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A Brief Guide to the 50 Eco-Friendly Materials Transforming Sustainable Construction

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Abstract

The adoption of eco-friendly construction materials represents a revolutionary shift in the physical infrastructure, challenging traditional building practices. This transformation reduces environmental impacts and sets a precedence for sustainable, resilient, and responsible construction practices, marking a crucial milestone in the evolution of the physical infrastructure. This study offers a brief examination of eco-friendly materials for sustainable construction practices. Addressing the growing urgency for environmentally conscious building practices to reduce greenhouse gas emissions from the construction material manufacturing industry. This study examines 50 eco-friendly materials, providing an understanding of their attributes, applications, and ecological benefits. Emphasizing the transformative potential of these materials, this article serves as a practical brief guide for architects, engineers, and construction professionals, facilitating informed decision-making without compromising construction performance. With a commitment to environmental responsibility and structural efficiency, this article contributes to a paradigm shift towards a greener and more sustainable future in the construction industry.

Keywords: Construction Materials; Sustainability; Eco-friendly; Construction; Applications

Introduction

The imperative to study eco-friendly construction materials stems from the urgent need to address the environmental challenges and sustainability concerns that have become increasingly prominent in the contemporary world [1]. As traditional construction methods and materials contribute to global warming significantly and cause environmental degradation, there is a growing realization that a shift toward eco-friendly alternatives is imperative for mitigating the negative impacts of human activities on the Earth. The construction industry, known for its resource-intensive nature and significant carbon footprint, is now under scrutiny to adopt more sustainable materials during construction. Eco-friendly construction materials play a pivotal role in meeting this demand to build physical infrastructure by offering alternatives while minimizing environmental harm, conserving natural resources, and promoting long-term ecological balance [2].

The production and use of traditional construction materials, such as concrete and steel, are notorious for their substantial environmental impact due to the release of Greenhouse Gas (GHG) emissions while manufacturing [3]. Cement, a key component of concrete, is responsible for a significant portion of global carbon dioxide emissions due to its energy-intensive manufacturing process. Similarly, steel production involves high energy consumption and releases GHG into the atmosphere. Eco-friendly construction materials, on the other hand, often utilize recycled or renewable resources, reducing the demand for extraction and processing of raw materials. Materials like recycled steel, bamboo, or reclaimed wood contribute to the conservation of natural resources and decrease the carbon footprint associated with their production, making them essential for sustainable construction practices [4,5].

Secondly, the construction industry is a major contributor to the generation of construction and demolition waste, which poses significant challenges for landfill management and environmental degradation. Eco-friendly construction materials prioritize the reduction of waste generation through recycling and reusability. Materials designed for deconstruction and recycling, such as modular components or reclaimed materials, facilitate a more circular and sustainable approach to construction. This not only minimizes the environmental impact of construction activities but also contributes to the creation of a more resilient and resource-efficient built environment [6,7]. Lastly, the increasing awareness of climate change and the need for carbon footprint reduction underscores the necessity for eco-friendly construction materials. Sustainable materials often possess lower embodied energy, meaning that their production and transportation result in fewer GHG emissions [8]. As the construction industry seeks to align with global sustainability goals,

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the adoption of eco-friendly materials becomes paramount for reducing the sector's overall contribution to climate change. In essence, the imperative for eco-friendly construction materials arises from the industry's responsibility to address environmental challenges, conserve resources, and contribute to a more sustainable and resilient built environment.

Eco-Friendly Construction Materials

This section provides a concise overview of the top 50 eco-friendly construction materials, offering brief insights into their diverse applications. Delving into the versatility of these sustainable alternatives, it outlines how each material addresses specific construction needs while adhering to environmentally conscious principles. From recycled steel and reclaimed wood to cutting-edge innovations, this discussion serves as a comprehensive guide, shedding light on the varied applications that make these materials instrumental in fostering sustainable construction practices. Eco-friendly construction materials are essential for sustainable building practices, reducing environmental impact, conserving resources, and promoting energy efficiency. They contribute to healthier indoor environments, minimize waste, and align with global sustainability goals, fostering responsible and resilient construction for a more environmentally conscious and resilient built environment [9,10]. The key necessities of eco-friendly construction materials are presented in Figure 1 and the benefits of these materials are discussed respectively under each material.

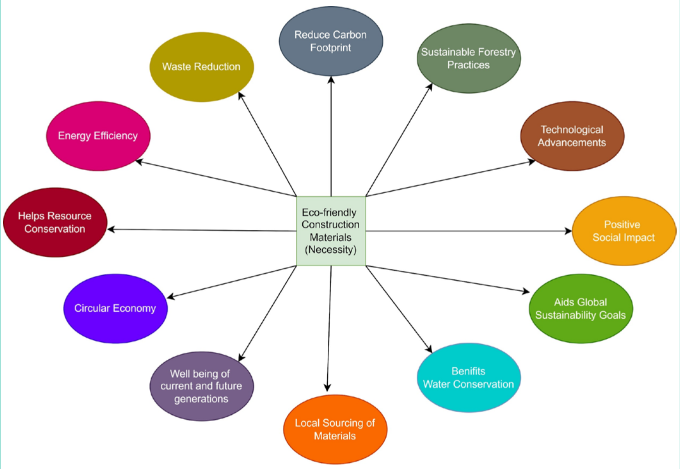

Figure 1: The Key Necessities of Use of Eco-Friendly Materials in the Construction Industry.

Bamboo

Bamboo stands as an exemplary eco-friendly construction material, prized for its remarkable construction properties and versatile applications. With a tensile strength exceeding that of many traditional building materials, bamboo offers robust structural integrity, making it an ideal choice for various construction purposes. Its rapid growth and renewability contribute to sustainability, as bamboo can be harvested in a fraction of the time required for traditional lumber. As a building material, bamboo demonstrates excellent flexibility, allowing for innovative designs and earthquake-resistant structures. Its natural resistance to pests and durability in diverse climates further enhance its appeal. Widely employed in residential and commercial construction, bamboo finds applications in structural elements like beams and columns, as well as in flooring, wall cladding, and decorative finishes, exemplifying its adaptability and eco-friendly attributes in the modern construction landscape [11].

