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Review

A Short Review of Recent Innovations in Acoustic Materials and Panel Design: Emphasizing Wood Composites for Enhanced Performance and Sustainability

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Abstract: The aim of this study is to investigate the potential of wood composites as sustainable acoustic materials and to explore their integration with advanced manufacturing techniques for improved performance. Using a comprehensive review methodology, the paper analyzes recent innovations in wood composites, focusing on the combination with other sustainable materials such as expanded polystyrene (EPS) and natural fibers. The results show that wood composites can achieve sound absorption coefficients (α) of up to 0.9, with oak panels showing transmission losses of up to 11 dB. In addition, advanced designs, including biodegradable panels and lightweight honeycomb structures, significantly improve sound transmission loss, with an average sound transmission loss (TLeq) of up to 28.3 dB reported for composite panels made from waste tire rubber. In addition, the study highlights the environmental benefits achieved through the use of agricultural byproducts and industrial waste in the development of these materials, confirming the role of wood composites as a carbon-neutral alternative in the quest for green building solutions. This study provides valuable insights into the transformative potential of wood composites for sustainable acoustic applications.

Keywords: wood composites; sustainable acoustic materials; sound absorption; eco-friendly building solutions; acoustic panel design; natural fiber composites; noise reduction; bio-based materials

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1. Introduction

The materials used in civil structures play a key role in shaping the physical integrity of buildings and their acoustic performance. This review focuses on sustainable materials such as wood composites, natural fibers, and recycled agricultural byproducts due to their dual functionality of providing the necessary structural support and enhancing the sound absorption and insulation properties. Using these materials helps meet the growing demand for sustainable construction methods. In particular, wood composites have exceptional acoustic properties, making them suitable for reducing noise pollution in urban environments and improving acoustic comfort in classrooms and offices.

One of the main problems with traditional materials used for structural purposes, such as concrete and steel, is their significant environmental impact, including high carbon emissions associated with production and a reliance on non-renewable resources. Additionally, these materials often exhibit acoustic performance limitations, leading to noise control challenges within built environments. In contrast, this review paper highlights how innovative wood composites and bio-based materials offer enhanced sustainability through renewable resources and improved acoustic properties, addressing the dual challenges of environmental responsibility and noise reduction in structural applications.

The research methodology for this review paper comprises a structured approach to assess the advancements in wood composites and their acoustic performance. A comprehensive literature review is conducted to gather existing studies on integrating wood composites with advanced manufacturing techniques, focusing on their acoustic properties and the identification of parameters influencing sound absorption and insulation. The bibliography findings are synthesized into thematic categories, such as using different sustainable materials and manufacturing approaches. The review also includes a comparative analysis of experimental results from various studies, highlighting the performance of wood composites in acoustic applications. In addition to the review, gaps in the current literature are identified, suggesting areas for future research. This dual approach will aim to bridge theoretical insights with practical implications, providing a holistic view of the potential for wood composites in sustainable acoustic material applications.

The development of sustainable and high-performance acoustic materials is a key focus in contemporary research. Wood composites, such as those incorporating wood particles, fibers, or chips, have demonstrated significant promise in enhancing acoustic performance in green dividing panels [1]. Additive manufacturing, particularly 3D printing, has revolutionized the design of complex acoustic structures, including those based on wood composites. For instance, biodegradable panels made from polylactic acid (PLA) and wood particles have achieved high sound absorption coefficients, showcasing the potential of wood-based composites in sustainable acoustic applications [2]. Additionally, 3D-printed honeycomb structures filled with wood-derived nanofillers have shown potential for lightweight applications in industries such as defense and aviation [3]. Studies have also highlighted the influence of manufacturing parameters, such as the nozzle diameter and internal configurations, on the acoustic performance of 3D-printed wood composite panels [4].

The integration of wood composites with other sustainable materials, such as expanded polystyrene (EPS) or natural fibers like kenaf and jute, has further expanded their acoustic potential [5,6]. Research into lightweight concrete panels incorporating wood-based recycled aggregates has addressed the long-term sustainability of noise barriers, while structural pervious concrete with wood composites has been developed to balance acoustic absorption, structural strength, and porosity [7,8].

Advancements in acoustic panel design have been achieved through both experimental and numerical approaches, with wood composites playing a central role. Corrugated-core sandwich panels, optimized using numerical modeling and genetic algorithms, have demonstrated significant improvements in sound transmission loss when incorporating wood-based materials [9]. Lightweight wood composite sandwich panels offer structural and acoustic benefits, though they may require additional insulation to meet stringent performance standards [10].

Tunable acoustic materials with inline cavity structures, often utilizing wood composites, provide customizable solutions for sound absorption and transmission properties [11]. Parallel-arranged perforated wood composite panels have proven effective in enhancing low-frequency sound absorption, achieving high performance within reduced thicknesses [12,13]. Lightweight membrane-type acoustic metamaterials incorporating wood composites have also shown promise for broadband sound insulation, offering high transmission loss with minimal weight compared to traditional materials [14].

The strategic placement of wood composite-based sound-absorbing materials within a room is critical for maximizing acoustic performance [5]. Passive constrained layer damping (PCLD) applied to grid-stiffened wood composite panels has been effective in reducing sound radiation [15]. Preconstructed wall modules utilizing wood composites show promise for indoor acoustic comfort, though careful consideration is required for low-frequency performance [16].

The demand for eco-friendly alternatives to conventional acoustic materials has driven research into wood composites and other bio-based solutions. Agricultural byproducts, such as hemp, wheat straw, and rice husk, have been combined with wood composites to create sustainable building materials, including insulation and bio-bricks [17]. Wood composites derived from industrial waste streams have also been explored as carbon-neutral and cost-effective options for noise reduction, with software simulations comparing their performance to synthetic alternatives [18].

Natural fibers, such as kenaf, coconut fiber, and jute, have been extensively studied for their sound absorption capabilities when integrated into wood composites, with performance optimized through adjustments in density and thickness [19]. These renewable and biodegradable materials offer a sustainable alternative to synthetic options, further enhancing the appeal of wood composites in acoustic applications [20].

Advancements in material science have led to the development of fibrous and porous wood composite materials, with their sound absorption properties influenced by material structure and arrangement [21]. Acoustic metamaterials, particularly plate-type designs incorporating wood composites, have demonstrated high sound transmission loss with minimal thickness, highlighting the importance of understanding their underlying physical mechanisms [22]. The integration of metamaterials with wood composite structures has further enhanced sound insulation in thin-walled applications [23].

Foamed concrete with wood composites has been recognized for its lightweight nature, strength, and thermal insulation properties, making it suitable for structural applications [24]. Mycelium-based bio-composites, derived from waste paper substrates and combined with wood fibers, represent an innovative approach to sustainable sound absorption, though data limitations due to industrial secrecy remain a challenge [25]. Wood composite panels in flooring systems have been optimized for airborne and impact sound insulation, showcasing their versatility [26].

Micro-perforated wood composite panels (MPPs) and advanced foams have been widely studied for their acoustic applications, with modifications integrating artistic design elements to enhance performance [27,28].

Acoustic comfort is critical in specific environments, such as classrooms, where wood composite panels have been utilized to improve learning environments through professional and student-led interventions [29]. Modeling techniques for simulating sound wave propagation through porous wood composite media have also facilitated material design and selection [30].

2. Advances in Composite Materials for Sustainable Soundproofing Applications

2.1. Sound-Absorbing Composites Based on Natural Materials

The increasing environmental concerns and stringent regulations on synthetic materials have spurred significant interest in developing sustainable alternatives for sound insulation and absorption. In this context, the use of natural materials and residues of natural materials is of significant interest both for environmental protection and for the creation of environmentally friendly new composite materials.

Wood composites incorporating sustainable and recycled components from agricultural and industrial waste streams offer a viable alternative to traditional soundproofing materials. Hybridized natural fibers, such as pineapple, areca, and ramie, reinforced with wood-based industrial tea waste and epoxy matrices, have demonstrated effective sound absorption [31].

One study [32] created panels from various wood waste species (pine, oak, mahogany, and olive tree pruning) using different assembly techniques and adhesives. These panels demonstrated thermal and acoustic performance comparable to commercial products, with oak panels exhibiting particularly good sound absorption (α peak of 0.9) and insulation properties (transmission loss up to 11 dB).

The incorporation of wood plastic composite (WPC) into structural wood walls has been shown to affect sound insulation performance [33]. This study found that WPC can be a viable substitute for traditional wood studs and that the type of external panel material significantly influences the overall sound insulation of the wall. Further improvements were achieved by using sound-absorbing materials as elastic strips.

The utilization of stranded driftwood residues as a building material with thermo-acoustic properties is explored in another study [34]. The researchers investigate the thermal and acoustic characteristics of both unbound and mineralized (cement-based additive) samples. The results demonstrate that stranded driftwood residues, especially in their mineralized form, possess competitive thermo-acoustic properties, showing promise as a sustainable building material.

Many recent studies explore the potential of natural fibers in acoustic applications. One study evaluated the acoustic and mechanical properties of coir (Cocos nucifera) and fique (Furcraea Agavaceae) fibers and panels, finding that fique generally exhibited superior performance in most tests, particularly in high-frequency sound absorption due to its fiber diameter [35]. Another study utilized water hyacinth and pineapple leaf fibers, combined with polylactic acid (PLA), in 3D-printed acoustic panels [36]. This research demonstrated high sound absorption coefficients (α-max > 0.5 at high frequencies) at low fiber loadings, showcasing the potential for waste mitigation and sustainable material usage. The successful 3D printing of these biopolymer composites highlights the potential of additive manufacturing in creating lightweight, customizable acoustic panels.

The study of [37] explored the use of waste flax fibers as the core material in multi-layered panels, sandwiched between perlite layers of varying grain sizes. This approach resulted in panels with varying mechanical, thermal, and acoustic properties. The study found that perforation of the panels' surface further enhanced the sound absorption coefficients, achieving values up to 0.95 at specific frequencies. This highlights the potential for optimizing acoustic performance through material selection and panel design.

Three-dimensional materials are of particular interest for light and effective soundproofing. A study [38] investigated the sound insulation performance of 3D woven hybrid fabric-reinforced composites incorporating jute, E-glass, and biomass fillers such as coffee husk and waste palm fiber. These composites showed significantly enhanced sound insulation, with jute-based composites achieving noise reduction levels as high as 44.9 dB at 10,000 Hz. The study concluded that both coffee husk and palm fiber are effective and eco-friendly fillers.

Another study [39] investigated the acoustic absorption of date palm midribs-based fabric acoustic panels. This research found that the panel thickness and density significantly influenced absorption, with optimal performance observed in certain configurations. These panels offer a sustainable and aesthetically pleasing alternative for interior design applications. Similarly, the potential of sunflower straw as a bio-based sound absorber was explored [40].

