessment is a valuable tool for informing decisions regarding material choice, construction recycling, and managing construction and demolition waste processes. The physical characteristics of substances and their ecological consequences should be considered (35).
2. It is crucial to examine the harmonies and compromises between energy efficiency and material selection.
3. The indoor air quality is impaired by construction materials and the overall ecological footprint impact of buildings should be examined. This includes investigating potential health issues associated with both short- and long-term effects. Post-occupancy evaluations, regular checks, and monitoring methods can be used to investigate these factors.
4. Verification and management processes involve the establishment of management strategies that incorporate inventories to minimize negative environmental effects. A monitoring system should be in place to ensure consistent maintenance and inspection protocols.

Certification

Evaluate the volume and caliber of materials accessible in the marketplace, specifically those that are green-certified. Certification initiatives can aid in the following ways.

1. Investigate the market's capacity for reused, recycled, renewable, and locally sourced materials, encompassing their pricing and functional prerequisites.
2. Guaranteeing adherence to third-party certifications for sustainable resource management.
3. Furnishing reliable and enlightening information regarding the ecological consequences of products.

Consider sustainable material selection and procurement as challenging endeavors in a building project. This is primarily because of several reasons.

1. The need to evaluate numerous products and materials is important.
2. Discrepancies in evaluation criteria among various product types and countries of manufacture.
3. Absence of clarity in production methods.
4. The absence of a universally agreed approach for evaluating products and materials.

Sustainable construction materials are essential for promoting environmentally friendly practices in the building industry as individuals increasingly prioritize environmental preservation. Architects, construction workers, and homeowners are actively seeking ways to enhance their practices, and opting for sustainable building materials has proven to be a viable solution for minimizing their ecological footprint.

ATTRIBUTES OF GOOD SUSTAINABLE MATERIALS

Khatib (2009) [37] recommended sustainable materials must possess the following attributes.

- Establishing acceptable levels of environmental performance attributes is crucial.
- The entire life cycle of materials must be taken into account.
- There should be no lasting environmental pollution throughout the material's lifespan.

- It is important to avoid combining materials into compositions that are difficult to disassemble. The materials should not be mixed in ways that prevent disassembly.
- Third-party certification for certain products is recommended.
- Sustainable materials are frequently more cost-effective than commonly believed.
- They contribute to enhanced indoor air quality.
- Deconstruction should be feasible after the building's use.

SUSTAINABLE CONSTRUCTION MATERIALS SELECTION

The use of green materials is essential to promote environmentally friendly practices in the construction industry. Architects, builders, and clients are increasingly choosing sustainable materials to reduce their environmental impact [37]. Bamboo is an exceptionally sustainable construction material, possessing many qualities that propel it to the forefront of the eco-friendly building sector. This plant is renowned for its rapid growth and ranking among the fastest-growing plants on Earth. With a harvesting period of just four to five years, bamboo has emerged as an optimal choice for individuals seeking to embrace an environmentally conscious way of life [38]. Bamboo is an environmentally friendly building material and a highly advantageous substitute for timber. It boasts high tensile and compressive strengths, flexibility, and durability, serving as an exceptional sound barrier with inherent durability and the ability to withstand harsh weather conditions, all of which are significantly lighter in weight compared to traditional wood. Bamboo exhibits an impressive strength-to-weight ratio. Surpassing steel (23,000 PSI) in strength, bamboo is two to three times stronger than hardwoods, concrete, and bricks, such as oak. Bamboo finds applications in a wide range of products, including various decorative elements, walls, flooring, furniture, and ceilings. This sustainable material has applications in flooring, cabinetry, and various other areas. Specific types of bamboo can replace construction materials with high carbon emissions, such as steel, bricks, and concrete. This sector has witnessed an increase in the utilization of bamboo materials for housing, buildings, infrastructure, and bridges.