Recycled Steel

Recycled steel is a paramount eco-friendly construction material, renowned for its exceptional construction properties and diverse applications. Derived from post-consumer and post-industrial sources, recycled steel significantly reduces the environmental impact associated with traditional steel production. Its inherent strength, durability, and fire resistance make it an ideal structural component for buildings, bridges, and other infrastructure projects. The recycling process retains the material's structural integrity, offering a sustainable alternative without compromising quality [12]. In construction, recycled steel finds extensive use in framing, beams, columns, and reinforcement, contributing to the creation of resilient and environmentally conscious structures. Additionally, its versatility extends to applications in roofing, cladding, and various architectural elements. The adoption of recycled steel in construction not only conserves valuable resources but also minimizes energy consumption and carbon emissions, aligning with the imperative for sustainable building practices [13].

Recycled Concrete

Recycled concrete, a pivotal eco-friendly construction material, is celebrated for its commendable construction properties and multifaceted applications. Derived from crushed concrete debris, it mitigates the environmental impact associated with traditional concrete production by repurposing existing materials. The recycling process maintains its fundamental properties, such as compressive strength and durability, offering a sustainable alternative without compromising structural integrity. Recycled concrete finds extensive use in various construction applications, serving as a base material for road construction, embankments, and foundations. Its versatility extends to structural components like beams and columns, showcasing its adaptability in creating resilient and environmentally responsible buildings. Beyond structural use, recycled concrete can be employed for landscaping purposes, erosion control, and as an aggregate in new concrete mixes. The adoption of recycled concrete not only reduces the demand for virgin aggregates but also curtails the carbon footprint associated with traditional concrete production, making it a vital component in the pursuit of sustainable and circular construction practices [13].

Recycled Paper

Recycled paper countertops are an innovative and eco-friendly construction material crafted from post-consumer waste paper, often mixed with non-petroleum-based resin and pigments. The paper fibers are compressed and sealed with the resin to create a durable, solid surface. Not only does this process divert significant amounts of paper from landfills, but it also results in a lightweight and heat-resistant material suitable for various applications. Recycled paper countertops exhibit excellent tensile strength and resistance to scratches, making them an ideal choice for kitchen and bathroom surfaces. Their smooth and customizable finish allows for seamless integration into modern design aesthetics, offering a sustainable alternative to traditional countertop materials [14]. With a commitment to environmental responsibility, recycled paper countertops reduce resource consumption and promote a circular economy in the construction industry.

Reclaimed Wood

Reclaimed wood emerges as a quintessential eco-friendly construction material, distinguished by its unique construction properties and a broad spectrum of applications. Sourced from salvaged timber, reclaimed wood promotes sustainability by repurposing materials that would otherwise go to waste. Its inherent strength, durability, and character make it a versatile choice for a myriad of construction projects. In terms of structural applications, reclaimed wood excels in creating sturdy beams, columns, and framing elements, contributing to the construction of robust and aesthetically appealing structures [15]. The material's weathered patina and distinct grains add a sense of history and authenticity, enhancing its desirability for interior finishes, flooring, and wall cladding. Beyond aesthetics, reclaimed wood demonstrates excellent thermal insulation properties, making it an energy-efficient choice in construction. Moreover, its natural resistance to pests, when combined with appropriate treatments, further bolsters its longevity. The sustainability quotient of reclaimed wood extends beyond its construction applications; its reuse helps conserve forests and reduces the demand for freshly harvested timber. As a result, reclaimed wood finds favor in sustainable architecture, eco-conscious renovations, and adaptive reuse projects, embodying a harmonious blend of environmental responsibility and craftsmanship [16]. By choosing reclaimed wood, builders and designers contribute to the circular economy, diminishing waste, and affirming a commitment to responsible construction practices that prioritize both ecological preservation and the creation of enduring, visually captivating structures.

Photovoltaic Glass

Photovoltaic glass, or solar glass, stands as a cutting-edge eco-friendly construction material with integrated photovoltaic cells that convert sunlight into electricity. Typically composed of layers of tempered glass, these panels are designed to harness solar energy while maintaining transparency. The construction involves embedding thin-film photovoltaic cells within the glass layers, allowing for flexibility and adaptability to various architectural applications. Photovoltaic glass not only serves as a building envelope but also generates clean and renewable energy. Widely used in windows, facades, and skylights, it seamlessly integrates sustainable energy production into the structure. Its applications extend beyond residential and commercial buildings to infrastructure projects, providing an aesthetically pleasing solution to power generation [17]. With advancements in technology, photovoltaic glass exemplifies the synergy between energy efficiency and architectural design, contributing to the transition towards greener and more sustainable construction practices.

Cork

Cork stands as a highly sustainable and eco-friendly construction material, valued for its exceptional properties and diverse applications. Harvested from the bark of cork oak trees, the process is environmentally benign, allowing trees to regenerate and continue absorbing carbon dioxide. One of the cork's notable properties is its natural resilience, offering a compressible and elastic material that recovers well from compression. This makes cork an excellent choice for insulation, as it effectively seals gaps and provides thermal and acoustic insulation in walls and floors. Its lightweight nature facilitates ease of handling and installation, reducing the overall environmental impact of transportation. In addition to its insulation properties, cork is impermeable to liquids and gases, making it an ideal flooring material, particularly in areas prone to moisture [18]. Furthermore, cork's adaptability extends to aesthetic applications, including wall coverings and ceiling finishes. The material's natural texture and warmth also make it a popular choice for interior design elements. As a renewable and versatile resource, cork embodies sustainability in construction, offering a viable alternative that not only enhances the energy efficiency of buildings but also supports responsible forestry practices and biodiversity conservation.

Recycled Steel Framing

Recycled steel framing stands as a key eco-friendly construction material, offering both structural integrity and environmental sustainability. This construction method involves utilizing recycled steel, often sourced from salvaged cars, appliances, or industrial scrap, reducing the demand for raw steel production and minimizing the environmental impact associated with mining and manufacturing. The recycled steel is carefully fabricated into framing members that provide robust support for buildings. Known for its durability, resistance to pests, and fire-retardant properties, recycled steel framing is particularly suitable for residential, commercial, and industrial structures. Its versatility allows for various architectural designs, while its inherent strength contributes to the longevity and resilience of the built environment. Embracing recycled steel framing supports the circular economy by repurposing materials, making it a sustainable choice that aligns with modern construction practices prioritizing both strength and environmental responsibility [19,20].