The study of [41] investigated the acoustic, mechanical, and thermal properties of epoxy composites reinforced with cotton, coconut, and sugarcane fibers. The results indicated that increasing the fiber content enhanced sound absorption, with coconut fiber composites exhibiting the highest sound absorption coefficient. Another study utilized pineapple leaf fiber and silica aerogel in mortars, demonstrating that the addition of pineapple leaf fiber offset the compressive strength reduction caused by silica aerogel [42]. Table 1 summarizes the acoustic properties of certain mineral, bio-based, and fiber composites.

Table 1. Acoustic properties of selected mineral, bio-based, and fiber composites.

No.	Material	Referenced to Frequency Range, Hz	Reference
1	Paper sludge and clay composites	250–1600	[43]
2	Sheep wool	524	[44]
3	Mycelium-based composites	125–1000	[45]
4	Epoxy-based composites filled with pineapple/areca/ramie hybridized with industrial tea leaf wastes/GFRP	600–6300	[31]
5	Sugarcane fiber-reinforced composites	1600	[41]
6	Coconut fiber-reinforced composites	1600	[41]
7	Cotton fiber-reinforced composites	1600	[41]
8	Larch bark panels	>750	[46]

The reported sound absorption coefficients (α) of various natural fiber composites reveal significant variations in performance, influenced by the material composition, structural design, and tested frequency ranges (Figure 1).

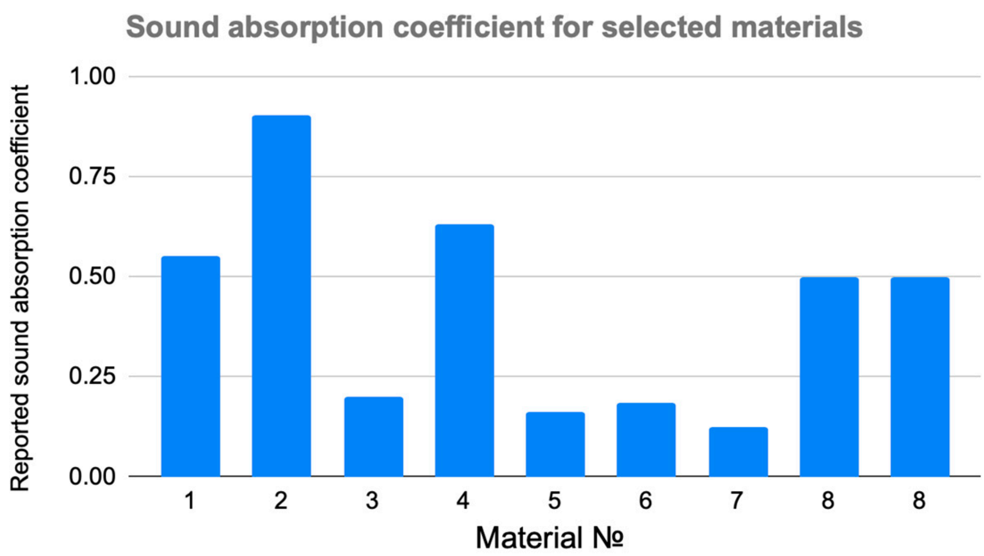

Figure 1. Sound absorption for selected materials listed in Table 1.

Sheep wool demonstrates exceptional acoustic efficiency, achieving a peak α of 0.903 at 524 Hz, likely due to its porous, fibrous structure that effectively dissipates sound energy. Similarly, epoxy-based composites hybridized with pineapple/areca/ramie fibers and tea waste exhibit strong broadband absorption ($\alpha = 0.63$ across 600–6300 Hz), attributed to their multi-scale porosity and reinforced polymer matrix. Paper sludge–clay composites and larch bark panels also perform well ($\alpha = 0.55$ and 0.5, respectively), with their moderate absorption linked to the particle density and air gap integration. In contrast, mycelium-based composites show limited low-frequency absorption ($\alpha = 0.2$ at 125–1000 Hz), suggesting a need for structural modifications (e.g., increased pore size or layered designs) to enhance performance. Notably, sugarcane, coconut, and cotton fiber composites exhibit lower absorption ($\alpha < 0.2$ at 1600 Hz), likely due to insufficient fiber density or untreated surface morphology, highlighting opportunities for chemical or mechanical fiber treatments to improve energy dissipation.

Mycelium-based composites, produced through bio-based manufacturing processes and combined with wood fibers, represent a novel approach to creating sound-absorbing structures from waste paper substrates [45]. The acoustic performance of these composites is influenced by material properties, such as the particle size, orientation, and density, as demonstrated in studies on larch bark panels [46]. The inclusion of air gaps in paper sludge and clay composites with wood fibers has been shown to significantly enhance sound absorption [43]. Their applications span building insulation, automotive components, and noise barriers, highlighting their potential for widespread adoption [47].

Sheep wool and orange tree pruning fibers have also been utilized in wood composite sandwich panel structures, showcasing the versatility of waste materials [44,48].

Table 2 outlines a SWOT analysis based on the reviewed information about natural fiber-reinforced composites for acoustic applications.

Table 2. SWOT analysis of natural fiber-reinforced composites for acoustic applications.

STRENGTHS	WEAKNESSES
1. **Sustainability:** Utilizes agricultural and industrial waste (e.g., coconut fiber, rice husk), reducing CO_2 emissions by up to 30% compared to traditional materials. Promotes a circular economy by repurposing waste streams. 2. **Acoustic Performance:** High sound absorption coefficients (e.g., 0.95 for flax–perlite panels, 0.7 NRC for foxtail millet husk composites). Enhanced sound insulation (e.g., 44.9 dB noise reduction at 10,000 Hz for jute-based composites). 3. **Versatility:** Applicable in building insulation, automotive components, and noise barriers. Compatible with 3D printing, producing lightweight panels with densities of 200–600 kg/m^3. 4. **Thermal and Mechanical Properties:** Low thermal conductivity (e.g., 0.15 W/m·K for arbolite). Compressive strengths of 1–10 MPa in materials like sawdust concrete. 5. **Innovative Design:** Air gaps and resonators improve low-frequency absorption (e.g., 0.5–0.9 absorption coefficients in the 100–500 Hz range). Hybrid designs (e.g., jute–E-glass composites) reduce noise by up to 44.9 dB.	1. **Material Variability:** Inconsistent quality due to heterogeneous fibers (e.g., hemp shive density ranges from 200–600 kg/m^3). Performance depends on fiber type, density, and processing. 2. **Durability Concerns:** Natural fibers degrade under moisture and UV exposure (e.g., hemp–lime compressive strength < 1 MPa). Additional treatments (e.g., mineralization) may reduce sustainability. 3. **Limited Standardization:** lack of standardized processes hinders scalability (e.g., wood–cement compressive strength varies from 1.07–1.59 MPa). 4. **Cost and Processing:** High initial costs (e.g., 3D-printed panels cost 20–30% more than traditional ones). Synthetic binders (e.g., epoxy) increase environmental impact (up to 5 kg CO_2 per kg).
OPPORTUNITIES	**THREATS**
1. **Growing Demand:** global market for sustainable acoustic materials projected to grow at 6.5% CAGR (2023–2030). 2. **Technological Advancements:** machine learning and 3D printing reduce development time by up to 50% and achieve material efficiencies of over 90%. 3. **New Markets:** Applications in automotive and aerospace (e.g., lightweight composites with densities of 300–550 kg/m^3). Utilization in developing countries, where agricultural residues account for over 30% of waste.	1. **Competition from Conventional Materials:** traditional materials hold over 70% of the global market and cost 20–40% less than bio-composites. 2. **Technological Limitations:** Slow hardening rates (e.g., hemp–lime takes up to 28 days to reach full strength). Production yields vary by ±15%, affecting scalability. 3. **Consumer Perception:** Over 60% of consumers prefer conventional materials due to perceived reliability. Aesthetic concerns limit adoption in high-end markets, where traditional materials dominate over 80%.

The study utilizing *Arundo donax* L. [49] demonstrates a viable pathway for converting agricultural waste into functional building materials. The significant finding regarding the impact of the particle size on both the sound absorption and mechanical properties emphasizes the need for precise control over the processing parameters to optimize the final product. Larger particle sizes (2–4 mm) yielded better sound absorption in the Class D range, while smaller particles (0.25–1 mm) resulted in superior sound transmission loss, indicating potential applications in different acoustic scenarios.

The research employing cork granulates and egg white proteins [50] highlights the potential of bio-based composites. The use of microwave foaming provides an energy-efficient method for creating lightweight, open-cell structures, improving thermal and acoustic insulation. The investigation into varying compositions and additives (eggshells and intumescent fillers) shows a path toward optimizing both acoustic performance and fire resistance. Future work should explore the scalability and cost-effectiveness of this approach for broader application in the construction sector.

The study utilizing coffee waste [51] showcases a compelling example of a circular economy strategy. By combining coffee waste with a resin binder, sound-absorbing panels were created and tested in a real-world café setting. The observed reduction in reverberation time (RT) and improvement in acoustic definition (D50), quantified through ODEON simulations, confirm the effectiveness of this material.

An interesting approach in the use of foxtail millet husk powder in polypropylene composites demonstrates the potential of agricultural waste [52]. The study showed that varying the fiber mass content and density affected sound absorption, with optimal combinations achieving a noise reduction coefficient (NRC) of 0.7 and an average sound absorption coefficient (SAC) of 0.63, comparable to commercial panels. The incorporation of air gaps and rigid backing materials further improved low-frequency sound absorption.

A research work [53] investigated the use of almond skin residues, a readily available agricultural byproduct, to produce building panels with enhanced acoustic and thermal properties. By incorporating different binder solutions (polyvinyl acetate glue and gum Arabic), researchers explored the correlation between material composition and acoustic (air-flow resistivity and sound absorption coefficient), thermal (conductivity, diffusivity, and volumetric heat capacity), and hygrothermal (water vapor permeability) performance.

A study [54] that analyzed a bamboo particleboard coated with polyurethane varnish revealed that the coating significantly impacts the surface characteristics and acoustic properties. While the coating improves low-frequency sound absorption, it reduces high-frequency performance. The study highlights the importance of optimizing the coating thickness to achieve the desired acoustic outcomes. The effect of the board density on the noise reduction coefficient is also investigated, demonstrating the significance of the material density in the overall acoustic performance.

Bio-based polyurethane foam (PUF) composites offer another avenue for sustainable acoustic panel development [55]. This study integrates nanofillers like carboxy-methyl cellulose (CMC), magnesium oxide (MgO), and bamboo charcoal (BC) into PUF using a PVA and borax slime matrix. Response surface methodology (RSM) is used to optimize the nanofiller weight percentages to maximize the noise reduction coefficient (NRC). The results showcase the potential of bio-based PUF composites for effective sound absorption, offering a sustainable solution for building interiors.

The study of [56] explored the use of biomass fiber-reinforced polyester resins combined with tailed cavity resonators to improve sound absorption. The researchers employed an impedance tube technique to test various configurations, including single and multiple tailed cavities with added fibrous layers. The results demonstrated that tailored cavity inclusions can enhance sound absorption performance across a range of frequencies, particularly with hemp and kenaf fibers. The findings suggest that this method can create effective sound absorbers for interior applications.