Compressed Earth Blocks (CEB)

CEB is a blend of loam, clay, and sand with varying mixing ratios, as per expert advice, and is shaped using steel molds. It is compressed using mechanical press machines, either a screw press or a hydraulic press. When constructed correctly, buildings constructed using these blocks can be sustainable and durable. They are comparable to fired bricks in terms of size, thermal properties, cost-effectiveness, flexibility, durability, energy efficiency, and dependence on firewood. Some benefits of utilizing CEB include the ability to utilize on-site materials, resulting in cost reduction, decreased transportation expenses for materials, and improved efficiency and sustainability.

Concrete

Many scholars have characterized concrete as a fundamental element in building construction. It has been confirmed that over 10 billion tons of concrete are manufactured annually worldwide. Concrete is considered a sustainable material, yet the challenge arises from the cementitious components that are mixed with it [6]. When producing one ton of Portland cement, an almost equivalent amount of CO₂ is emitted into the atmosphere. It is estimated that the cement industry alone accounts for approximately 7% of global CO₂ emissions. Iqbal and Swapnil (2017) [7] stated that by incorporating fly ash as a significant pozzolan with Portland cement, concrete mixtures can decrease the heat of hydration, enhance durability and strength characteristics, and reduce carbon dioxide emissions. Hemp Crete, made from the inner core of the hemp plant, water, and lime, creating a distinctive bio-composite material is an environmentally friendly material that is lightweight and offers breathability, durability, thermal insulation, fire resistance, natural pest-repelling qualities, and promotes a healthy indoor environment. Additionally, it serves as a natural pest deterrent. It consists of hemp shives mixed with a lime-based binder, making it an excellent choice for sustainable construction by replacing traditional materials, such as concrete, wood, and insulation. Resistance to damage makes it suitable for high-traffic areas in buildings such as public spaces. It is crucial to ensure that the gaps are properly filled to

prevent thermal bridges. This eco-friendly alternative offers a sustainable option for construction materials commonly utilized in the insulation and construction of both residential and commercial buildings. Cork is a sustainable building material with excellent fire-resistant properties, waterproofness, and mold resistance. The source of this substance is the outer layer of the cork oak tree, which renders it an entirely natural and sustainable source. It is free from harmful air pollutants and has a lower CO₂ emission than other materials. It exhibits exceptional acoustic insulation properties. Cork is durable, lightweight, and easy to shape, making it versatile for various applications. It uses spans across floorings, walls, furniture, and decorative objects. Cork flooring offers comfort and has a unique and elegant appearance. When used on walls, corks help regulate indoor temperature, absorb excess moisture, and add a distinctive decorative element to any space. This material exhibits extraordinary characteristics that render it an ideal building material. It is durable, adaptable, and capable of returning to its original form, even when subjected to significant pressure. Its durability and resistance to wear make it a popular choice for floor tiles. Timber Crete is manufactured using sawdust and wood chips, which are derived from the timber industry as byproducts that would otherwise be discarded. It is a state-of-the-art and environmentally friendly construction material that combines sustainability, insulation, and reduced environmental impacts [39]. Incorporating recycled wood and reducing cement usage contributes to the advancement of eco-conscious building practices. Furthermore, it can be manufactured on a local scale using wood waste from the region, leading to lower transportation expenses compared to imported concrete or alternative construction materials. By utilizing these materials, Timber Crete significantly minimized resource consumption, thereby mitigating its ecological footprint. It is a type of concrete material that is lightweight and insulating. It is created using sawdust and small wood chips, which are considered waste products in the timber industry [40].

Recycled Rubber

The environment is at risk owing to the production of rubber, which frequently leads to the disposal of the material in landfills. Recycling rubber presents a straightforward solution to reduce the demand for new rubber and minimize the environmental consequences. The inclusion of recycled rubber can negatively affect the strength of composites. Additionally, prediction models for the strength of rubberized concrete were developed using literature data, demonstrating a close alignment with the experimental findings. These models offer a cost-effective and time-saving method for assessing material strength.

