

Valorization of Wood Waste for Sustainable Construction: Circular Economy Approaches Using Sawdust in Cementitious Materials

TIMITIMI, P. E.¹, ALERU, K.K.², DAVID-SAROGORO, N³., CHUKUNDA, F A.⁴

²ORCID ID: 0009-0002-2570-5106

^{1,2}Department of Forestry and Environment, Rivers State University, Nkpulu-Oroworukwo Port Harcourt, Nigeria

Abstract- *The construction industry faces mounting pressure to adopt sustainable practices amid escalating wood waste generation from sawmilling and demolition activities. This review explores the valorization of sawdust, a prevalent wood waste byproduct within cementitious materials as a cornerstone of circular economy strategies. Drawing on recent literature, we examine sawdust's integration as a partial aggregate replacement, filler, or biochar precursor in concrete, mortars, and magnesium oxychloride cement (MOC) composites. Key findings highlight optimal incorporation levels of 5–20% by volume, which yield lightweight materials with enhanced thermal insulation (conductivity reduced to 0.176–0.745 W/mK) and sound absorption (coefficients up to 0.979), while maintaining compressive strengths of 17–50 MPa suitable for non-structural applications. Environmental benefits include diverted landfill waste (e.g., 64 million tonnes annually in the USA), lowered CO₂ emissions (up to 71% reduction compared to plywood), and carbon sequestration via biochar (870 kg CO₂/ton). Challenges such as reduced workability, durability concerns in humid environments, and variability in sawdust quality are addressed through pretreatment methods like boiling or sodium silicate addition. This synthesis underscores sawdust's potential to foster resource-efficient construction, aligning with UN Sustainable Development Goals, and proposes future research on standardized protocols and life-cycle assessments to accelerate adoption.*

Keywords: *Sawdust, wood waste, cementitious materials, circular economy, sustainable construction, biochar, lightweight concrete*

I. INTRODUCTION

The global construction sector is indeed a substantial consumer of raw materials and producer of solid waste, resulting in significant environmental degradation and resource depletion. Studies consistently report that the sector accounts for approximately 40% of worldwide raw material consumption and similarly generates about 35–40%

of global solid waste (Backes and Traverso, 2021; Maier, 2023). This immense demand on primary resources is driven by the extraction, processing, and manufacturing of construction materials, notably concrete, steel, glass, and aluminum, each contributing significantly to resource depletion, emissions, and habitat destruction (Crawford and Cadorel, 2017).

Wood waste, particularly sawdust from timber processing and construction/demolition activities, constitutes a significant portion of this burden, with estimates of over 500 million tonnes produced annually worldwide (Korba *et al.*, 2025). Traditionally landfilled or incinerated, this lignocellulosic residue poses risks including methane emissions, groundwater contamination, and lost economic value. In the context of circular economy (CE) principles, emphasizing reduce, reuse, recycle, and recover, valorizing sawdust in cementitious materials offers a pathway to sustainable construction by transforming waste into functional inputs (Waqar *et al.*, 2024; Shah and Mushtaq, 2024; Priya, 2025; Titan Cement Group, 2025).

Cementitious materials, such as Portland cement concrete and alternatives like MOC, dominate building applications due to their versatility and strength (Maier and Manea, 2022; Ahmad *et al.*, 2024). However, their production accounts for 8% of global CO₂ emissions, underscoring the need for eco-friendly amendments (Karunarathna *et al.*, 2025). Sawdust, comprising 40–50% cellulose, 20–35% hemicellulose, and 15–30% lignin, exhibits pozzolanic potential when ashed and lightweight properties ideal for insulation (Hikmet, 2024). This review synthesizes recent advancements in sawdust incorporation, evaluating mechanical performance, durability, and sustainability metrics. By integrating CE frameworks, it aims to guide researchers and

practitioners toward scalable, low-carbon building solutions.