Recycled Glass

Recycled glass emerges as a sustainable and versatile construction material, lauded for its unique properties and diverse real-time applications. Produced from post-consumer and post-industrial glass, its use significantly reduces the demand for new raw materials, curbing energy consumption and landfill waste. In construction, recycled glass finds application in various forms, primarily as aggregates in concrete, contributing to improved structural strength and durability. Its use enhances the aesthetic appeal of terrazzo flooring, countertops, and decorative elements, showcasing its adaptability in both residential and commercial spaces. The reflective nature of glass aggregates adds a distinctive touch to landscaping materials, such as exposed aggregate pathways and architectural concrete finishes. Moreover, recycled glass is utilized in the production of glassphalt, an eco-friendly alternative to traditional asphalt, enhancing road surfaces with increased durability and reduced environmental impact [21]. By repurposing glass waste into functional construction materials, recycled glass embodies sustainability in real-time applications, providing an eco-conscious solution for builders and designers striving to reduce the environmental footprint of construction projects.

Sun Tubes

Sun tubes, also known as solar tubes or daylighting systems, are eco-friendly construction solutions designed to harness and distribute natural sunlight into interior spaces. Comprising a roof-mounted dome, reflective tubing, and a diffuser, these devices capture sunlight from the roof, channeling it through highly reflective tubes to illuminate the interior. The construction properties of sun tubes maximize energy efficiency by minimizing heat transfer and maximizing light diffusion. This technology provides an eco-friendly alternative to traditional electric lighting, reducing the need for artificial illumination during daylight hours and decreasing overall energy consumption [22]. Sun tubes find applications in both residential and commercial buildings, enhancing indoor environments by creating well-lit and visually appealing spaces. Their flexibility in installation and ability to penetrate areas with limited access to direct sunlight make sun tubes a sustainable choice, promoting energy conservation and fostering a connection between the built environment and the natural world.

Hempcrete

Hempcrete, an eco-friendly construction material, has gained prominence for its unique blend of sustainability, insulation properties, and versatile applications. Composed of the inner woody fibers of the hemp plant, lime, and water, hempcrete exhibits remarkable environmental benefits. Its cultivation requires minimal pesticides and fertilizers, making it a low-impact crop with a rapid growth cycle. Hempcrete's insulation properties contribute to energy-efficient buildings, as it regulates temperature and humidity, providing a comfortable living environment. The material is lightweight, reduces transportation-related carbon emissions, and possesses excellent fire resistance, adding to its safety credentials. In real-time applications, hempcrete is employed as a non-structural infill material, creating well-insulated walls with a breathable quality that prevents mold growth. Its versatility extends to both residential and commercial construction, where it serves as an insulating material in walls, floors, and roofs. Furthermore, hempcrete's ability to sequester carbon dioxide during its curing process aligns with sustainability goals, mitigating the environmental impact of construction projects. The material's insulating properties contribute to reduced energy consumption for heating and cooling, making it a practical choice for eco-conscious builders. As hempcrete gains traction in the construction industry, it exemplifies a harmonious integration of renewable resources, energy efficiency, and environmental responsibility, fostering a paradigm shift towards sustainable and resilient built environments [23].

Recycled Granite

Recycled granite, an eco-friendly construction material, is produced by repurposing discarded granite remnants from countertop fabrication processes. This sustainable construction approach involves crushing and reconstituting granite scraps into tiles, pavers, and veneers. The resulting material maintains the natural beauty and durability of granite while significantly reducing waste and the environmental impact associated with quarrying. Recycled granite exhibits robust construction properties, including resistance to heat, scratches, and weathering. Applications for recycled granite encompass various architectural elements such as countertops, flooring, wall cladding, and outdoor hardscaping. Its versatility and aesthetic appeal make it an attractive choice for both interior and exterior design projects [24]. Embracing recycled granite not only contributes to resource conservation but also adds a distinctive, eco-conscious character to construction endeavors, aligning with the growing trend toward sustainable building practices and responsible material sourcing.

Straw Bales

Straw bales, recognized as a sustainable construction material, offer a plethora of eco-friendly qualities and practical applications. Comprising tightly bound straw harvested from grains like wheat or rice, these bales present exceptional insulation properties. The hollow, fibrous structure of straw creates a natural thermal barrier, providing energy-efficient solutions for buildings. Straw bale construction boasts a low environmental impact as it often utilizes agricultural byproducts that would otherwise be considered waste. In real-time applications, straw bales are employed as load-bearing elements in walls, where they provide both structural support and insulation. The assembly of straw bale walls typically involves stacking bales, securing them with a mesh or wire, and applying a plaster or stucco finish for weather protection. This construction method is known for its simplicity, affordability, and rapid construction pace. Straw bale buildings demonstrate remarkable energy efficiency, maintaining comfortable interior temperatures throughout the year. Beyond residential applications, straw bale construction has found utility in schools, commercial buildings, and even larger infrastructure projects [25]. With its renewable sourcing, insulation capabilities, and practical applications, straw bales exemplify an eco-friendly approach to construction, offering a sustainable alternative that aligns with the goals of energy efficiency and environmental stewardship in the built environment.

Algae-Based Building Materials

Algae-based building materials represent an innovative and sustainable approach to construction, leveraging the natural properties of algae to create eco-friendly solutions. These materials often involve incorporating algae into concrete or other matrices, offering benefits such as enhanced carbon capture, reduced energy consumption, and a lower carbon footprint. Algae's rapid growth and ability to thrive in diverse environments contribute to its eco-friendly nature. Algae-based building materials can enhance the structural strength of traditional construction components while introducing biodegradability and potential improvements in indoor air quality. Applications range from algae-infused concrete for building structures to panels and coatings that harness algae's photosynthetic capabilities for energy efficiency. This approach aligns with the broader goals of creating sustainable, regenerative building materials that mitigate environmental impact, making algae-based materials a promising avenue for eco-conscious construction practices [26].

Recycled Plastic

Recycled plastic, heralded for its contribution to sustainable construction, demonstrates unique properties and versatile real-time applications. Derived from post-consumer and post-industrial plastic waste, its use diverts plastic from landfills, reducing environmental impact and conserving resources. In construction, recycled plastic finds application in various forms, including lumber, panels, and structural elements.