Adobe Bricks

Adobe bricks are manufactured by mixing clay-based soil, water, and sometimes straw. It has a minimal environmental footprint, particularly when sourced from local sources. Buildings constructed with adobe bricks have the potential to endure for centuries while maintaining low energy expenses. The wet adobe mixture was then molded into bricks and left to dry in the sun. Building methods vary based on climate conditions. They are predominantly found in rural areas. Adobe bricks offer several benefits, such as their ability to provide soundproofing, fire resistance, durability, eco-friendliness, and high thermal efficiency.

Improved Concrete Panels

This offers a solution for the construction of high-quality homes. These panels provide earthquake resistance and excellent insulation properties by utilizing hollow concrete blocks with strong frameworks. This widely used and durable building material can be considered sustainable when locally produced using readily available resources such as sand and pebbles. The choice of framework materials can be wood, bamboo, concrete, aluminum, or steel.

Stone

Stones are the key construction materials. It can be recycled and utilized for various purposes such as countertops and foundations. They are environmentally friendly and do not release harmful chemicals during construction.

Cigarette Butt Bricks

Incorporating cigarette butts into bricks is an effective method to decrease pollution resulting from cigarette waste. The process of making bricks from cigarette butts is not only more energy-efficient than traditional brickmaking but also requires a short time.

Block

It is made from plastic waste and is one of the biggest issues in the world today. The conversion of plastic waste into construction blocks is achieved through steam and compression, eliminating the need for chemicals. Unlike other plastic recycling methods, there is no requirement to wash or pre-sort the feedstock. Blocks can be utilized in a multitude of ways, such as sound walls, sheds, privacy fencing, terracing, accent walls, and furniture. This innovative solution not only reduces plastic waste but also reuses it into a long-lasting building material, contributing to an eco-friendly approach. They have a low-emission process and require minimal materials for installation. They can be used for retaining walls, paving blocks, sheds, fencing, and landscaping.

Enviro Board

The Enviro Board is manufactured by grinding agricultural byproducts, such as rice straw, wheat straw, and elephant grass, into modular construction panels, which can be used as sustainable building materials. The use of waste materials, such as rice straws and husks, to mitigate pollution is crucial for addressing environmental issues and enhancing sustainability. These materials have been employed as natural environmental adsorbents, either in their original state or after different treatments, to enhance their ability to absorb pollutants. Natural fibers of agricultural waste can be repurposed to create lightweight and cost-effective polymers for building and construction purposes. By incorporating rice straw into cement bricks, it is possible to lower the costs while maintaining thermal insulation, mechanical strength, and fire resistance. Additionally, rice straw-based composites with starch adhesives show promise for ceiling panels and bulletin boards, and research has indicated that cornstarch-based composites exhibit superior flexural properties compared to those made with cassava or potato starch.

Cob

Cob construction uses clay soil, sand, and straw as the primary ingredients. These components were combined to form a pliable mixture, which was then shaped into cobs. These cobs serve as fundamental building blocks for the construction of walls, floors, and other architectural elements. One of the remarkable qualities of a cob is its flexibility, allowing for the creation of organic shapes, curves, and flowing lines. Unlike traditional linear materials, such as lumber, cobs can be sculpted into various forms. Furthermore, cob walls are self-supporting and capable of bearing loads. Once the cobs dried, they hardened, resembling lean concrete. This characteristic makes cobs an ideal choice for constructing stable structures, without the need for additional framing or support. In addition, cob construction is relatively easy to learn, requires no specialized equipment, and promotes sustainability by utilizing eco-friendly materials. Cob can be used to create long-lasting walls without the use of artificial substances.

Breathe Bricks

Numerous concepts and strategies exist for integrating nature into architectural designs to enhance indoor air quality and increase natural ventilation while reducing pollution. An example is the implementation of Breathing Walls constructed using porous materials. These materials help decrease energy consumption in air-conditioned buildings. Breeze-Way offers an ideal design concept for warm climates, effectively managing airflow throughout the structure, and cooling internal spaces through various methods. Breathe bricks enhance the purification of indoor air by filtering out pollutants from outdoor air, eliminating the need for external filtration devices.