The study of [57] explored the acoustic performance of rice husk–PU-reinforced composite sound barriers, utilizing finite element analysis (ANSYS) to determine the sound absorption coefficients and transmission loss across a 0–4000 Hz frequency range. The results showed superior sound absorption at lower frequencies compared to existing data, and higher transmission loss at higher frequencies.

2.2. Sound-Absorbing Composites Based on Synthetic and Secondary Raw Materials

In contrast to bio-based approaches, research also investigates the optimization of synthetic materials for acoustic performance. One study examined the soundproofing properties of poly (vinyl chloride) (PVC) multilayered composites with alternating foam and film layers [58]. The findings emphasized the importance of acoustic impedance mismatch and layer number in achieving high sound transmission loss (STL), suggesting avenues for optimizing existing materials. Another study focusing on a modular sandwich panel system for non-load-bearing walls tested various face sheet materials (gypsum plasterboard, fire-resistant gypsum plasterboard, and magnesium oxide board) with an extruded polystyrene (XPS) core [59]. This research demonstrates the potential for improving the acoustic performance of modular wall systems through material selection and design optimization.

The utilization of industrial waste offered environmental benefits by reducing waste volume and mitigating noise pollution. The paper of [60] focused on incorporating waste materials into composite panels. The use of waste tire rubber (WTR) in plywood composites showed a significant improvement in sound insulation properties with increasing WTR and adhesive content. The study also demonstrated the influence of pressing methods and veneer arrangement on the acoustic performance. Similarly, a study employed fly ash (FA) and WTR granules with cement to create sound-absorbing panels [61]. This research demonstrated significant improvements in the average sound absorption coefficient (ASAC) and noise reduction coefficient (NRC) with varying proportions of the waste materials.

Several studies focus on the use of agricultural and industrial waste streams for acoustic panel production. One paper investigates the creation of composite acoustic panels using waste tire textile fibers (WTTFs) and paper sludge (PS) bound with polyvinyl acetate (PVA) [62]. The researchers found that varying the proportions of these waste materials significantly impacted the panels' sound absorption and transmission loss. Optimal combinations yielded average sound absorption coefficients (αavg) as high as 0.50 and a sound transmission loss (TLeq) up to 28.3 dB, demonstrating the viability of these waste materials in acoustic applications.

The use of recycled plastics also shows promise. A study investigated the creation of acoustic panels from recycled plastic bottles and PET felt [63]. Beyond demonstrating promising acoustic properties, this research prioritized biocompatibility, performing antifungal resistance tests, VOC emission assessments, and cell viability experiments to ensure the safety of the material for use in healthcare environments, where noise reduction is crucial.

The utilization of recycled materials is also a significant theme. A study explored the potential of fly ash, a waste product from thermal power plants, and recycled polyethylene terephthalate (PET) fibers in the creation of lightweight composite aerogels [64]. These aerogels exhibited low density, high porosity, and good thermal and acoustic insulation properties, demonstrating a promising approach to waste reduction and resource recovery in the construction sector.

The potential of incorporating waste rubber particles into concrete has also been explored [65]. This research analyzed the use of rubber buffing dust (RBD) and recovered crumb rubber (RCR) as partial replacements for natural fine aggregate. While the incorporation of RBD negatively impacted certain mechanical properties, RCR-modified concrete maintained sufficient compressive strength and exhibited improved sound absorption, particularly at thicknesses of 15 and 25 mm. This study demonstrates the possibility of diverting significant waste streams while potentially improving a material's acoustic performance.

The sound insulation properties of wood waste tire rubber composite (WRCP) panels were assessed [66]. This research highlighted the influence of the rubber content and adhesive type on the sound insulation performance, demonstrating that increased rubber and PMDI adhesive content led to improved soundproofing properties.

The paper of [67] investigates the soundproofing performance of panels made from acrylonitrile butadiene styrene (ABS) chips, a waste product from the milling process. The research analyzes factors influencing sound insulation, including panel thickness, distance from the sound source, and receptor position. The results indicate that the ABS panels exhibit promising acoustic properties, offering a viable and eco-friendly alternative for sound barrier construction.

Another study [68] focuses on repurposing plastic caps, another common waste product. The researchers create prototypes using various combinations of plastic caps and sustainable materials like jute, textile waste, hemp felt, and cork board. Their findings show that these panels can achieve sound reduction indices up to 30 dB at certain frequencies and near-unity sound absorption coefficients in tailored configurations, indicating their potential application as lightweight sound insulation elements or for room acoustic conditioning.

The study of [69] compares the thermal and environmental performance of panels made from various industrial and agricultural waste materials, including cork scraps, rice husk, coffee chaff, and end-of-life granulated tires. The results based on LCA methodology indicate that combinations of cork, rice husk, and coffee chaff offer a good balance between thermal performance and minimal environmental impact.

The use of recycled materials is another significant area of research. A study examined the thermal and acoustic properties of panels made from cardboard packaging, egg boxes, polyester, and felt [70]. These panels demonstrated acceptable thermal and acoustic performance (R_w = 19 dB, α_w = 0.30, NRC = 0.64), showcasing the potential for reusing waste materials in construction. Another study focused on the reuse of waste textile face masks made of polyamide fabric [71], evaluating their thermal, acoustic, and fire performance. The results indicated that the recycled polyamide fiber offers comparable thermal insulation to glass or mineral wool, and good sound absorption at medium and high frequencies. The research also investigated recycled bovine leather cutting waste for panel production [72], evaluating the panels' thermal, acoustic, and hygrothermal properties. The results indicated good sound absorption and transmission loss properties, demonstrating the feasibility of using leather waste in acoustic applications. Finally, the acoustic properties of virgin cork were investigated [73], revealing its potential as a sustainable acoustic absorber, particularly with the outer bark facing upwards, exhibiting high sound absorption coefficients in the 1–5 kHz range.

A different approach utilized post-industrial textile waste (cotton/polyester) and natural rubber to create sound insulation materials [74]. The study optimized the molding parameters to achieve sound absorption and noise reduction coefficients comparable to commercially available panels. Increased panel thickness further enhanced the sound insulation properties. Finally, a study assessed the acoustic properties of sawdust and fine sharp sand for soundproof security doors [75]. The results indicated that this locally sourced and readily available material provided comparable acoustic performance to imported products.

The study using wool waste [76] showed high sound absorption coefficients, particularly above 500 Hz, with the thermal conductivity comparable to conventional materials. The use of chitosan and gum Arabic as binders adds another dimension to the sustainability of the approach. The study on recycled denim [77] shows impressive results, achieving high sound absorption coefficients and demonstrating the potential for optimizing properties through a varying thickness, density, and resin content. The use of response surface methodology (RSM) is noteworthy, demonstrating a systematic approach to material optimization.

Waste cotton fabric (WCF), a significant textile waste stream, has shown promise as a reinforcing agent in polylactic acid (PLA) composites for construction applications [78]. The researchers investigated the effects of the processing parameters on the composite's mechanical and thermal properties and demonstrated that combining the WCF/PLA composite with porous sound-absorbing materials resulted in enhanced sound absorption capabilities. This approach offers a viable route for textile waste recycling while contributing to improved building acoustics.

2.3. Bio-Fiber and Wood Composites Based on Mineral Binder

The main aim of this chapter is to provide a systematic and thorough assessment of bio-fiber and wood-based composites that employ mineral binders. This research aims to clarify the fundamental mechanisms that dictate the physical and mechanical properties of these composites through the analysis of the current literature and experimental data. The primary objective is to find and assess effective solutions for boosting the performance attributes of wood–wool composites, concentrating on improving their structural integrity, durability, and functional efficiency.

The idea of combining vegetable fibrous filler and mineral binder has such positive properties as environmental friendliness, mechanical stability, fire resistance, and good acoustic characteristics. Based on modern requirements, the advantage of this composition is its low impact on the environment during production and operation, reducing energy consumption and carbon dioxide emissions throughout the entire life cycle of the material [79,80] (Table 3).

Table 3. Promising raw materials for bio-fiber and wood composites.

Binder	Portland cement, lime, clay, MOC (magnesium oxychloride cement), MPC (magnesium phosphate cement), gypsum
Fiber/filler	Hemp shive, flax wool, saw dust, wood chips, wood wool, rockwool
Admixtures	Calcium chloride, sodium silicate, accelerators
Filler	Sand, cenospheres

Building materials derived from plant-based resources, including various bio-fiber components and wood particles, have been utilized by humans since ancient times. Among the earliest examples are wall materials created by combining natural clay with straw. Clay, representing the most basic form of mineral binder [81], exhibits certain limitations, such as low water resistance and a tendency to soften under humid conditions. However, upon drying, clay forms a relatively strong monolith, wherein straw acts as both a filling and reinforcing agent. This combination also imparts favorable thermal and acoustic insulation properties to the material. A notable advantage of mineral–organic composites is their enhanced fire resistance compared to materials composed solely of organic raw materials, such as wood.

When examining wood–cement and analogous materials, it is essential to consider historical context, particularly the production and use of such materials in earlier periods. Historically, these materials were often employed due to the limited availability of alternative options and the absence of advanced technologies for producing polymers and composites. In contrast, contemporary interest in developing and utilizing materials with natural fillers is primarily motivated by the growing emphasis on environmental sustainability. Modern efforts are driven by the aspiration to reduce the ecological impact, promote a cleaner environment, and minimize the carbon footprint of construction materials. This shift reflects a broader commitment to sustainable practices and the development of eco-friendly solutions in material science.

The most recent publications cover a wide range of cement-bonded materials. The table below shows the trends in the materials under study and the main directions of research into their properties (Table 4).

Table 4. Trends in the materials and the main research directions.

Type of Structure Under Investigation	Details on Research Trends	Reference
Bioblocks (MDF resin-based)	Sustainable wood-based composite utilizing MDF resin.	[82]
Lignocellulosic composites	Review covering different types of lignocellulosic materials.	[83]
Cementitious composites with treated wood fiber	Explores chemically treated waste wood fiber.	[84]
Composite materials with clay and waste inserts	Focused on the combination of plant waste with clay matrices.	[85]
Lightweight cement composites	Composites containing end-of-life treated wood.	[86]
Cement-bonded composites	Explores the compatibility of tropical woods with cement.	[87]
Concrete with organic waste aggregates	Replacement aggregates derived from organic waste.	[88]
Extruded wood fiber cement products	Composite structures created through extrusion.	[89]
Modified wood–cement composites	Examines durability with modified compositions.	[90]
Lightweight building materials based on wood ash	Focus on binders that utilize wood ash.	[91]
Cement mortars with hydrothermally treated fibers	Studies performance in cement mortars.	[92]
Wood–concrete composites	Focus on compressive strength behavior in composites.	[93]
Composite boards (rockwool–cement)	Eco-friendly composite boards for acoustic performance.	[94]
Wood–cement composites	Studies on wood chips modification for composites.	[95]
Cementitious composites	Assessment of factors affecting thermal conductivity.	[96]

Table 4. *Cont.*

Type of Structure Under Investigation	Details on Research Trends	Reference
Light cementitious composite materials	Created with waste wood chips for insulation properties.	[97]
Wood bio-concretes	A focus on designing sustainable low-carbon structures.	[98]
Wood–cement composites	Discusses structural aspects and environmental impact mitigation.	[99]

A summary of the properties of the submitted materials based on published data is shown in Table 5.