As a building material, recycled plastic exhibits high durability, moisture resistance, and immunity to insects, making it particularly suitable for outdoor applications. Recycled plastic lumber, for instance, can replace traditional wood in decking, fencing, and landscaping, offering a low-maintenance, long-lasting alternative. Moreover, recycled plastic panels contribute to wall construction, providing insulation and weather resistance. Real-time applications extend to structural elements such as pilings, which are used in marine construction due to their resistance to water degradation. Beyond these uses, recycled plastic is employed in modular building components, promoting efficient construction practices [27]. By incorporating recycled plastic into construction projects, builders contribute to circular economy principles, mitigate the environmental impact of plastic waste, and create durable, eco-friendly structures that align with the growing emphasis on sustainability in the construction industry [28].

Coconut Coir

Coconut coir, derived from the fibrous husk of coconuts, serves as a versatile and eco-friendly construction material with unique properties beneficial for erosion control and insulation. Recognized for its natural strength and resilience, coconut coir is extensively used in erosion control applications such as stabilizing soil on slopes and preventing water runoff. In construction, it is employed as an insulation material due to its exceptional thermal properties, moisture resistance, and fire-retardant characteristics. Coconut coir's fibrous structure allows for efficient airflow, maintaining insulation effectiveness. This sustainable material is renewable, biodegradable, and sourced as a byproduct of coconut harvesting, contributing to waste reduction. As a dual-purpose solution, coconut coir embodies eco-conscious construction practices, addressing erosion challenges while providing an effective, natural insulation option that aligns with the principles of sustainability and environmental responsibility [29].

Soy-Based Insulation

Soy-based insulation emerges as an environmentally conscious construction material, boasting distinctive properties and versatile real-time applications. Produced from soybean oil, a renewable resource, this insulation material demonstrates exceptional sustainability. In its manufacturing process, soy-based insulation minimizes the dependence on fossil fuels and significantly reduces GHG emissions compared to traditional insulation materials. Offering excellent thermal resistance, soy-based insulation provides effective temperature regulation, reducing energy consumption for heating and cooling purposes [30]. Its composition also ensures resistance to moisture and mold growth, contributing to a healthier indoor environment. In real-time applications, soy-based insulation is widely used in residential and commercial construction, filling wall cavities, attics, and crawl spaces. Its spray-on form allows for seamless application, creating a continuous thermal barrier. Moreover, it adheres well to various surfaces, enhancing its versatility in retrofitting existing structures. By choosing soy-based insulation, builders and homeowners not only prioritize energy efficiency and indoor air quality but also support sustainable agriculture, marking a significant step towards eco-friendly construction practices in line with the global drive for environmental stewardship [31].

Thermally Modified Wood

Thermally modified wood is an eco-friendly construction material that undergoes a controlled heating process, altering its cellular structure to enhance durability, stability, and resistance to decay. This thermal modification involves heating the wood to high temperatures in the absence of oxygen, resulting in improved dimensional stability and reduced moisture absorption.

The process also enhances the wood's natural resistance to insects and fungi, reducing the need for chemical treatments. With a rich, caramelized appearance, thermally modified wood finds applications in decking, siding, flooring, and outdoor furniture, combining aesthetic appeal with sustainable building practices. Recognized for its eco-friendly attributes, this material minimizes the environmental impact associated with traditional preservative treatments, making it an attractive choice for projects that prioritize both longevity and environmental responsibility in construction [32].

Low VOC Paints

Low VOC (Volatile Organic Compounds) paints represent a pivotal advancement in eco-friendly construction materials, offering distinct properties and widespread real-time applications. Comprising minimal harmful chemicals, low VOC paints emit fewer pollutants into the air during and after application, contributing to enhanced indoor air quality and occupant health. These paints typically utilize water-based or plant-based solvents instead of traditional petroleum-based ones, reducing the environmental impact associated with paint production. Real-time applications encompass a broad spectrum of residential, commercial, and institutional settings. Low VOC paints are used for interior and exterior wall coatings, furniture finishes, and decorative elements, providing the same vibrant color options and durability as traditional paints. Their application contributes to sustainable construction practices, aligning with green building standards and certifications [33]. By choosing low VOC paints, builders and homeowners prioritize environmental responsibility without compromising on performance or aesthetic appeal, fostering healthier indoor environments and supporting the broader shift towards sustainable and eco-friendly construction practices.

Recycled Plastic Roofing Shingles

Recycled plastic roofing shingles offer an eco-friendly alternative to traditional roofing materials, utilizing post-consumer plastic waste in their construction. These shingles are manufactured by processing recycled plastic, typically from bottles and containers, into durable and weather-resistant roofing materials. The construction properties of recycled plastic roofing shingles include lightweight design, resistance to UV rays, and exceptional durability. These shingles mimic the appearance of traditional roofing materials such as slate or wood, providing an aesthetically pleasing option for various architectural styles. The use of recycled plastic not only diverts plastic waste from landfills but also reduces the demand for new raw materials. As an eco-conscious choice, recycled plastic roofing shingles contribute to sustainable building practices, offering longevity, low maintenance, and energy efficiency in roofing applications while simultaneously addressing environmental concerns associated with plastic pollution [34,35].

Green Roofs

Green roofs, heralded as an eco-friendly construction solution, exhibit unique properties and practical applications that contribute to sustainable urban development. These roofs are characterized by a layered system, typically including a waterproof membrane, a drainage layer, a growing medium, and vegetation. One of the key benefits of green roofs lies in their ability to mitigate the urban heat island effect by providing natural insulation and reducing ambient temperatures. Furthermore, they effectively manage stormwater runoff, absorbing rainwater and decreasing the strain on urban drainage systems. Real-time applications of green roofs extend to a variety of structures, including residential, commercial, and industrial buildings. Their insulating properties enhance energy efficiency, reducing heating and cooling needs. Additionally, green roofs offer aesthetic and recreational value, providing urban spaces with greenery and creating communal areas for occupants [36]. By integrating green roofs into construction projects, builders contribute to enhanced environmental sustainability, improved energy performance, and the creation of resilient, eco-conscious urban landscapes.