Precast Concrete

Precast concrete exemplifies three key sustainability factors: eco-friendliness, cost-effectiveness, and social consciousness. It can be recycled multiple times for various purposes and manufactured nearby, thereby reducing its environmental impact.

Grass Crete

This type of on-site concrete is reinforced and contains cells that can be filled with soil or stones to allow natural grass to grow. This innovative material offers numerous environmental benefits, such as facilitating stormwater infiltration, being made from recycled materials, and contributing to the expansion of green spaces.

Cordwood

Cordwood is manufactured from locally sourced materials, such as wood and sawdust, along with construction waste. It is commonly utilized in architectural designs, such as round- or curved-wall structures, as well as stack-wall corners. The advantages of using cordwood include improved energy efficiency and simplified construction processes. <https://instead.com/blog/cordwood-construction/>

Ash Crete

It is durable, supports the reduction of carbon dioxide emissions, and has the potential to replace 25% of cement usage. Ashcrete, an environment-friendly substitute for concrete, is made from fly ash as its main ingredient. By blending fly ash with borate, bottom ash, and a chlorine compound, ashcrete is manufactured, offering a stronger and more durable option than conventional concrete. Less water is required for solidification, which aids water conservation. Moreover, it sequesters carbon dioxide, reduces emissions, and possesses a lower embodied energy than regular concrete. In construction, the round fly ash particles act as ball bearings, providing lubrication in the concrete mixture. Ashcrete exhibits greater resistance to acid, fire, extreme temperatures, and corrosion than traditional concretes. Furthermore, fly ash cement is more cost-efficient, making it a practical alternative.

Rammed Earth

This method involves the compression of layers of soil, granite, sand, and clay to create robust walls. This construction technique is well known for its durability, longevity, and ease of access. The exceptional thermal mass of rammed earth walls enables efficient temperature control within the enclosed areas. Rammed earth presents an intriguing method for building foundations, floors, and walls by compacting natural materials, such as earth, chalk, lime, or gravel. This age-old construction technique involves the compression of unsaturated loose soil within a formwork.

Reclaimed Materials

This aids in reducing the need to cut down new trees. This particular type of timber is used in furniture, flooring, and structural elements, adding a unique appeal to buildings while promoting eco-friendly forestry practices. The utilization of recycled glass in construction not only minimizes waste but also preserves energy resources. Crushed glass can serve as an aggregate in concrete or be incorporated as a decorative feature in walls and facades, enhancing the aesthetic appeal of buildings while allowing natural light to penetrate. The volume of waste glass has been steadily rising owing to urbanization and industrialization, with the majority being disposed of in landfills. Only a small portion can be recycled, mainly because of the expensive process of cleaning and sorting by color. Recent research has indicated that waste glass can be efficiently utilized in concrete, either as an aggregate (fine or coarse) or as a substitute for cement. Waste glass is recycled in a closed-loop system to create alternative products, which are later disposed of once they have served their purpose. Some examples of these products include materials such as ceiling insulation, which are commonly made from glass fiber.

Engineered Lumber

Engineered lumber and cross-laminated timber are considered the optimal sustainable materials for construction purposes. Engineered lumber, specifically designed to possess greater strength than traditional lumber, is an excellent option for various building projects. This type of wood is created by bonding multiple layers of wood veneers, which are subsequently molded into a log. As a result, the final product exhibits the durability and stability of solid wood while also offering the advantages of faster, more efficient, and cost-effective manufacturing processes compared to solid wood.

Recycled Concrete Aggregate

Recycled concrete aggregate (RCA) is created by crushing large pieces of recycled material into smaller fragments and mixing them with new concrete components, usually sand. The consumption of natural aggregates and energy has significantly increased because of the recent global surge in structural development. Recycling construction and demolition waste, particularly concrete waste, is advantageous for construction activities. Waste concrete can be repurposed as a substitute for natural aggregates by producing RCAs. This not only helps reduce waste disposal at landfills but also conserves energy, thereby preserving the environment. The utilization of RCAs in concrete mixtures has attracted the attention of numerous researchers because it offers the potential for the full or partial substitution of natural aggregates. This process helps minimize waste and protect the environment from degradation.