II. WOOD WASTE GENERATION AND CHALLENGES

Wood waste arises primarily from sawmilling (sawdust and shavings), construction/demolition (offcuts and panels), and forestry operations, with sawdust alone accounting for 20–30% of mill outputs (Korba *et al.*, 2025). Globally, sawmills, furniture industries, and construction sectors collectively generate millions of tonnes of wood residues annually, with sawdust constituting a major fraction (Priya *et al.*, 2025). In the European Union, construction wood waste totals 33.2 million tonnes yearly, much of which is underutilized due to contamination and regulatory hurdles (Maier, 2023). In developing countries such as Nigeria, poor waste management practices, outdated milling technologies, and lack of recycling infrastructure contribute to significant wood material losses often exceeding 40% of total log volume (Nwuisuator *et al.*, 2011; Owoyemi *et al.*, 2016; Akhator *et al.*, 2017). Challenges include heterogeneous composition (e.g., varying moisture content of 10–50% and presence of adhesives), leading to inconsistent quality for reuse, and environmental hazards from open burning, which releases particulate matter and volatile organics (Berger *et al.*, 2020; Kulikova *et al.*, 2022; Pazzaglia and Castellani, 2023).

Sawdust, wood shavings, and offcuts are typically disposed of through open dumping or burning, leading to air pollution, greenhouse gas emissions, and occupational health risks (Kassim *et al.*, 2024). These residues, when unmanaged, clog drainage systems, occupy valuable land space, and pose fire hazards. Moreover, the heterogeneous composition and high moisture content of wood waste make collection, transportation, and reuse difficult (Taylor and Warnken, 2008; Pazzaglia and Castellani, 2023; Korba *et al.*, 2025).

Table 1 presents a synthesis of peer-reviewed studies and official statistics, providing a current view of

wood waste management globally, with a focus on Nigeria. Annually, Nigeria generates approximately 5.2 million tonnes of wood waste, of which sawdust accounts for about 34–35%, predominantly from sawmill operations (Owoyemi *et al.*, 2016; Udokpoh and Nnaji, 2022, 2023). Disposal remains largely informal, through open dumping and burning, leading to environmental pollution and health risks. Emerging recycling initiatives, such as sawdust briquette production, show promise in mitigating these impacts while offering economic benefits (Udokpoh and Nnaji, 2023; WorkPlus, 2021). Persistent challenges include inadequate waste infrastructure, policy gaps, and limited public awareness (Nwuisuator *et al.*, 2011; Oluoti *et al.*, 2014). In contrast, regions like the European Union (~35–40 Mt annually) and the United States (~12.2 Mt to landfills in 2018) implement more advanced management systems involving recycling, reuse, biomass energy, and landfill reduction, though contamination, regulatory fragmentation, and circular economy adoption gaps remain (European Union, 2018; Korba *et al.*, 2025; U.S. EPA, 2024; Agyemang *et al.*, 2024; Priya *et al.*, 2025; Leone *et al.*, 2025; Coherent Market Insights, 2025). Overall, sustainable reuse strategies and improved policy implementation could significantly enhance Nigeria's wood waste management, unlocking environmental and socio-economic benefits.

From a circular economy standpoint, these challenges highlight the urgent need for sustainable valorization pathways. Transforming wood waste, particularly sawdust into value-added materials for construction aligns with global sustainability targets by minimizing environmental pollution and promoting resource efficiency. However, limited awareness, inadequate policy frameworks, and weak market incentives still hinder large-scale adoption of wood waste recycling technologies in many regions (Leone *et al.*, 2025; Jonathan and Onyoni, 2025; Maduwage *et al.*, 2025). Addressing these challenges is essential for transitioning from a linear “take–make–dispose” model to a circular bioeconomy that supports sustainable construction and waste minimization.