Polyurethane Foam Roofing (energy-efficient insulation)

Polyurethane foam roofing, renowned for its energy-efficient insulation properties, serves as an eco-friendly construction material with diverse applications. This material is created by spraying liquid polyurethane foam onto roof surfaces, where it expands and solidifies into a seamless, lightweight, and highly insulating layer. The construction properties of polyurethane foam include exceptional thermal resistance, superior adhesion to various surfaces, and resistance to water infiltration. As an energy-efficient insulation solution, it minimizes heat transfer, reducing the need for extensive HVAC usage and subsequently decreasing energy consumption. Polyurethane foam roofing is suitable for both flat and sloped roofs, providing a continuous, airtight layer that seals and insulates structures effectively. This eco-friendly material contributes to sustainable building practices by improving energy efficiency, reducing GHG emissions, and enhancing the overall environmental performance of structures through its insulation capabilities [37].

FSC-Certified Wood

FSC-Certified Wood stands as a cornerstone of eco-friendly construction, embodying sustainable practices with distinct properties and versatile real-time applications. This wood is certified by the Forest Stewardship Council (FSC), ensuring it is sourced from responsibly managed forests that prioritize biodiversity, community engagement, and environmental conservation. FSC-certified wood possesses the same structural integrity and aesthetic appeal as conventional wood but distinguishes itself through its commitment to sustainable forestry. Its application spans a myriad of construction projects, including residential and commercial structures, as well as furniture and interior finishes. In real-time scenarios, FSC-certified wood is used for framing, flooring, decking, and various architectural elements. Beyond structural applications, it is employed in decorative finishes and furnishings, aligning with green building standards. By opting for FSC-certified wood, builders contribute to forest conservation, promote ethical forestry practices, and support a more sustainable timber industry, emphasizing the integration of eco-conscious materials into construction for a healthier planet [38].

Plant-Based Polyurethane

Plant-based polyurethane represents a sustainable and eco-friendly construction material derived from renewable resources. Unlike traditional polyurethane, which relies on petrochemicals, plant-based polyurethane incorporates bio-based ingredients, often sourced from plant oils like soy or castor beans. The construction properties of plant-based polyurethane include versatility, durability, and low environmental impact. It can be used in various applications such as insulation, adhesives, sealants, and coatings. As an insulation material, it exhibits excellent thermal performance, contributing to energy efficiency in buildings. Plant-based polyurethane is also valued for its lower carbon footprint, as it reduces reliance on fossil fuels and encourages the use of sustainable agricultural practices. By incorporating plant-derived components, this material aligns with the principles of renewable sourcing and environmental responsibility, making it a compelling choice for environmentally conscious construction projects seeking greener alternatives to traditional polyurethane products [39,40].

Geothermal Heating and Cooling Systems

Geothermal heating and cooling systems represent a groundbreaking eco-friendly construction solution, characterized by innovative properties and widespread real-time applications. These systems harness the Earth's stable underground temperatures to provide energy-efficient heating in the winter and cooling in the summer [41]. A network of pipes buried in the ground circulates a fluid that absorbs or releases heat, ensuring consistent indoor temperatures. In real-time applications, geothermal systems are integrated into residential, commercial, and institutional buildings, contributing to energy savings and environmental sustainability. Their installation involves minimal environmental impact, as they utilize the Earth's natural thermal energy. Geothermal systems significantly reduce dependence on traditional heating and cooling methods, reducing GHG emissions and enhancing energy efficiency. By incorporating geothermal heating and cooling into construction projects, builders contribute to a greener and more sustainable future, emphasizing the importance of harnessing renewable energy sources for a resilient and eco-conscious built environment [42].

Insulated Concrete Forms (ICFs)

Insulated Concrete Forms (ICFs) stand as a sustainable construction material, showcasing distinctive properties and versatile real-time applications. ICFs consist of interlocking, lightweight forms made of materials like Expanded Polystyrene (EPS) or other insulating materials. Builders use these forms as molds, filling the gap with concrete to create a durable and well-insulated structure. The resulting walls provide exceptional thermal performance, reducing energy consumption for heating and cooling. Real-time applications of ICFs span residential and commercial construction, offering a balance of structural strength, energy efficiency, and ease of installation [43]. ICF construction facilitates quicker build times, reduces waste, and contributes to a more sustainable built environment, emphasizing the significance of incorporating eco-friendly materials into contemporary construction practices.

Salvaged Bricks

Salvaged bricks, repurposed from previous constructions, represent a sustainable and eco-friendly choice in contemporary building practices. These bricks, often recovered from deconstructed buildings or construction sites, retain their structural integrity and aesthetic appeal, showcasing a weathered charm that adds character to new projects. Their reuse significantly reduces the demand for new clay extraction and the energy-intensive brick manufacturing process. Real-time applications of salvaged bricks range from residential renovations to commercial developments, offering a unique blend of historic authenticity and environmental responsibility. Salvaged bricks can be employed for exterior facades, pathways, accent walls, and landscaping projects, emphasizing their versatility in various construction contexts. By opting for salvaged bricks, builders contribute to waste reduction, conservation of resources, and the promotion of circular economy principles, highlighting the importance of integrating sustainable and reclaimed materials into the construction landscape for a more eco-conscious built environment [44].

Salvaged Metal

Salvaged metal, sourced from recycled materials or repurposed structures, stands as an environmentally conscious construction material with distinct properties and versatile applications. The reuse of salvaged metal reduces the need for new metal extraction and processing, thereby minimizing the environmental impact associated with traditional manufacturing methods. Real-time applications of salvaged metal encompass a wide range of construction projects, including residential, commercial, and industrial developments. Salvaged metal can be transformed into structural components, such as beams and columns, contributing to the creation of durable and robust buildings. Additionally, its malleability allows for versatile design options, making it suitable for decorative elements, fencing, roofing, and interior finishes. By choosing salvaged metal, builders not only embrace a sustainable and circular approach to construction but also benefit from the material's inherent durability and resilience, creating structures that are both environmentally responsible and structurally sound. This emphasis on eco-friendly construction practices aligns with the global shift towards sustainability in the built environment [45].

Rice Husk Particle Board

Rice husk particle board stands out as an eco-friendly construction material, offering a sustainable alternative to traditional wood-based boards. Comprising rice husk, a byproduct of rice milling, and a binder, this construction material is manufactured through a process of high-pressure and heat compression. The rice husk, which would otherwise be considered agricultural waste, lends the board excellent properties such as resistance to water, pests, and decay. Its construction properties include lightweight design, strength, and versatility. Rice husk particleboard finds applications in various construction elements, including furniture, cabinetry, and interior paneling. Not only does it reduce reliance on timber resources, promoting sustainable forestry practices, but it also mitigates the environmental impact of rice husk disposal. Embracing rice husk particle board supports circular economy principles, repurposing agricultural byproducts into a durable and functional construction material suitable for diverse building applications [46,47].