Table 5. Mechanical and physical properties of reviewed composites.

Composite Material	Compressive Strength, MPa	Flexural Strength, MPa	Density, kg/m^3	Thermal Conductivity, W/m·K	Water Absorption, %	Durability Characteristics
Wood–Cement Composite	30–50	10–25	600–1200	0.10–0.30	5–15	Good moisture resistance, subject to biodegradation if untreated.
Bioblocks	25–35	12–20	700–1300	0.15–0.35	6–12	Moderate durability, performs well in freeze–thaw cycles.
Lignocellulosic Composite	20–30	8–15	500–900	0.05–0.20	10–20	Vulnerable to environmental aging, better with protective coatings.
Lightweight Cement Composite	30–40	10–18	300–800	0.08–0.25	4–10	High durability, low erosion risk.
Plant Waste Composite	15–25	5–12	400–850	0.06–0.20	15–25	Moderate to low durability; suitable for non-structural applications.
Modified Wood–Cement Composite	35–55	15–28	750–1400	0.10–0.30	8–18	Enhanced durability through chemical treatments.
Extruded Wood Fiber Composite	25–30	10–18	400–1000	0.12–0.30	5–15	Moderate resistance; structure depends on fiber orientation.

The data indicate that compressive strengths for these materials typically range from 15 to 55 MPa, showcasing certain formulations' potential to effectively support structural demands. For instance, the upper echelon of compressive strength seen in modified wood–cement composites, which can exceed 50 MPa, exemplifies how targeted treatments and formulations can optimize performance, ensuring they meet or exceed that of traditional concrete. Flexural strength, often a critical factor for load-bearing applications, generally demonstrates variability based on the wood content. With values ranging from 5 to 28 MPa, the trends reveal that while increased wood content can lead to reduced flexural strength, innovative mixture designs are mitigating this issue. The findings suggest that incorporating smaller wood particles or using advanced binding agents can improve the overall mechanical integrity, allowing for a balanced approach that prioritizes sustainability without significantly compromising strength. Thermal conductivity data present another compelling aspect of these composites. The lower thermal conductivity observed in wood–cement composites, particularly those containing lightweight aggregates, indicates an enhanced potential for energy efficiency in building applications. This property is increasingly significant as the construction industry shifts toward designing energy-efficient structures that comply with strict environmental standards. Water absorption rates vary across composite types, with some formulations reaching absorption levels as high as 25%. This variance often correlates with the presence of untreated wood fibers, which can compromise durability if not addressed. However, treatments and the proper formulation of mixtures can significantly improve moisture resistance, making wood–cement composites more viable for outdoor applications.

One of the most widely used wood–cement materials in the 20th century was sawdust concrete, a composite consisting of sawdust, sand, Portland cement as the binder, and lime as an additive. This material exhibited favorable mechanical properties, including a compressive strength ranging from 1 to 10 MPa, making it suitable for monolithic applications in low-rise construction. However, sawdust concrete also presented notable limitations, particularly its high density (700–1400 kg/m^3), which contributed to suboptimal thermal insulation properties, as evidenced by a thermal conductivity coefficient (λ) exceeding 0.2 W/(m·K). The incorporation of porous concrete also shows promise. A study investigating different mix designs of porous concrete, using various aggregates, demonstrated weighted absorption coefficients (αw) ranging from 0.30 to 0.75, depending on the thickness and mounting conditions [100]. This highlights the potential for this material to be effective in indoor and outdoor acoustic applications.

One of the most widely used wood–cement composite materials at the end of the 20th century was arbolite. The name "arbolite" is derived from the Latin word arbor (meaning "wood") and the Greek word λίθος (meaning "stone"). This material utilizes specially prepared wood chips with a specific granulometric composition and shape as the organic filler. The structural framework of arbolite is formed by wood fibrous particles bonded together by hardened cement paste (HCP), effectively combining the advantageous properties of both wood and concrete. Among its notable characteristics is its fire resistance; arbolite is difficult to ignite and, when exposed to high temperatures, it smolders rather than burning with an open flame. Additionally, arbolite contributes to a healthy indoor microclimate and serves as an excellent substrate for plastering and the application of other finishing materials. Selected physical and mechanical properties of arbolite blocks produced by the Multibau company (Riga, Latvia) are presented in (Table 6).

Table 6. Physical and mechanical properties of arbolite blocks.

Property	Block Thickness: 350 mm	Block Thickness: 200 mm
Compressive strength, MPa	1.07–1.59	0.72–1.20
Material density, kg/m^3	350–480	330–450
Elastic modulus (initial), GPa	1.5–4.0	-
Thermal conductivity, W/mK	0.15	0.15
The mass of one block, kg	14–20	8–11

2.4. The Use of Alternative Binder in Bio-Fiber and Wood Composites

Despite the widespread use and climatic resilience of wood–cement compositions, several challenges persist, particularly concerning the interfacial zone between wood particles and the cement matrix. This interface often represents a weak point, affecting the overall performance and durability of the material. Additionally, the reliance on Portland cement as a binder poses significant environmental concerns due to its substantial carbon dioxide emissions during production. Projections indicate that global cement production will continue to rise until at least 2050 [101], exacerbating its environmental impact. In response, researchers and policymakers are actively exploring strategies to reduce cement consumption in materials and to replace Portland cement clinker with more sustainable alternative binders [102].

To address environmental challenges and explore effective alternatives to Portland cement clinker, a study [103] investigated the production of wood–cement composites using porous bottom ash as a partial replacement for cement. The findings revealed that while the incorporation of bottom ash led to a reduction in bulk density and compressive strength, it also resulted in an increased water demand during the mixing process. This trade-off highlights the need for further optimization to balance the ecological benefits of reduced cement usage with the mechanical and physical properties required for practical applications.

It is important to highlight that Portland cement and cement-based binders create a dense microstructure in the paste and ensure a high-quality interfacial zone with plant fibers. However, these binders do not facilitate moisture exchange within the material, which is a critical factor for envelope structures to maintain an optimal indoor microclimate and prevent the formation of dew points within the wall. In contrast, hemp–lime compositions address these requirements effectively [104]. Traditional hemp concrete is composed of hemp shives and lime binder (hydrated lime, $Ca(OH)_2$), which hardens through carbonation, forming a monolithic structure. The density of hemp–lime materials typically does not exceed 750 kg/m^3, and their compressive strength is generally less than 1 MPa [105,106]. While these properties are sufficient to provide self-bearing capacity and adequate thermal insulation for buildings, the low final strength and slow hardening rate of lime–hemp composites remain significant drawbacks.

The energy efficiency and hygrothermal properties of hemp–lime insulation materials have been extensively investigated and validated under real-world conditions [107]. Measurements were conducted using a specially designed data logger equipped with temperature and humidity sensors, allowing for precise monitoring of the material's performance. A comparison between theoretical and experimental U-values revealed slight discrepancies, which can be attributed to the moisture buffering capacity of hemp–lime composites. This property enhances thermal comfort by regulating indoor humidity levels. The findings demonstrate that bio-based materials, such as hemp–lime, are highly effective as insulation in civil engineering applications, offering both energy efficiency and improved indoor environmental quality.

To enhance the mechanical properties of hemp–lime composites, hydraulic lime and mineral additives that promote pozzolanic reactions can be incorporated, thereby increasing the material's final strength [105]. Research has demonstrated that replacing lime with magnesium oxychloride cement (MOC) significantly improves the strength [107] and accelerates the hardening process. Additionally, life cycle assessment studies have indicated that both magnesium-based and lime-based bio-composites exhibit similarly low environmental impacts, making them sustainable alternatives [108].

Innovative advancements have also led to the development of hemp composite boards using a magnesium-based binder. These boards, measuring 500 by 1200 mm with thicknesses ranging from 25 to 50 mm, were designed primarily as shell elements for building frames. The interior spaces between the boards are filled with a lightweight lime–hemp mixture, creating a system that combines structural integrity with excellent thermal insulation and acoustic properties. This approach ensures that the fiber composite not only supports the building's framework but also enhances the energy efficiency and comfort of the enclosed structure.

It is important to emphasize that the physical and mechanical properties of natural fiber composites are significantly influenced by the shape and size of the natural fiber material [109]. These factors affect the composite's structural integrity, density, and overall performance. To address the inherent hydrophilicity of natural fibers, such as hemp shives, and improve their water resistance, advanced modification techniques can be employed. One effective approach involves the application of water-repellent sol–gel coatings, which create a protective barrier on the fiber surface, enhancing its durability and resistance to moisture [110]. Such modifications not only improve the material's performance in humid conditions but also expand its potential applications in construction and other industries.

By adjusting the proportions between the binder and the filler, a wide range of densities can be achieved, typically ranging from 200 to 600 kg/m^3 or higher. Studies have shown that lightweight hemp composites exhibit a thermal conductivity coefficient of approximately 0.55 W/m·K in a dry state, while denser composites (600 kg/m^3) demonstrate a significantly lower thermal conductivity of 0.16 W/m·K [111]. However, it has been observed that the thermal conductivity coefficient can increase substantially (by 50–70%) at relative humidity levels of 75% or higher. This phenomenon is attributed to the high hygroscopicity of the material, which can have both beneficial and detrimental effects depending on the application.

The aforementioned composites were formulated using a magnesium oxychloride cement (MOC) binder. The ratio of MgO to hemp shives varied from 0.5 (for a density of 200 kg/m^3) to 3 (for a density of 600 kg/m^3). The preparation of the hemp composite involved several steps: firstly, the hemp shives were pre-moistened, then mixed with dry MgO powder. Subsequently, a $MgCl_2 \cdot 6H_2O$ water solution (in a 1:1 ratio) was added at 63% by mass of MgO, and the mixture was thoroughly blended in a laboratory pan mixer. The resulting formulation was poured into oiled plywood formworks, subjected to a load of 2 kN/m^2, and cured for 24 h.

It is important to note that magnesium oxychloride cement (MOC) exhibits excellent adhesion to organic fillers, making it a suitable binder for bio-based composites. However, MOC has lower water resistance compared to Portland cement, and its high hygroscopicity poses a significant limitation, particularly for applications in external structures exposed to high relative humidity. Research has demonstrated that the incorporation of certain mineral additives and salts can substantially enhance the water resistance of MOC-based composites. For instance, the properties of MOC cement modified with rice husk silica have been explored in [112], while the influence of fly ash and silica fume on improving the water-resistant properties of MOC has been investigated in [113]. Additionally, studies have shown that replacing the activating magnesium chloride solution with a magnesium sulfate solution can significantly reduce the material's hygroscopicity, thereby improving its performance in humid conditions [114].