Table 1: Global Wood Waste Statistics and Management Challenges

Region / Country	Annual Wood Waste (Mt)	Sawdust Share (%)	Primary Disposal / Use Method(s)	Key Challenges (in context)	Sources
Global General	~18 Mt (2018 data)	Varies by region	Recycling, reuse, biomass, landfill (significant portion)	Scarcity of recycling facilities, contamination, sorting complexity, regulatory and technological limitations	WorkPlus, 2021; Agyemang <i>et al.</i> , 2024; Priya <i>et al.</i> , 2025; Leone <i>et al.</i> , 2025; Coherent Market Insights. 2025.
European Union	Estimated 35-40 Mt	Not separately specified	Recycling, biomass energy, reuse in boards, landfill reduction efforts	Lack of harmonized classification standards; contamination issues; regulatory fragmentation; circular economy adoption gaps	European Union, 2018; Korba <i>et al.</i> , 2025;
United States	~12.2 Mt (wood waste sent to landfills, 2018)	Not clearly specified	Recycling, reuse, biomass energy, landfiling	Emissions from burning; mold/fungal contamination in landfills; recycling contamination	WorkPlus, 2021, U.S. Environmental Protection Agency. (2024).
Nigeria	~5.2 Mt total wood waste; ~1.8 Mt sawdust	~34-35% (estimated sawdust share)	Largely open dumping and burning; some briquette production; limited recycling and reuse	Insufficient waste management infrastructure; open burning causing air pollution and health risks; lack of policy enforcement and public awareness	Nwiisuator <i>et al.</i> , 2011; Oluoti <i>et al.</i> , 2014; Owoyemi <i>et al.</i> , 2016; Udokpoh and Nnaji, 2022; Udokpoh and Nnaji, 2023.
Ghana	~0.003 (3 Mt) (wood waste)	~ 40 (timber sector)	Some reuse / pellet / briquette production	Outdated equipment, poor conversion efficiency, low market uptake	Mawusi <i>et al.</i> 2023

III. CIRCULAR ECONOMY PRINCIPLES IN CONSTRUCTION

CE in construction shifts from linear extraction to closed-loop systems, with wood waste valorization exemplifying the 4R hierarchy (Hikmet, 2024). Reduce strategies minimize waste at source through efficient design; reuse repurposes untreated sawdust in non-structural elements; recycle converts it into aggregates or pozzolans; and recover leverages pyrolysis for biochar (Karunarathna *et al.*, 2025). In cementitious contexts, these approaches lower embodied carbon, e.g., Sawdust–Magnesium Oxychloride Cement (MOC) composites emit 71%

less CO₂ than plywood while enhancing material circularity (Maier, 2023).

Policy frameworks, including the EU's Waste Framework Directive, incentivize such innovations, yet gaps in standardization hinder market penetration (Korba *et al.*, 2025). Successful cases, like sawdust-amended bricks in developing regions, demonstrate economic viability through cost savings of 10–20% on aggregates (Narsinge *et al.*, 2022, Hikmet, 2024). As such, figure 1 captures the circular economy potential of sawdust in sustainable construction through treatment, reuse, and favorable feedback loops that minimize environmental impact.