Soy-Based Spray Foam Insulation

Spray foam insulation is an exceptionally energy-efficient and sustainable construction material that is commercially available. Its versatility is another remarkable feature as it can be applied to various areas within a house, ranging from exterior walls to basements and attics. The remarkable aspect of spray foam insulation lies in its ability to adhere tightly to almost any surface. While the majority of spray foam insulation is composed of polyurethane, certain brands incorporate a minor proportion of soy-based filler, typically approximately 10%. This inclusion helps diminish the foam's CO₂ emissions and environmental impacts.

Reclaimed Brick Veneer Tile

Reclaimed brick veneer tiles represent an excellent sustainable option for construction. This material was crafted from salvaged bricks obtained from demolished structures, which were then repurposed as flooring and wall coverings. To ensure longevity, the reclaimed bricks underwent thorough cleaning, sanding, and the application of a protective sealant. Although the color of each brick may vary depending on its origin, most reclaimed bricks exhibit a light tan or grayish hue. This versatile tile is commonly utilized as an accent wall or exterior cladding owing to its ease of installation, ability to be laid horizontally or vertically, and durability in withstanding foot traffic.

Paper Stone

It is an eco-friendly choice for building homes, as it is made primarily from recycled materials or obtained from sustainably managed forests, rendering it eco-friendly. This sustainable material is ideal for those who want to minimize their environmental impact. It is more beneficial and devoid of formaldehyde, petroleum, and harmful off-gassing. Construction experts discovered that it is simpler to handle because it can be constructed on-site. They are resistant to water and do not support bacterial growth. This offers a cost-effective solution for a wide range of applications. Its durability exceeds that of wood, making it suitable for use indoors and outdoors, such as countertops, windowsills, cabinets, tabletops, wall cladding, and fireplace surrounds. Straw bales have gained popularity as sustainable building materials because of their numerous benefits. Straw bales made from leftover stalk material from grain crops such as wheat, rye, and barley are tightly bound together and used for wall insulation. This can also serve as an alternative to wood framing during construction. Straw bales possess excellent insulation qualities, making them energy-efficient and aiding in lowering cooling and heating expenses. Additionally, they offer effective sound insulation and high fire resistance when paired with plasters. It can withstand vertical, lateral, and seismic loads. In terms of environmental impact, straw bales offer natural insulation properties, cost-effectiveness, accessibility, renewability, fireproofness, and resistance to wind and water penetration.

Silica Fume

A notable achievement in utilizing industrial byproducts is the case of condensed silica fume, a by-product of the semiconductor industry. This siliceous substance enhances the strength and longevity of concrete to the point where contemporary high-performance concrete mix formulations typically include silica fume. Numerous studies have highlighted the advantages of silica fumes as both pozzolan and filler materials.

Recycled Glass Tiles

Recycled glass tiles are a sustainable choice for construction. Crafted from recycled glass, these tiles possess both aesthetic appeal and contribute to minimizing the environmental footprint of the project. With a wide range of colors and styles available, including mosaics and decorative pieces, recycled glass tiles can be utilized as countertops, backsplashes, and flooring in both commercial and residential settings. When employed as countertops and backsplashes, these tiles require minimal upkeep and are effortless. Their matte finish prevents fingerprinting, eliminating the need for constant cleaning or polishing. In addition, they are resistant to scratches, thus ensuring long-lasting durability.