Rapidly Renewable Wood

Rapidly renewable wood, derived from fast-growing species with short harvest cycles, serves as a cornerstone of eco-friendly construction due to its unique properties and diverse real-time applications. Species like bamboo, cork, and certain types of softwoods fall into this category, offering an abundant and swiftly replenished resource. The fast growth of these trees allows for more frequent harvesting, making them an environmentally responsible alternative to traditional hardwoods. Real-time applications of rapidly renewable wood span various construction projects, including flooring, furniture, paneling, and decorative elements. Its favorable strength-to-weight ratio makes it suitable for structural components, while its aesthetic appeal contributes to interior finishes. Utilizing rapidly renewable wood supports sustainable forestry practices, reduces dependence on slower-growing species, and mitigates environmental impact. This material, celebrated for its renewability and versatility, aligns with the imperative for eco-conscious construction, providing builders with a viable and responsible option in creating aesthetically pleasing, durable structures with a reduced ecological footprint [48].

Alumasc Green Roofing System

The Alumasc Green Roofing System is a sustainable construction solution designed to enhance building performance and environmental responsibility. Comprising various layers such as waterproofing membranes, drainage systems, and vegetation, this system offers excellent construction properties for green roofs. The waterproofing membranes ensure protection against water infiltration, while the drainage layers manage excess water efficiently. The vegetation layer includes a diverse range of plants, contributing to insulation, stormwater management, and biodiversity. Alumasc's system provides insulation, reduces energy consumption, and mitigates the urban heat island effect. Applications of the Alumasc Green Roofing System span commercial, residential, and industrial buildings, offering an aesthetically pleasing and environmentally beneficial solution. Beyond energy efficiency, the green roof system promotes sustainable development, contributes to air quality improvement, and exemplifies a holistic construction approach that aligns with contemporary eco-conscious building practices [49].

Mycelium-Based Materials

Mycelium-based materials, derived from the fibrous root system of fungi, represent a cutting-edge and sustainable construction material with distinctive properties and diverse real-time applications. Mycelium possesses remarkable structural strength, providing a viable alternative to traditional construction materials. When combined with organic waste or agricultural byproducts in a controlled environment, mycelium forms a composite material that is lightweight, durable, and fire-resistant. Real-time applications of mycelium-based materials include insulation, packaging, and even structural components like bricks and panels. As it grows and binds together, mycelium creates a resilient and biodegradable matrix, showcasing its potential as an eco-friendly alternative. The cultivation of mycelium-based materials requires minimal energy and resources compared to conventional manufacturing processes, contributing to a reduced environmental impact. By harnessing mycelium's regenerative properties, builders can create structures that not only prioritize sustainability but also offer innovative solutions for a more environmentally conscious and resilient built environment, aligning with the growing emphasis on biomimicry and circular economy principles in contemporary construction practices [50].

Cast Earth Blocks

Cast Earth Blocks represent an eco-friendly construction material with sustainable properties that contribute to environmentally conscious building practices. Comprising a mixture of earth, stabilizers, and sometimes fibers, these blocks are cast and compressed to form durable, load-bearing units. The construction properties of cast earth blocks include natural thermal mass, which regulates indoor temperatures, and breathability, promoting healthy indoor air quality. These blocks are often produced on-site, minimizing transportation-related environmental impacts. Cast earth blocks find applications in both load-bearing and non-load-bearing walls, providing a sustainable alternative to traditional bricks or concrete blocks. The material's adaptability and ease of production make it suitable for various construction projects, particularly in regions where the raw materials are readily available [51]. Embracing cast earth blocks aligns with sustainable construction practices, utilizing local resources and reducing the ecological footprint associated with traditional building materials.

Earthbags

Earthbags, a sustainable and eco-friendly construction material, are gaining recognition for their unique properties and diverse real-time applications. Comprising polypropylene or burlap bags filled with locally sourced earth or other natural materials, earthbags serve as a versatile building component. Their composition contributes to thermal mass, providing energy-efficient temperature regulation within structures [52]. Real-time applications of earthbags include constructing homes, retaining walls, and even disaster-resistant shelters. The interlocking nature of the bags and their ability to conform to various shapes make them adaptable to different architectural designs and structural needs. Additionally, earthbags are earthquake-resistant, environmentally friendly, and cost-effective, making them particularly suitable for sustainable building initiatives in various regions. With the added benefit of utilizing on-site or locally available materials, earthbags exemplify a low-impact and community-oriented approach to construction, supporting eco-conscious builders in creating resilient and environmentally responsible structures that align with the principles of sustainability and affordability [53].

Recycled Rubber Roofing

Recycled rubber roofing stands as an eco-friendly construction material, repurposing discarded rubber tires into durable and sustainable roofing solutions. The construction properties of recycled rubber roofing include resilience, weather resistance, and excellent impact absorption. Typically manufactured in shingle or sheet form, this material is designed to withstand harsh environmental conditions, such as UV exposure and extreme temperatures. The rubber shingles are lightweight, easy to install, and offer effective insulation, contributing to energy efficiency. Applications for recycled rubber roofing extend to residential, commercial, and industrial buildings, providing an environmentally responsible alternative to traditional roofing materials. Beyond its durability and weatherproofing capabilities, recycled rubber roofing helps address the global issue of tire waste, offering a circular economy solution that repurposes discarded materials into a functional and sustainable building component [54,55].

Recycled Rubber Flooring

Recycled rubber flooring heralded as an eco-friendly construction material, is characterized by distinctive properties and diverse real-time applications. This flooring is typically crafted from recycled tires, diverting these rubber materials from landfills and contributing to waste reduction. The construction properties of recycled rubber flooring include outstanding durability, resilience, and shock absorption. These features make it an ideal choice for high-traffic areas, gyms, playrooms, and commercial spaces, providing a comfortable and safe surface. The material's insulating properties make it suitable for use over radiant heating systems, enhancing energy efficiency in buildings [56]. Real-time applications extend to various settings, such as residential homes, educational institutions, and healthcare facilities. Beyond its practical attributes, recycled rubber flooring is available in a wide array of colors and patterns, offering design flexibility. By choosing recycled rubber flooring, builders and homeowners not only contribute to environmental sustainability by repurposing discarded materials but also benefit from a versatile, durable, and aesthetically pleasing flooring solution that aligns with the principles of eco-conscious construction [55].