Other researchers have demonstrated that gypsum can also serve as an effective binder in bio-fiber composites [115]. In such studies, hemp fibers were utilized to produce reinforced gypsum composites, which exhibited significant improvements in mechanical properties compared to unreinforced gypsum. Specifically, the inclusion of hemp reinforcement increased the flexural strength by up to 320% and enhanced the energy absorption capacity, indicating a strong interfacial bond between the gypsum matrix and the plant fibers. Another promising alternative binder is magnesium phosphate cement (MPC), which has been explored for its potential in bio-composite applications [116]. MPC offers advantages such as rapid hardening, high early strength, and good durability, making it a viable option for specialized construction needs.

An innovative approach involves the use of rice husks in cement-based composites designed for acoustic barriers and thermal insulating layers [117]. In this study, the authors incorporated rice husks, treated wood, and recycled rubber granules as fillers, resulting in a material with a density of approximately 1000 kg/m^3, a thermal conductivity coefficient of 0.20 W/m·K, and a bending strength of up to 3 MPa.

In another study [118], researchers developed a cement-bonded wood–wool composite using eucalyptus (Eucalyptus camaldulensis) and poplar (Populus deltoides) fibers, with calcium chloride ($CaCl_2$) added as a modifying agent to enhance the material's properties.

Further research [119] focused on the development of low-density wood–cement particleboards for interior wall finishes. The resulting material achieved a flexural strength of up to 8 MPa and a density of 0.7 kg/m^3, making it suitable for lightweight construction applications.

A novel prefabricated wall system utilizing wood–wool cement composite panels was also developed [120]. These panels, measuring 600 × 2400 mm with thicknesses ranging from 25 to 100 mm, were shown to significantly improve construction efficiency and performance.

The study "Modelling and optimization of the sound absorption of wood-wool cement boards" [121] aimed to enhance the acoustic properties of wood–wool cement boards (WWCBs). WWCBs, which have been in use for nearly a century, are valued for their excellent acoustic, thermal insulation, and aesthetic properties, making them an attractive and eco-friendly option for interior decoration. The material typically has a density range of 300 to 550 kg/m^3, achieved by maintaining a wood–wool-to-binder ratio of 0.43 to 0.57 in the mix composition.

In the paper "The recycling potential of wood waste into wood-wool/cement composite" [122], the authors explored the effective utilization of wood waste in composite materials. They concluded that wood waste could successfully replace up to 50% of the conventional materials without compromising performance.

It is also worth noting that the production of wood–cement composites generates significant amounts of fine waste containing hydrated cement paste and wood particles. Researchers P. Argalis et al. developed novel bio-based materials by repurposing waste from cement–wool board manufacturing [123,124]. These materials were rigorously tested for properties such as density, thermal conductivity, and compressive strength, demonstrating the potential for sustainable waste utilization in construction materials.

A summary of the advantages and disadvantages of bio-fiber and wood composites using mineral binders is presented in Table 7.

Table 7. Advantages and disadvantages of bio-fiber and wood composites using mineral binders.

Advantages of Bio-Fiber and Wood Composites Using Mineral Binders.	
Thermal and Acoustic Insulation	• Excellent thermal insulation properties (e.g., thermal conductivity as low as 0.15 W/m·K for arbolite). • Effective sound absorption and insulation, making them suitable for acoustic barriers and interior applications.

Table 7. *Cont.*

Advantages of Bio-Fiber and Wood Composites Using Mineral Binders.	
Environmental Sustainability	• Utilizes renewable and waste materials (e.g., hemp shives, flax wool, sawdust, rice husks), reducing reliance on non-renewable resources. • Low carbon footprint and reduced energy consumption during production and operation. • Promotes circular economy by repurposing agricultural and industrial waste.
Fire Resistance	• Mineral binders (e.g., cement, lime, MOC) enhance fire resistance compared to purely organic materials. • Materials like arbolite smolder rather than burn, improving safety in construction.
Mechanical Properties	• Good compressive strength (e.g., 1–10 MPa for sawdust concrete, up to 8 MPa for low-density wood–cement particleboards). • Flexibility in adjusting density and strength by varying binder-to-filler ratios.
Indoor Microclimate Regulation	• Materials like hemp–lime and arbolite contribute to a healthy indoor environment by regulating humidity and temperature.
Cost-Effectiveness	• Use of low-cost or waste-derived materials can reduce production costs. • Potential for local sourcing of raw materials, minimizing transportation costs.
Disadvantages of bio-fiber and wood composites using mineral binders.	
Moisture Sensitivity	• High hygroscopicity of natural fibers (e.g., hemp shives) can lead to increased thermal conductivity and reduced performance in humid conditions. • Some binders (e.g., MOC) have lower water resistance, limiting their use in external structures.
Durability Aspects	• Natural fibers may degrade due to environmental factors (e.g., moisture, UV exposure). • Weak interfacial zones between wood particles and cement matrices can affect long-term durability.
Low Strength in Some Composites	• Hemp–lime composites have low compressive strength (<1 MPa), limiting their structural applications.
Slow Hardening	• Lime-based binders (e.g., hemp–lime) have slow hardening rates, delaying construction timelines.
Material Variability	• Heterogeneous nature of natural fibers and waste materials can lead to inconsistent quality and performance.
Environmental Impact of Binders	• Portland cement production is energy-intensive and contributes significantly to CO_2 emissions. • Alternative binders (e.g., MOC, MPC) may have limitations in water resistance or require additional treatments.

3. Conclusions

Innovations in acoustic materials and panel design, particularly those involving wood composites and bio-based materials, offer significant potential for sustainable, high-performance solutions. Their strengths are environmental friendliness, excellent acoustic and thermal properties, and versatility. However, challenges related to moisture sensitivity, durability, and material variability must be addressed. Opportunities exist in technological advancements, waste utilization, and expanding markets, while threats include competition from conventional materials and economic barriers.

The future of acoustic materials lies in sustainability, innovation, and multi-functionality. Key areas of development include the use of renewable and waste-derived materials, advanced manufacturing techniques, and tunable designs. While challenges remain in cost, scalability, and performance optimization, the growing demand for eco-friendly and high-performance solutions presents significant opportunities for innovation and market growth. By leveraging digital tools, hybrid materials, and smart designs, the next generation of acoustic materials can address environmental and functional needs, paving the way for quieter, healthier, and more sustainable built environments.

Recent research on wood-based composites with mineral binders highlights the need to optimize interfacial bonding between wood particles and cementitious matrices through surface treatments like alkali modification or nano-silica coatings, while exploring alternative low-carbon binders such as magnesium-based cements (MOC, MPC), geopolymers, and carbonation-cured lime–hemp systems to reduce the environmental impact. Key challenges include balancing strength–density trade-offs in lightweight composites (200–600 kg/m^3) through fiber hybridization or pozzolanic additives, improving acoustic performance via controlled porosity, and managing hygroscopicity with sol–gel coatings to stabilize thermal conductivity under varying humidity. Industrial scalability requires innovations in prefabrication, waste valorization (e.g., repurposing wood–cement production waste), and curing techniques like carbonation curing, alongside durability testing for moisture, freeze–thaw, and fire resistance using natural retardants. These composites—exemplified by wood–wool cement boards (α up to 0.5) and MOC–hemp systems—demonstrate promise for sustainable construction.

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References

1. Tămaş-Gavrea, D.-R.; Iştoan, R.; Tiuc, A.E.; Dénes, T.-O.; Manea, D.L.; Ciorîță, A.; Vasile, O. Sustainable Approach to Achieve New Green Solutions for the Construction Industry. *Sustainability* **2024**, *16*, 10556. [CrossRef]
2. Zaharia, S.-M.; Pop, M.A.; Cosnita, M.; Croitoru, C.; Matei, S.; Spîrchez, C. Sound Absorption Performance and Mechanical Properties of the 3D-Printed Bio-Degradable Panels. *Polymers* **2023**, *15*, 3695. [CrossRef]
3. Santoni, A.; Bonfiglio, P.; Fausti, P.; Marescotti, C.; Mazzanti, V.; Pompoli, F. Characterization and Vibro-Acoustic Modeling of Wood Composite Panels. *Materials* **2020**, *13*, 1897. [CrossRef]
4. Tsirigoti, D.; Giarma, C.; Tsikaloudaki, K. Indoor Acoustic Comfort Provided by an Innovative Preconstructed Wall Module: Sound Insulation Performance Analysis. *Sustainability* **2020**, *12*, 8666. [CrossRef]
5. Hemalatha, G.; Sudheer, G.; Shelton, J.J.; Carmichael, M.J. Exploring the Impact of EPS Incorporation on Insulated Concrete Form (ICF) Wall Panels under Axial Compression and Flexure. *J. King Saud Univ.-Eng. Sci.* **2024**, *36*, 207–215. [CrossRef]
6. Wang, G.; Luo, J.; Yuan, W.; Ma, B. Investigation on Low Frequency Acoustic Characteristics of Parallel-Arranged Microperforated Panel with Aerogel-Filled Back Cavities. *Appl. Acoust.* **2023**, *207*, 109347. [CrossRef]