Wool Insulation

Wool insulation is a top-notch, sustainable building material. Recycled wool is an eco-friendly product. Moreover, this material possesses fire-resistant properties and aids in averting the growth of mold within the anode. Additionally, wool insulation is non-toxic and devoid of bromine or formaldehyde. It further boasts biodegradability and refrains from emitting detrimental chemicals into the air quality of the home. Strawbales are a sustainable, economical, and readily available resource for board construction. This offers an excellent opportunity to develop sustainable materials. Straw, derived from grain farming, serves as an environmentally friendly resource that does not require the use of additional materials. Moreover, working with straw is convenient because it can be utilized for insulation purposes or as the primary building block itself. Over the years, straw has been widely employed in construction because of its exceptional insulation properties and effective regulation of temperature by retaining heat during winter and keeping it out during summer. Additionally, straw exhibits remarkable fire resistance, making it an ideal choice for construction near forests and other flammable areas. Furthermore, strawbale houses are highly sustainable, as they consume less energy than traditional homes, requiring nothing more than a hammer and chisel for construction. Straw is a bio-based material that can regulate indoor temperature and relative humidity while consuming less energy and emitting less CO₂, ultimately leading to improved indoor comfort and reduced environmental impact. Wheat board, a combination of wheat straw and resin, is a flexible material that offers numerous benefits for construction purposes. The rise in awareness regarding climate change and sustainable development has led to a greater need for environmentally friendly materials in the construction sector. A large amount of wheat straw residue is unused, with only 19% utilized for agricultural purposes, such as bedding and animal feed. The rest is often burned in fields, resulting in harmful emissions, such as carbon monoxide, carbon dioxide, and nitrogen oxide, posing risks to both the environment and human health. By utilizing straw as insulation in buildings, we can not only tackle the issue of wasted wheat straw as a by-product of agriculture but also construct homes with minimal environmental impact. Not only is it fireproof and resistant to mold, but it also does not emit harmful chemicals. In addition to its application as insulation in walls and ceilings, it can also serve as a reliable flooring material. Moreover, working with a wheat board is a breeze, as it can be cut effortlessly using standard tools. Furthermore, it can be securely fixed in place using nails or screws without the need for specialized equipment or adhesives. The utilization of recycled plastic as a sustainable construction material has gained immense popularity in recent times. Plastic materials play a crucial role in the construction sector and are commonly used in pipes, thin coverings, sheets, panels, foams, and other applications. The increased use of plastics not only enhances the practicality and durability of traditional building materials but also improves efficiency and cost-effectiveness. Plastics are occasionally incorporated into construction projects to reinforce concrete structures. Opting for recycled plastic is a choice that promotes environmental friendliness, as it not only diminishes plastic pollution but also aids in the preservation of natural resources. Moreover, it is a cost-effective and versatile material that can be used in various applications. It is useful in numerous aspects of construction projects, encompassing window frames, decking, roofing, outside furniture, and insulation. It is durable, has remarkable compressive strength, and exhibits exceptional resistance to water, mold, rot, UV exposure, and other adverse weather conditions. Recycled steel plays an important role in the development of eco-friendly construction materials. Its strength, durability, and recyclability, without compromising its properties, make it an ideal option for sustainable structures. Many building materials such as frames, walls, beams,