Silicate Paints

Silicate paints are renowned as eco-friendly construction materials, consisting of inorganic mineral silicates as binders. These paints bond chemically with mineral surfaces, forming a highly durable and breathable finish [57]. The construction properties of silicate paints include resistance to UV radiation, weathering, and fungal growth, making them suitable for exterior applications. They offer excellent vapor permeability, allowing moisture to escape while preventing water ingress. Silicate paints create a mineral matte finish that is fade-resistant and fire-resistant. With low VOC (volatile organic compound) content, these paints contribute to healthier indoor air quality. Silicate paints are versatile and applicable to various surfaces such as concrete, brick, and plaster. Embracing silicate paints in construction not only enhances building longevity but also aligns with sustainable practices by minimizing environmental impact and promoting a healthier living environment [33].

Recycled Aluminum

Recycled aluminum, a prominent eco-friendly construction material, boasts distinct properties that contribute to sustainability and various real-time applications. Derived from post-consumer and post-industrial sources, recycled aluminum reduces the demand for primary aluminum extraction, conserving energy and resources. Its inherent corrosion resistance, strength, and lightweight nature make it an ideal choice for construction applications. Real-time uses encompass roofing, façades, structural components, and window frames, showcasing its versatility in both residential and commercial projects. Beyond its structural benefits, recycled aluminum supports green building initiatives, aligning with environmental standards and certifications. By opting for recycled aluminum, builders actively participate in the circular economy, promoting resource conservation and minimizing the environmental impact associated with traditional aluminum production processes [58,59].

Recycled Carpet Tiles

Recycled carpet tiles, recognized as an eco-friendly construction material, exhibit unique properties and find diverse applications in contemporary building projects. Crafted from post-consumer or post-industrial recycled materials, these tiles contribute to waste reduction and resource conservation. Their construction properties include durability, resilience, and ease of installation. In real-time applications, recycled carpet tiles are employed as versatile flooring solutions in commercial spaces, offices, and residential interiors. The tiles often feature innovative designs, providing aesthetic appeal while maintaining sustainability. The use of recycled materials in their production minimizes the environmental footprint, aligning with green building principles [60]. By incorporating recycled carpet tiles, builders prioritize both functionality and environmental responsibility, fostering sustainable practices in the construction industry.

Energy-Efficient Windows

Energy-efficient windows stand as a key eco-friendly construction material, designed with properties that enhance energy conservation and real-time applications that contribute to sustainable building practices. Constructed with advanced glazing technologies, such as low-emissivity coatings and multiple panes filled with insulating gases, these windows minimize heat transfer, improving thermal insulation. In real-time applications, energy-efficient windows are integral to residential and commercial buildings, reducing heating and cooling demands, and thereby decreasing energy consumption. Their ability to enhance natural lighting further complements green building initiatives, promoting energy efficiency and occupant comfort while minimizing environmental impact in the realm of modern construction [61].

Bio-Based Polyurethane Foam

Bio-based Polyurethane Foam, an eco-friendly construction material, is derived from renewable plant-based oils, showcasing unique construction properties and diverse real-time applications. Recognized for its excellent insulation, lightweight composition, and closed-cell structure, it offers energy-efficient solutions in walls, roofs, and floors. Used in furniture and interior elements, it blends comfort with sustainability. This foam serves as an effective sealant, adhesive, and soundproofing material. Its renewable sourcing reduces reliance on finite fossil resources, aligning with green building principles, while its potential biodegradability supports a cradle-to-cradle approach, exemplifying a commitment to circular economy practices in modern construction [62].

Fly Ash Concrete

Fly ash concrete, regarded as an eco-friendly construction material, possesses distinctive properties and finds versatile real-time applications, significantly impacting sustainable construction practices. Derived from the byproducts of coal combustion, fly ash is a pozzolanic material that, when mixed with cement, enhances concrete properties. Its construction properties include improved workability, increased long-term strength, and reduced permeability. In real-time applications, fly ash concrete is extensively used in various construction projects. In structural elements like foundations, beams, and columns, it enhances durability and longevity. Its use in pavements and transportation infrastructure contributes to better performance under heavy loads and reduces cracking. Additionally, fly ash concrete is employed in the construction of environmentally sustainable buildings, where its thermal properties enhance energy efficiency. By utilizing industrial waste as a valuable resource, fly ash concrete minimizes environmental impact, mitigates the demand for traditional cement production, and exemplifies a circular economy approach in the construction industry [63].

Recycled Content Ceiling Tiles

Recycled content ceiling tiles stand as an eco-friendly construction material, incorporating post-consumer or post-industrial recycled materials [64]. These tiles are crafted from a variety of recycled materials, such as reclaimed metals, paper, or fiberglass, depending on the specific product. The construction properties of recycled content ceiling tiles encompass acoustic performance, fire resistance, and thermal insulation, meeting or exceeding the standards of conventional ceiling materials. Available in various designs and finishes, they offer aesthetic versatility for commercial, residential, and institutional spaces. Beyond their sustainable sourcing, recycled content ceiling tiles contribute to indoor air quality by typically having low VOC emissions. As a responsible choice in construction, these tiles exemplify the circular economy by diverting materials from landfills, reducing the demand for virgin resources, and promoting a more sustainable and environmentally conscious approach to building design and interior finishes [65].

Recycled Aggregates

Recycled aggregates, a cornerstone of eco-friendly construction, exhibit unique properties and diverse real-time applications, transforming traditional building practices into sustainable endeavors. Comprising crushed concrete, asphalt, and other reclaimed materials, recycled aggregates serve as an environmentally conscious alternative to conventional virgin aggregates. Their construction properties include excellent strength, durability, and versatility, making them suitable for a wide range of applications. Real-time uses encompass road construction, where recycled aggregates can be incorporated into base layers and asphalt mixes, reducing the need for virgin materials and lessening the overall environmental impact. In concrete production, recycled aggregates offer a sustainable substitute for natural aggregates, maintaining structural integrity while minimizing resource consumption. Landscaping projects benefit from the versatility of recycled aggregates, which can be utilized in pathways, driveways, and as backfill material. Beyond their construction attributes, recycled aggregates significantly contribute to waste reduction and support circular economy principles by repurposing materials that would otherwise end up in landfills [66]. By embracing recycled aggregates, builders actively engage in sustainable construction practices, promoting resource conservation and environmental responsibility in the quest for more eco-conscious built environments.