7. Ahac, M.; Ahac, S.; Lakušić, S. Long-Term Sustainability Approach in Road Traffic Noise Wall Design. *Sustainability* **2021**, *13*, 536. [CrossRef]
8. Alemu, A.S.; Yoon, J.; Tafesse, M.; Seo, Y.-S.; Kim, H.-K.; Pyo, S. Practical Considerations of Porosity, Strength, and Acoustic Absorption of Structural Pervious Concrete. *Case Stud. Constr. Mater.* **2021**, *15*, e00764. [CrossRef]
9. Ren, L.; Yang, H.; Liu, L.; Zhai, C.; Song, Y. Sound Insulation of Corrugated-Core Sandwich Panels: Modeling, Optimization and Experiment. *Materials* **2021**, *14*, 7785. [CrossRef]
10. Proença, M.; Neves e Sousa, A.; Garrido, M.; Correia, J.R. Acoustic Performance of Composite Sandwich Panels for Building Floors: Experimental Tests and Numerical-Analytical Simulation. *J. Build. Eng.* **2020**, *32*, 101751. [CrossRef]
11. Titze, M.; Misol, M.; Monner, H.P. Examination of the Vibroacoustic Behavior of a Grid-Stiffened Panel with Applied Passive Constrained Layer Damping. *J. Sound Vib.* **2019**, *453*, 174–187. [CrossRef]
12. Cucharero, J.; Hänninen, T.; Lokki, T. Influence of Sound-Absorbing Material Placement on Room Acoustical Parameters. *Acoustics* **2019**, *1*, 644–660. [CrossRef]
13. Kumar Saini, M.; Kumar Bagha, A.; Kumar, S. Experimental Study to Measure the Transmission Loss of Double Panel Natural Fibers. *Mater. Today Proc.* **2020**, *26*, 482–486. [CrossRef]
14. Jang, J.-Y.; Park, C.-S.; Song, K. Lightweight Soundproofing Membrane Acoustic Metamaterial for Broadband Sound Insulation. *Mech. Syst. Signal Process.* **2022**, *178*, 109270. [CrossRef]
15. Sahu, N.R.; Mandal, B.B. Development of Tunable Acoustic Materials with Inline Cavity Structure for Enhanced Sound Absorption and Transmission Loss. *J. Build. Eng.* **2024**, *82*, 108305. [CrossRef]
16. Matei, S.; Pop, M.A.; Zaharia, S.-M.; Coșniță, M.; Croitoru, C.; Spîrchez, C.; Cazan, C. Investigation into the Acoustic Properties of Polylactic Acid Sound-Absorbing Panels Manufactured by 3D Printing Technology: The Influence of Nozzle Diameters and Internal Configurations. *Materials* **2024**, *17*, 580. [CrossRef]
17. Ghisellini, P.; Quinto, I.; Passaro, R.; Ulgiati, S. Bio-Based Products for a More Sustainable Construction Sector. Technical, Environmental and Social Performances and Impacts. *Procedia Struct. Integr.* **2024**, *64*, 1689–1695. [CrossRef]
18. Oliveira, M.A.; António, J. Animal-Based Waste for Building Acoustic Applications: A Review. *J. Build. Eng.* **2024**, *84*, 108430. [CrossRef]
19. Salunkhe, S.; Patil, C.; Thakar, C.M. Exploring the Potential of Natural Materials as Eco-Friendly Sound Absorbers. *Mater. Today Proc.* **2023**, *in press*. [CrossRef]
20. Mohammadi, M.; Taban, E.; Tan, W.H.; Che Din, N.B.; Putra, A.; Berardi, U. Recent Progress in Natural Fiber Reinforced Composite as Sound Absorber Material. *J. Build. Eng.* **2024**, *84*, 108514. [CrossRef]
21. Sharma, S.; Sudhakara, P.; Singh, J.; Singh, S.; Singh, G. Emerging Progressive Developments in the Fibrous Composites for Acoustic Applications. *J. Manuf. Process.* **2023**, *102*, 443–477. [CrossRef]
22. Assouar, B.; Oudich, M.; Zhou, X. Acoustic Metamaterials for Sound Mitigation. *Comptes Rendus Phys.* **2016**, *17*, 524–532. [CrossRef]
23. Zhang, Y.; Zhang, J.; Li, Y.; Yao, D.; Zhao, Y.; Ai, Y.; Pan, W.; Li, J. Research Progress on Thin-Walled Sound Insulation Metamaterial Structures. *Acoustics* **2024**, *6*, 298–330. [CrossRef]
24. Shankar, A.N.; Chopade, S.; Srinivas, R.; Kumar Mishra, N.; Eftikhaar, H.K.; Sethi, G.; Singh, B. Physical and Mechanical Properties of Foamed Concrete, a Literature Review. *Mater. Today Proc.* **2023**, *in press*. [CrossRef]
25. Girometta, C.; Picco, A.M.; Baiguera, R.M.; Dondi, D.; Babbini, S.; Cartabia, M.; Pellegrini, M.; Savino, E. Physico-Mechanical and Thermodynamic Properties of Mycelium-Based Biocomposites: A Review. *Sustainability* **2019**, *11*, 281. [CrossRef]
26. Nurzyński, J.; Nowotny, Ł. Acoustic Performance of Floors Made of Composite Panels. *Materials* **2023**, *16*, 2128. [CrossRef]
27. Kishore, S.E.; Sujithra, R.; Dhatreyi, B. A Review on Latest Acoustic Noise Mitigation Materials. *Mater. Today Proc.* **2021**, *47*, 4700–4707. [CrossRef]
28. Lee, H.P.; Kumar, S.; Aow, J.W. Proof-of-Concept Design for MPP Acoustic Absorbers with Elements of Art. *Designs* **2021**, *5*, 72. [CrossRef]
29. Laurìa, A.; Secchi, S.; Vessella, L. Acoustic Comfort as a Salutogenic Resource in Learning Environments—A Proposal for the Design of a System to Improve the Acoustic Quality of Classrooms. *Sustainability* **2020**, *12*, 9733. [CrossRef]
30. Tao, Y.; Ren, M.; Zhang, H.; Peijs, T. Recent Progress in Acoustic Materials and Noise Control Strategies—A Review. *Appl. Mater. Today* **2021**, *24*, 101141. [CrossRef]
31. Gokulkumar, S.; Thyla, P.R.; Prabhu, L.; Sathish, S.; Karthi, N. A Comparative Study on Epoxy Based Composites Filled with Pineapple/Areca/Ramie Hybridized with Industrial Tea Leaf Wastes/GFRP. *Mater. Today Proc.* **2020**, *27*, 2474–2476. [CrossRef]
32. Merli, F.; Belloni, E.; Buratti, C. Eco-Sustainable Wood Waste Panels for Building Applications: Influence of Different Species and Assembling Techniques on Thermal, Acoustic, and Environmental Performance. *Buildings* **2021**, *11*, 361. [CrossRef]
33. Yang, X.; Tang, X.; Ma, L.; Sun, Y. Sound Insulation Performance of Structural Wood Wall Integrated with Wood Plastic Composite. *J. Bioresour. Bioprod.* **2019**, *4*, 111–118. [CrossRef]

34. Pisello, A.L.; Fabiani, C.; Makaremi, N.; Castaldo, V.L.; Cavalaglio, G.; Nicolini, A.; Barbanera, M.; Cotana, F. Sustainable New Brick and Thermo-Acoustic Insulation Panel from Mineralization of Stranded Driftwood Residues. *Energies* **2016**, *9*, 619. [CrossRef]
35. Gomez, T.S.; Zuluaga, S.; Jimenez, M.; Navacerrada, M.d.L.Á.; Barbero-Barrera, M.d.M.; de la Prida, D.; Restrepo-Osorio, A.; Fernández-Morales, P. Evaluation of Colombian Crops Fibrous Byproducts for Potential Applications in Sustainable Building Acoustics. *Polymers* **2021**, *13*, 101. [CrossRef]
36. Wijekoon, N.K.; Appuhamillage, G.A.; Dassanayake, R.S.; Liyanage, R.N.; Mapage, D.; Wijenayake, A.; Lokuge, E.L.; Rajapaksha, S.M.; Abeygunawardane, G.A.; Senarath, N.D.D.D. Facile Fabrication of 3D-Printed Cellulosic Fiber/Polylactic Acid Composites as Low-Cost and Sustainable Acoustic Panels. *Sustain. Chem. Environ.* **2024**, *8*, 100168. [CrossRef]
37. Tămaş-Gavrea, D.-R.; Iştoan, R.; Tiuc, A.E.; Dénes, T.-O.; Vasile, O.; Constantinescu, H. Development of New Composite Products Based on Flax Fibres. *Coatings* **2021**, *11*, 551. [CrossRef]
38. Nazari, S.; Ivanova, T.A.; Mishra, R.K.; Müller, M.; Akhbari, M.; Hashjin, Z.E. Effect of Natural Fiber and Biomass on Acoustic Performance of 3D Hybrid Fabric-Reinforced Composite Panels. *Materials* **2024**, *17*, 5695. [CrossRef]
39. Darwish, E.A.; Midani, M. The Potential of Date Palm Midribs-Based Fabric Acoustic Panels for Sustainable Interior Design. *Ain Shams Eng. J.* **2023**, *14*, 102100. [CrossRef]
40. Gomez-Campos, A.; Sablayrolles, C.; Hamelin, L.; Rouilly, A.; Evon, P.; Vialle, C. Towards Fossil-Carbon Free Buildings: Production and Environmental Performance of Innovative Sound Absorbing Panels Made from Sunflower Straw. *J. Clean. Prod.* **2023**, *400*, 136620. [CrossRef]
41. Hassan, T.; Jamshaid, H.; Mishra, R.; Khan, M.Q.; Petru, M.; Novak, J.; Choteborsky, R.; Hromasova, M. Acoustic, Mechanical and Thermal Properties of Green Composites Reinforced with Natural Fibers Waste. *Polymers* **2020**, *12*, 654. [CrossRef]
42. Kueh, A.; Razali, A.; Lee, Y.; Hamdan, S.; Yakub, I.; Suhaili, N. Acoustical and Mechanical Characteristics of Mortars with Pineapple Leaf Fiber and Silica Aerogel Infills—Measurement and Modeling. *Mater. Today Commun.* **2023**, *35*, 105540. [CrossRef]
43. Astrauskas, T.; Januševičius, T.; Grubliauskas, R. Acoustic Panels Made of Paper Sludge and Clay Composites. *Sustainability* **2021**, *13*, 637. [CrossRef]
44. Tămaş-Gavrea, D.-R.; Dénes, T.-O.; Iştoan, R.; Tiuc, A.E.; Manea, D.L.; Vasile, O. A Novel Acoustic Sandwich Panel Based on Sheep Wool. *Coatings* **2020**, *10*, 148. [CrossRef]
45. Walter, N.; Gürsoy, B. A Study on the Sound Absorption Properties of Mycelium-Based Composites Cultivated on Waste Paper-Based Substrates. *Biomimetics* **2022**, *7*, 100. [CrossRef]
46. Tudor, E.M.; Kristak, L.; Barbu, M.C.; Gergel', T.; Němec, M.; Kain, G.; Réh, R. Acoustic Properties of Larch Bark Panels. *Forests* **2021**, *12*, 887. [CrossRef]
47. Gil-Lopez, T.; Medina-Molina, M.; Verdu-Vazquez, A.; Martel-Rodriguez, B. Acoustic and Economic Analysis of the Use of Palm Tree Pruning Waste in Noise Barriers to Mitigate the Environmental Impact of Motorways. *Sci. Total Environ.* **2017**, *584–585*, 1066–1076. [CrossRef]
48. Reixach, R.; Del Rey, R.; Alba, J.; Arbat, G.; Espinach, F.X.; Mutjé, P. Acoustic Properties of Agroforestry Waste Orange Pruning Fibers Reinforced Polypropylene Composites as an Alternative to Laminated Gypsum Boards. *Constr. Build. Mater.* **2015**, *77*, 124–129. [CrossRef]
49. Ferrandez-García, M.T.; Ferrandez-Garcia, A.; Garcia-Ortuño, T.; Ferrandez-Garcia, C.E.; Ferrandez-Villena, M. Assessment of the Physical, Mechanical and Acoustic Properties of *Arundo donax* L. Biomass in Low Pressure and Temperature Particleboards. *Polymers* **2020**, *12*, 1361. [CrossRef]
50. Luciano, G.; Vignali, A.; Vignolo, M.; Utzeri, R.; Bertini, F.; Iannace, S. Biocomposite Foams with Multimodal Cellular Structures Based on Cork Granulates and Microwave Processed Egg White Proteins. *Materials* **2023**, *16*, 3063. [CrossRef]
51. Yun, B.Y.; Cho, H.M.; Kim, Y.U.; Lee, S.C.; Berardi, U.; Kim, S. Circular Reutilization of Coffee Waste for Sound Absorbing Panels: A Perspective on Material Recycling. *Environ. Res.* **2020**, *184*, 109281. [CrossRef] [PubMed]
52. Balasubramanian, D.; Rajendran, S.; Srinivasan, B.; Angamuthu, N. Elucidating the Sound Absorption Characteristics of *Foxtail millet* (*Setaria italica*) Husk. *Materials* **2020**, *13*, 5126. [CrossRef]
53. Liuzzi, S.; Rubino, C.; Stefanizzi, P.; Martellotta, F. Performance Characterization of Broad Band Sustainable Sound Absorbers Made of Almond Skins. *Materials* **2020**, *13*, 5474. [CrossRef] [PubMed]
54. Karlinasari, L.; Adzkia, U.; Sudarsono, A.S.; Larasatie, P.; Amin, Y.; Nugroho, N. Surface Characteristics and Acoustical Properties of Bamboo Particle Board Coated with Polyurethane Varnish. *Forests* **2021**, *12*, 1285. [CrossRef]
55. Selvaraj, V.K.; Subramanian, J.; Rajendran, V.; Raja, S.; Yuvaraj, L.; Jeevan, S.; Krishnan, P.; Zachariah, A.A. Sustainable Development, Optimization, and Simulation of Bio-Based Polyurethane Foam Composites for Enhanced Building Acoustics. *J. Build. Eng.* **2025**, *99*, 111576. [CrossRef]
56. Setyowati, E.; Hardiman, G.; Purwanto, P. Tailoring Acoustic Performances of Resin Reinforced Biomass Fiber-Based Panel with Single and Multiple Tailed Cavity Inclusions for Interior Work. *Fibers* **2019**, *7*, 85. [CrossRef]