and joists can be produced using recycled steel. It can be utilized in numerous sustainable architectural applications owing to its low energy consumption. Additionally, because it is made from old steel, it can be melted and repurposed into new items, reducing the waste generated from steel production. It helps in reducing energy expenses and maintenance compared with other materials. Reclaimed wood is a highly sought-after sustainable building material and is gaining popularity as a viable option. It has a history of use in various applications before being repurposed for construction. This versatile material can be obtained from a range of sources, such as demolished structures and deconstructed furniture, and can be utilized in different ways, such as flooring, trimming, and cabinets [18]. Sheep's wool is a sustainable building material with exceptional insulation, strength, and durability. Their long fibers enable them to withstand extreme temperature changes and resist fire, making them suitable for walls, other structural components, and roofs. It is suitable for individuals with asthma and allergies and is non-toxic. This is an excellent option for energy-efficient and eco-friendly building materials. It is a renewable resource, and its thermal and soundproofing properties make it ideal for insulation and construction. Furthermore, the natural beauty of wool adds both style and warmth to all building projects. It is not without challenges, such as proper maintenance, that prevent shrinkage. In addition, wool is not inherently waterproof, necessitating treatment before its use in wetter climates. Clay is a widely used sought-after sustainable building material with a rich history of use in construction. Clay is versatile and can be molded into various shapes and sizes without additional materials. Fire and termite resistance makes it an excellent choice for construction projects. Clay is an energy-efficient option for builders. Durability allows structures to stand for over a century, while resilience to weather damage makes them suitable for various climates. The clay insulation properties also make it ideal for use in cooler regions. By utilizing clay in construction, the carbon footprint of projects can be significantly reduced because it is a natural material that requires no mining or transportation. Furthermore, clay helps minimize air pollution by not emitting particulate matter. Ferrock is an innovative and sustainable building material crafted from recycled components, such as steel dust and carbon dioxide emissions. It is eco-friendly and durable. They are resistant to harsh temperatures, chemical substances, and biological elements. They are more environmentally conscious than cement-based alternatives. Moreover, it has the potential to absorb more carbon dioxide than it released during production, positioning it as a carbon-neutral building material. A notable advantage of this sustainable building material is its malleability, which allows architects and designers unparalleled creative liberty. Its adaptability makes it a prime choice for intricate architectural design, enabling the creation of elaborate curved surfaces and innovative structures. Manufactured sand serves as a viable alternative to natural river sand with a particle size of less than 5.0 mm. It is produced through the crushing of hard rocks and oversized stones in crushing plants. The economic benefits of manufactured sand are particularly significant in areas with limited access to natural sand. Utilizing manufactured sand in construction not only minimizes environmental damage but also optimizes resource utilization.

Coconut Tree

Coconut trees have been described as sustainable construction materials. The fibrous nature of coconut trees makes them ideal for constructing walls, ceilings, roofs, lintels, and bridges. Moreover, they are frequently used as overlays in toilet pits. Unlike timber, coconut trees are resistant to termites and do not deteriorate easily unless subjected to prolonged dampness.

Autoclaved Aerated Concrete

Iqbal and Swapnil (2017) [7] described Autoclaved Aerated Concrete (AAC) as a sustainable and environmentally friendly construction material certified as a green building product. It is characterized by its porous nature, non-toxic properties, reusability, renewability, and recyclability. This lightweight, load-bearing, highly insulation, and durable building material is available in various sizes and strengths, offering a wide range of construction applications. AAC presents significant advantages in terms of enhancing building quality while simultaneously reducing construction costs, particularly AAC blocks. Its lightweight nature and low thermal conductivity, attributed to its 50–60% air content, make it a highly desirable choice for sustainable construction projects.

CONCLUSION AND RECOMMENDATION

The objective of this study was to analyze the primary benefits, obstacles, and prospects of conventional construction materials in enhancing the availability and affordability of low-cost housing. The importance of adopting sustainable practices in the construction sector cannot be emphasized, as it hinges on both the future of industry and the environment. This study emphasized the importance of sustainable materials in contemporary architecture and construction. It is essential to ensure that sufficient knowledge and expertise are available regarding sustainable building materials. The promotion and guidance of sustainable building materials and practices at construction sites are crucial. Local communities should be actively involved in implementing sustainable construction techniques and materials. The construction industry can expedite the integration of sustainable materials through persistent research funding, favorable public policies, attractive incentives, and effective regulations. Moreover, it is crucial to promote the development of sustainable materials, technologies, and practices among developers, contractors, and property owners. It is crucial to highlight the significance of promoting interdisciplinary collaboration and knowledge exchange between academia, industry, and policymakers. Moreover, strengthening partnerships between academia and industry is essential to simplify testing and validation procedures for innovative sustainable materials, ensuring their feasibility, efficiency, and capacity for widespread adoption. The use of sustainable and readily accessible materials presents a significant opportunity for sustainability. It is imperative to integrate local construction methods with new, low-tech, and affordable technologies. The sustainability of the construction sector and the environment depends on sustainable practices because of the substantial greenhouse gas emissions and resource depletion that occur daily. Thus, it is crucial to shift towards sustainable practices to effectively address climate change and preserve natural resources. There is a need to digitalize and catalog all sustainable building materials to raise awareness among potential clients and industry stakeholders about their availability and significance.

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