Electrically Conductive Concrete

Electrically conductive concrete, often incorporating conductive materials like carbon fibers or carbon nanotubes, represents an innovative and eco-friendly construction material. The construction properties of electrically conductive concrete include the ability to carry electrical current, allowing it to function as a heating element for de-icing applications in cold climates. By applying electrical voltage to the concrete, it generates heat, preventing the formation of ice and enhancing safety on roads and sidewalks. This sustainable solution reduces the need for traditional de-icing methods, which often involve the use of salts and chemicals harmful to the environment [67]. Additionally, electrically conductive concrete has potential applications in smart infrastructure, offering possibilities for sensors, data transmission, and even wireless charging for electric vehicles [68]. Embracing this material not only improves infrastructure resilience but also aligns with eco-conscious practices by minimizing environmental impact and energy consumption associated with conventional de-icing methods.

Water-Based Adhesives

Water-based adhesives, recognized as an eco-friendly construction material, showcase essential properties and diverse real-time applications, marking a shift towards sustainable building practices. Composed primarily of water as the solvent, these adhesives significantly reduce Volatile Organic Compound (VOC) emissions compared to their solvent-based counterparts, contributing to improved indoor air quality [69]. Their construction properties include excellent bonding strength, versatility in application, and a reduced environmental impact. In real-time applications, water-based adhesives find use in various construction elements such as flooring installations, woodwork, and panel bonding. Their effectiveness in bonding porous and non-porous materials alike makes them suitable for a range of substrates, promoting resource efficiency and waste reduction [70,71]. By embracing water-based adhesives, builders not only enhance the structural integrity of their projects but also prioritize environmental sustainability, aligning with the global push for eco-conscious construction practices and healthier living spaces.

Recycled Content Gypsum Board

Recycled content gypsum board stands as an eco-friendly construction material, incorporating post-consumer or post-industrial recycled gypsum content. The construction properties of this board include fire resistance, sound insulation, and ease of installation. Utilizing recycled gypsum reduces the demand for virgin gypsum mining, conserving natural resources and decreasing environmental impact. Recycled content gypsum board performs comparably to conventional gypsum board, meeting industry standards and certifications. Its applications range from interior wall and ceiling surfaces to partitions and enclosures. The material is versatile, accommodating various finishes and paints [72]. Choosing recycled content gypsum board supports sustainable construction practices by diverting waste from landfills, promoting resource efficiency, and contributing to a circular economy. As an environmentally responsible alternative, it aligns with the growing demand for eco-conscious building materials, offering both performance and a reduced environmental footprint in construction projects.

Ferrock

Ferrock, hailed as an eco-friendly alternative to concrete, possesses exceptional construction properties and finds diverse real-time applications, reshaping sustainable building practices. Comprising recycled steel dust and industrial byproducts, Ferrock showcases notable properties such as impressive compressive strength, enhanced durability, and a unique carbon capture ability during its formation. In real-time applications, Ferrock serves as a versatile construction material, demonstrating efficacy in structural components like beams and columns, as well as in architectural elements such as facades and decorative finishes. Its moldable nature allows for intricate designs, providing architects and builders with creative flexibility. Unlike traditional concrete, Ferrock's carbon capture attribute helps mitigate environmental impact by sequestering carbon dioxide during its curing process, making it a carbon-negative material. Additionally, its resistance to corrosion and improved tensile strength contribute to increased longevity and reduced maintenance needs. In coastal areas, where traditional concrete structures often face degradation from saltwater exposure, Ferrock presents itself as a more resilient and sustainable solution. By incorporating Ferrock into construction projects, builders not only enhance structural performance but also actively contribute to carbon sequestration efforts, aligning with the global movement towards eco-friendly, low-carbon construction materials and environmentally responsible urban development [73].

Reflective Cool Roof Coatings

Reflective cool roof coatings stand as an eco-friendly construction solution designed to enhance energy efficiency and reduce urban heat island effects. Comprising reflective materials, typically coatings with high solar reflectance and infrared emittance, these coatings are applied to roof surfaces. The construction properties of reflective cool roof coatings include their ability to reflect sunlight and emit absorbed heat, effectively lowering roof temperatures and minimizing heat transfer into the building. This results in reduced energy consumption for cooling, improved indoor comfort, and prolonged roof life. Reflective cool roof coatings find applications in both commercial and residential buildings, contributing to sustainable construction practices by decreasing energy demand, lowering GHG emissions, and mitigating the environmental impact associated with urban heat islands. Embracing these coatings supports energy efficiency initiatives, creating a more resilient and eco-friendlier built environment [74,75].

Conclusion

In conclusion, this comprehensive review study delves into the multifaceted landscape of 50 eco-friendly construction materials, shedding light on their diverse properties, applications, and the transformative potential they bring to sustainable building practices. The materials examined, ranging from recycled aggregates to advanced bio-based polymers, collectively represent a paradigm shift towards environmentally responsible construction. The synthesis of knowledge presented herein underscores the imperative of adopting eco-friendly materials in the construction industry, offering not only innovative solutions but also addressing pressing global challenges such as climate change, resource depletion, and waste generation. As we navigate the complexities of contemporary urbanization, the findings emphasize the pivotal role these materials play in mitigating environmental impact, reducing carbon footprints, and fostering a more circular economy.

Furthermore, the review elucidates the dynamic interplay between material science, design, and construction methodologies, highlighting the importance of interdisciplinary collaboration for holistic sustainability. The materials explored exhibit a spectrum of benefits, from enhanced energy efficiency and improved structural performance to reduced reliance on finite resources and minimized waste production. As we usher in an era of eco-conscious construction, the knowledge synthesized in this review serves as a valuable resource for researchers, architects, builders, and policymakers alike. By leveraging the insights gained from these eco-friendly materials, the construction industry can embark on a trajectory towards regenerative practices that harmonize with the natural environment and contribute to resilient, healthier, and more sustainable built environments for future generations. Ultimately, this review advocates for a transformative approach to construction, one that embraces the inherent potential of eco-friendly materials as catalysts for positive change in the trajectory of global urban development.

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