57. Hanim Mohamed Ariff, A.; Dele-Afolabi, T.T.; Hossain Rafin, T.; Jung, D.-W.; Leman, Z.; Anas Md Rezali, K.; Calin, R. Temporary Sound Barrier System from Natural Fiber Polymeric Composite. *Mater. Today Proc.* **2023**, *74*, 438–449. [CrossRef]
58. Han, T.; Wang, X.; Xiong, Y.; Li, J.; Guo, S.; Chen, G. Light-Weight Poly(Vinyl Chloride)-Based Soundproofing Composites with Foam/Film Alternating Multilayered Structure. *Compos. Part A Appl. Sci. Manuf.* **2015**, *78*, 27–34. [CrossRef]
59. Ferreira, S.; Morais, M.; Costa, V.; Velosa, A.; Vela, G.; Teles, J.; Pereira, T. Modular Sandwich Panel System for Non-Loadbearing Walls—Experimental Mechanical, Fire and Acoustic Testing. *J. Build. Eng.* **2023**, *78*, 107642. [CrossRef]
60. Ghofrani, M.; Ashori, A.; Rezvani, M.H.; Arbabi Ghamsari, F. Acoustical Properties of Plywood/Waste Tire Rubber Composite Panels. *Measurement* **2016**, *94*, 382–387. [CrossRef]
61. Laxmi, V.; Thakre, C.; Bisarya, A.; Vijay, R. An Innovative Approach for the Development of Sound Absorbing Material Using Industrial Wastes. *Constr. Build. Mater.* **2023**, *369*, 130523. [CrossRef]
62. Ružickij, R.; Kizinievič, O.; Grubliauskas, R.; Astrauskas, T. Development of Composite Acoustic Panels of Waste Tyre Textile Fibres and Paper Sludge. *Sustainability* **2023**, *15*, 2799. [CrossRef]
63. del Rosario-Gilabert, D.; Carbajo, J.; Hernández-Pozo, M.; Valenzuela-Miralles, A.; Ruiz, D.; Poveda-Martínez, P.; Esquiva, G.; Gómez-Vicente, V. Eco-Friendly and Biocompatible Material to Reduce Noise Pollution and Improve Acoustic Comfort in Healthcare Environments. *Buildings* **2024**, *14*, 3151. [CrossRef]
64. Do, N.H.N.; Le, T.M.; Tran, H.Q.; Pham, N.Q.; Le, K.A.; Nguyen, P.T.T.; Duong, H.M.; Le, T.A.; Le, P.K. Green Recycling of Fly Ash into Heat and Sound Insulation Composite Aerogels Reinforced by Recycled Polyethylene Terephthalate Fibers. *J. Clean. Prod.* **2021**, *322*, 129138. [CrossRef]
65. Malaiškienė, J.; Astrauskas, T.; Januševičius, T.; Kizinievič, O.; Kizinievič, V. Potential Applications of Rubber Buffing Dust and Recovered Crumb Rubber in Cement Concrete. *Results Eng.* **2024**, *24*, 103266. [CrossRef]
66. Zhao, J.; Wang, X.-M.; Chang, J.M.; Yao, Y.; Cui, Q. Sound Insulation Property of Wood–Waste Tire Rubber Composite. *Compos. Sci. Technol.* **2010**, *70*, 2033–2038. [CrossRef]
67. Stanciu, M.D.; Curtu, I.; Cosereanu, C.; Lica, D. Soundproofing Performance Evaluation of Panels Made of Fibers of Acrylonitrile Butadiene Styrene Copolymer (ABS). *Procedia Technol.* **2015**, *19*, 260–267. [CrossRef]
68. Del Rey, R.; Crespo Amorós, J.E.; Escales Tur, J.; Alba, J. Study of Acoustic Prototypes Based on Plastic Cap Waste. *Buildings* **2024**, *14*, 1652. [CrossRef]
69. Ricciardi, P.; Belloni, E.; Merli, F.; Buratti, C. Sustainable Panels Made with Industrial and Agricultural Waste: Thermal and Environmental Critical Analysis of the Experimental Results. *Appl. Sci.* **2021**, *11*, 494. [CrossRef]
70. Neri, M. Thermal and Acoustic Characterization of Innovative and Unconventional Panels Made of Reused Materials. *Atmosphere* **2022**, *13*, 1825. [CrossRef]
71. Neri, M.; Cuerva, E.; Levi, E.; Pujadas, P.; Müller, E.; Guardo, A. Thermal, Acoustic, and Fire Performance Characterization of Textile Face Mask Waste for Use as Low-Cost Building Insulation Material. *Dev. Built Environ.* **2023**, *14*, 100164. [CrossRef]
72. Merli, F.; Fiorini, C.V.; Barbanera, M.; Pietroni, G.; Spaccini, F.; Buratti, C. Thermal, Acoustic, and Hygrothermal Properties of Recycled Bovine Leather Cutting Waste-Based Panels with Different Compositions. *Sustainability* **2023**, *15*, 1779. [CrossRef]
73. Barrigón Morillas, J.M.; Montes González, D.; Vílchez-Gómez, R.; Gómez Escobar, V.; Maderuelo-Sanz, R.; Rey Gozalo, G.; Atanasio Moraga, P. Virgin Natural Cork Characterization as a Sustainable Material for Use in Acoustic Solutions. *Sustainability* **2021**, *13*, 4976. [CrossRef]
74. Dissanayake, D.G.K.; Weerasinghe, D.U.; Thebuwanage, L.M.; Bandara, U.A.A.N. An Environmentally Friendly Sound Insulation Material from Post-Industrial Textile Waste and Natural Rubber. *J. Build. Eng.* **2021**, *33*, 101606. [CrossRef]
75. Mudashir, G. Assessment of Acoustic Property of Sawdust and Fine Sharp Sand for the Fabrication of Sound-Proof Security Door. *FJS* **2022**, *6*, 129–134. [CrossRef]
76. Rubino, C.; Bonet Aracil, M.; Gisbert-Payá, J.; Liuzzi, S.; Stefanizzi, P.; Zamorano Cantó, M.; Martellotta, F. Composite Eco-Friendly Sound Absorbing Materials Made of Recycled Textile Waste and Biopolymers. *Materials* **2019**, *12*, 4020. [CrossRef] [PubMed]
77. Hassani, P.; Soltani, P.; Taban, E.; Amininasab, S. Development and Optimization of Sustainable High-Performance Acoustic and Fire Retardant Building Panels Using Recycled Discarded Denim. *J. Build. Eng.* **2024**, *98*, 111209. [CrossRef]
78. Chen, Q.; Shi, Z.; Dan, R.; Xu, D.; Shapon, A.K.M.N.B.Z.; Sun, L.; Shang, X.; Zhang, D.; Hu, Y. Preparation and Characterization of Waste Cotton Fabric Reinforced Polylactic Acid Green Composites with Multifunctional Properties in a Low-Carbon Process. *Process Saf. Environ. Prot.* **2024**, *192*, 412–423. [CrossRef]
79. Sinka, M.; Korjakins, A.; Bajare, D.; Zimele, Z.; Sahmenko, G. Bio-Based Construction Panels for Low Carbon Development. *Energy Procedia* **2018**, *147*, 220–226. [CrossRef]
80. New Report: The Building and Construction Sector Can Reach Net Zero Carbon Emissions by 2050. Available online: https://worldgbc.org/article/new-report-the-building-and-construction-sector-can-reach-net-zero-carbon-emissions-by-2050/ (accessed on 20 February 2025).
81. McGregor, F.; Heath, A.; Fodde, E.; Shea, A. Conditions Affecting the Moisture Buffering Measurement Performed on Compressed Earth Blocks. *Build. Environ.* **2014**, *75*, 11–18. [CrossRef]

82. Lewandowski, P.T.; Larnøy, E.; Militz, H. Development and Characterization of Bioblocks: A Sustainable Wood-Based Composite Utilizing MDF Residues, Citric Acid and Polyols. *Eur. J. Wood Prod.* **2024**, *82*, 2181–2198. [CrossRef]
83. Emmanuel, O.U.; Kuqo, A.; Mai, C. Non-Conventional Mineral Binder-Bonded Lignocellulosic Composite Materials: A Review. *BioResources* **2021**, *16*, 4606–4648. [CrossRef]
84. Tuğluca, M.S.; Özdoğru, E.; İlcan, H.; Özçelikci, E.; Ulugöl, H.; Şahmaran, M. Characterization of Chemically Treated Waste Wood Fiber and Its Potential Application in Cementitious Composites. *Cem. Concr. Compos.* **2023**, *137*, 104938. [CrossRef]
85. Surdu, E.; Iatan, R.; Cardei, P.; Sporea, N.; Farcas-Flamaropol, D.-C.; Durbaca, I. Mechanical Properties of Composite Materials Obtained with Clay Matrices and Plant Waste Inserts. *Sustainability* **2025**, *17*, 2888. [CrossRef]
86. Dias, S.; Almeida, J.; Santos, B.; Humbert, P.; Tadeu, A.; António, J.; de Brito, J.; Pinhão, P. Lightweight Cement Composites Containing End-of-Life Treated Wood—Leaching, Hydration and Mechanical Tests. *Constr. Build. Mater.* **2022**, *317*, 125931. [CrossRef]
87. Fan, M.; Ndikontar, M.K.; Zhou, X.; Ngamveng, J.N. Cement-Bonded Composites Made from Tropical Woods: Compatibility of Wood and Cement. *Constr. Build. Mater.* **2012**, *36*, 135–140. [CrossRef]
88. Bertoldo, N.; Qureshi, T.; Simpkins, D.; Arrigoni, A.; Dotelli, G. Concrete with Organic Waste Materials as Aggregate Replacement. *Appl. Sci.* **2024**, *14*, 108. [CrossRef]
89. Nassar, R.-U.-D.; Soroushian, P.; Balachandra, A.; Nassar, S.; Weerasiri, R.; Darsanasiri, N.; Abdol, N. Effect of Fiber Type and Content on the Performance of Extruded Wood Fiber Cement Products. *Case Stud. Constr. Mater.* **2022**, *16*, e00968. [CrossRef]
90. Melichar, T.; Dufka, A.; Dvořák, K.; Bayer, P.; Vasas, S.; Novakova, I.; Schwarzova, I.; Bydžovský, J. Durability of Wood–Cement Composites with Modified Composition by Limestone and Stabilised Spruce Chips. *Materials* **2024**, *17*, 6300. [CrossRef]
91. Ndahirwa, D.; Zmamou, H.; Lenormand, H.; Chenot, E.; Potel, S.; Leblanc, N. Wood Ash-Based Binders for Lightweight Building Materials: Evaluating the Influence of Hydraulic Lime and Cement on the Setting and Mechanical Properties of Wood Ash Pastes. *Results Eng.* **2024**, *24*, 102738. [CrossRef]
92. Kampragkou, P.; Kamperidou, V.; Stefanidou, M. Evaluation of Hydrothermally Treated Wood Fibre Performance in Cement Mortars. *Fibers* **2024**, *12*, 21. [CrossRef]
93. Khelifi, W.; Bencedira, S.; Azab, M.; Riaz, M.S.; Abdallah, M.; Abdel Baki, Z.; Krauklis, A.E.; Aouissi, H.A. Conservation Environments' Effect on the Compressive Strength Behaviour of Wood–Concrete Composites. *Materials* **2022**, *15*, 3572. [CrossRef] [PubMed]
94. Hemmati, N.; Mirzaei, R.; Soltani, P.; Berardi, U.; SheikhMozafari, M.J.; Edalat, H.; Rezaieyan, E.; Taban, E. Acoustic and Thermal Performance of Wood Strands-Rock Wool-Cement Composite Boards as Eco-Friendly Construction Materials. *Constr. Build. Mater.* **2024**, *445*, 137935. [CrossRef]
95. Liu, Z.; Han, C.; Li, Q.; Li, X.; Zhou, H.; Song, X.; Zu, F. Study on Wood Chips Modification and Its Application in Wood-Cement Composites. *Case Stud. Constr. Mater.* **2022**, *17*, e01350. [CrossRef]
96. Khushefati, W.H.; Demirboğa, R.; Farhan, K.Z. Assessment of Factors Impacting Thermal Conductivity of Cementitious Composites—A Review. *Clean. Mater.* **2022**, *5*, 100127. [CrossRef]
97. Guo, H.; Wang, P.; Li, Q.; Liu, G.; Fan, Q.; Yue, G.; Song, S.; Zheng, S.; Wang, L.; Guo, Y. Properties of Light Cementitious Composite Materials with Waste Wood Chips. *Materials* **2022**, *15*, 8669. [CrossRef]
98. da Gloria, M.Y.R.; Caldas, L.R.; Barros, J.A.O.; Toledo Filho, R.D. A Comprehensive Approach for Designing Low Carbon Wood Bio-Concretes. *Materials* **2024**, *17*, 2742. [CrossRef]
99. Maier, D.; Manea, D.L.; Tămaș-Gavrea, D.-R.; Țiriac, A.; Costin, P. Wood–Cement Composites: A Sustainable Approach for Mitigating Environmental Impact in Construction. *J. Compos. Sci.* **2024**, *8*, 474. [CrossRef]
100. Shtrepi, L.; Astolfi, A.; Badino, E.; Volpatti, G.; Zampini, D. More Than Just Concrete: Acoustically Efficient Porous Concrete with Different Aggregate Shape and Gradation. *Appl. Sci.* **2021**, *11*, 4835. [CrossRef]
101. Fayomi, G.U.; Mini, S.E.; Fayomi, O.S.I.; Ayoola, A.A. Perspectives on Environmental CO_2 Emission and Energy Factor in Cement Industry. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *331*, 012035. [CrossRef]
102. Owaid, H.M.; Hamid, R.B.; Taha, M.R. A Review of Sustainable Supplementary Cementitious Materials as an Alternative to All-Portland Cement Mortar and Concrete. *Aust. J. Basic Appl. Sci.* **2012**, *6*, 287–303.
103. Caprai, V.; Gauvin, F.; Schollbach, K.; Brouwers, H.J.H. MSWI Bottom Ash as Binder Replacement in Wood Cement Composites. *Constr. Build. Mater.* **2019**, *196*, 672–680. [CrossRef]
104. Jami, T.; Karade, S.R.; Singh, L.P. A Review of the Properties of Hemp Concrete for Green Building Applications. *J. Clean. Prod.* **2019**, *239*, 117852. [CrossRef]
105. Demir, İ.; Doğan, C. Physical and Mechanical Properties of Hempcrete. *TOWMJ* **2020**, *13*, 26–34. [CrossRef]
106. Sassu, M.; Giresini, L.; Bonannini, E.; Puppio, M.L. On the Use of Vibro-Compressed Units with Bio-Natural Aggregate. *Buildings* **2016**, *6*, 40. [CrossRef]
107. Sinka, M.; Bajare, D.; Gendelis, S.; Jakovics, A. In-Situ Measurements of Hemp-Lime Insulation Materials for Energy Efficiency Improvement. *Energy Procedia* **2018**, *147*, 242–248. [CrossRef]

108. Sahmenko, G.; Sinka, M.; Paurins, U.; Bajare, D. Production Technology of Ecological High Performance Fibre Composite Construction Materials. *J. Phys. Conf. Ser.* **2023**, *2423*, 012005. [CrossRef]
109. Bourdot, A.; Moussa, T.; Gacoin, A.; Maalouf, C.; Vazquez, P.; Thomachot-Schneider, C.; Bliard, C.; Merabtine, A.; Lachi, M.; Douzane, O.; et al. Characterization of a Hemp-Based Agro-Material: Influence of Starch Ratio and Hemp Shive Size on Physical, Mechanical, and Hygrothermal Properties. *Energy Build.* **2017**, *153*, 501–512. [CrossRef]
110. Hussain, A.; Calabria-Holley, J.; Jiang, Y.; Lawrence, M. Modification of Hemp Shiv Properties Using Water-Repellent Sol–Gel Coatings. *J Sol-Gel Sci Technol* **2018**, *86*, 187–197. [CrossRef]
111. Kubiś, M.; Łapka, P.; Cieślikiewicz, Ł.; Sahmenko, G.; Sinka, M.; Bajare, D. Analysis of the Thermal Conductivity of a Bio-Based Composite Made of Hemp Shives and a Magnesium Binder. *Energies* **2022**, *15*, 5490. [CrossRef]
112. Gomes, C.M.; Garry, A.-L.; Freitas, E.; Bertoldo, C.; Siqueira, G. Effects of Rice Husk Silica on Microstructure and Mechanical Properties of Magnesium-Oxychloride Fiber Cement (MOFC). *Constr. Build. Mater.* **2020**, *241*, 118022. [CrossRef]
113. Li, C.; Yu, H. Influence of Fly Ash and Silica Fume on Water-Resistant Property of Magnesium Oxychloride Cement. *J. Wuhan Univ. Technol.-Mat. Sci. Edit.* **2010**, *25*, 721–724. [CrossRef]
114. Walling, S.A.; Provis, J.L. Magnesia-Based Cements: A Journey of 150 Years, and Cements for the Future? *Chem. Rev.* **2016**, *116*, 4170–4204. [CrossRef] [PubMed]
115. Boccarusso, L.; Durante, M.; Iucolano, F.; Mocerino, D.; Langella, A. Production of Hemp-Gypsum Composites with Enhanced Flexural and Impact Resistance. *Constr. Build. Mater.* **2020**, *260*, 120476. [CrossRef]
116. Mestres, G.; Ginebra, M.-P. Novel Magnesium Phosphate Cements with High Early Strength and Antibacterial Properties. *Acta Biomater.* **2011**, *7*, 1853–1861. [CrossRef]
117. Marques, B.; Almeida, J.; Tadeu, A.; António, J.; Santos, M.I.; de Brito, J.; Oliveira, M. Rice Husk Cement-Based Composites for Acoustic Barriers and Thermal Insulating Layers. *J. Build. Eng.* **2021**, *39*, 102297. [CrossRef]
118. Ashori, A.; Tabarsa, T.; Azizi, K.; Mirzabeygi, R. Wood–Wool Cement Board Using Mixture of Eucalypt and Poplar. *Ind. Crops Prod.* **2011**, *34*, 1146–1149. [CrossRef]
119. Tittelein, P.; Cloutier, A.; Bissonnette, B. Design of a Low-Density Wood–Cement Particleboard for Interior Wall Finish. *Cem. Concr. Compos.* **2012**, *34*, 218–222. [CrossRef]
120. Noh, M.S.M.; Ahmad, Z.; Ibrahim, A.; Walker, P. Development of New Prefabricated Wall Constructed Using Wood-Wool Cement Composite Panel. *Procedia Environ. Sci.* **2016**, *34*, 298–308. [CrossRef]
121. Botterman, B.; Doudart de la Grée, G.C.H.; Hornikx, M.C.J.; Yu, Q.L.; Brouwers, H.J.H. Modelling and Optimization of the Sound Absorption of Wood-Wool Cement Boards. *Appl. Acoust.* **2018**, *129*, 144–154. [CrossRef]
122. Berger, F.; Gauvin, F.; Brouwers, H.J.H. The Recycling Potential of Wood Waste into Wood-Wool/Cement Composite. *Constr. Build. Mater.* **2020**, *260*, 119786. [CrossRef]
123. Argalis, P.P.; Sinka, M.; Andzs, M.; Korjakins, A.; Bajare, D. Development of New Bio-Based Building Materials by Utilising Manufacturing Waste. *Environ. Clim. Technol.* **2024**, *28*, 58–70. [CrossRef]
124. Argalis, P.P.; Sinka, M.; Bajare, D. Recycling of Cement–Wood Board Production Waste into a Low-Strength Cementitious Binder. *Recycling* **2022**, *7*, 76. [CrossRef]