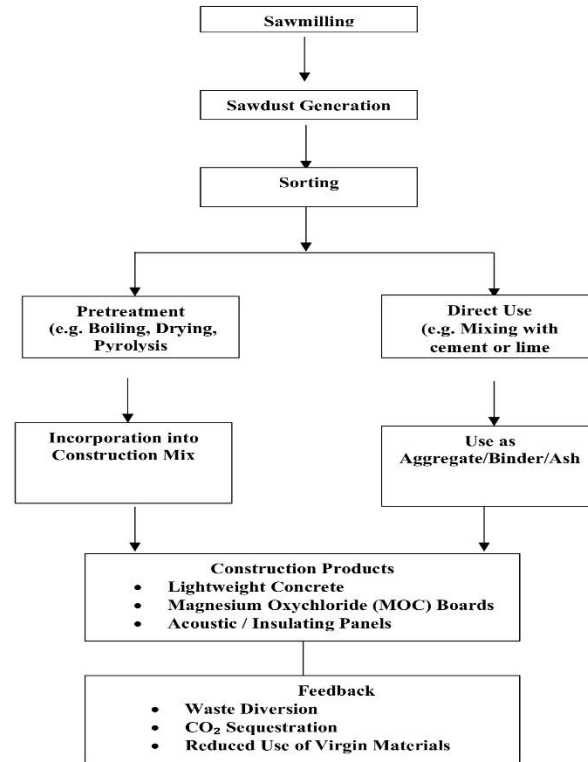


Figure 1: Circular Economy Framework for Sawdust in Construction

IV. PROPERTIES OF SAWDUST AND PRETREATMENT METHODS

Sawdust's fibrous structure imparts low density (200–400 kg/m³) and high porosity, beneficial for lightweight composites but challenging for hydration due to organic inhibitors like sugars (Pereira *et al.*, 2019; Alabduljabbar *et al.*, 2020; Hikmet, 2024). Key properties include thermal conductivity of 0.05–0.1 W/mK and water absorption up to 200%, necessitating pretreatments (Charai, 2020; Bahar *et al.*, 2024).

Common methods include mechanical grinding to <1 mm particles, chemical immersion in lime or aluminum sulfate to remove extractives, and thermal treatments like boiling or sodium silicate coating, which boost interfacial bonding by 20–30% (Hikmet, 2024). For biochar derivation, pyrolysis at 300–700°C yields porous carbon (surface area 200–600 m²/g) with neutral pH, ideal for internal curing (Karunarathna *et al.*, 2025). These enhancements ensure compatibility with cement matrices, mitigating early-age strength losses

Table 2: Sawdust Pretreatment Methods and Effects.

Method	Process Description	Effect on Properties
Grinding	Reduces particle size to <1 mm	Improves mix homogeneity and overall workability
Chemical (Lime Treatment)	Immersion in Ca (OH) ₂ solution	Removes sugars and inhibitory compounds; enhances bonding strength
Boiling	Hot water treatment at 80–100 °C	Reduces extractives, increases dimensional stability, and improves durability
Pyrolysis (Biochar Production)	Thermal decomposition at 300–700 °C	Increases surface area, promotes better hydration, and enhances pozzolanic activity

Sources: Hikmet, 2024; Karunarathna *et al.*, 2025

V. INCORPORATION OF SAWDUST IN CEMENTITIOUS MATERIALS

5.1 As Filler/Aggregate Replacement

Sawdust has emerged as a viable partial replacement for conventional fine aggregates such as sand in concrete production. When incorporated at proportions ranging between 5% and 15% (for example, in a 1:2:4 cement:sand:sawdust mix ratio), sawdust effectively reduces the overall density of concrete to about 1,120–1,920 kg/m³. This range falls within the limits specified by ASTM C330 for lightweight concrete applications (Oyedepo *et al.*, 2014; Rakshith and Dharshan, 2023). Although the inclusion of sawdust slightly lowers compressive strength compared to conventional concrete, the resulting mix still meets structural requirements for non-load-bearing and insulation purposes. The lightweight nature of such composites also offers advantages in thermal insulation and ease of handling during construction.

In the case of magnesium oxychloride cement (MOC) composites, higher proportions of wood waste ranging between 50% and 70% have been used to produce lightweight boards with enhanced fire resistance, excellent sound absorption, and dimensional stability (Maier, 2023). These properties make sawdust–MOC composites particularly suitable for interior wall panels, ceiling boards, and acoustic applications in buildings seeking sustainable and eco-friendly materials.

Furthermore, sawdust ash (SDA), obtained through controlled combustion of sawdust, serves as a supplementary cementitious material (SCM) in concrete production. Replacing 5–20% of ordinary Portland cement (OPC) with SDA can improve long-term mechanical strength and durability due to its high pozzolanic activity, typically characterized by silica (SiO₂) content exceeding 70% (Hikmet, 2024). This substitution not only reduces the demand for cement—a major source of CO₂ emissions but also contributes to waste minimization and circular economy goals in the construction sector. Thus, the integration of sawdust and its derivatives as fillers or partial aggregate replacements represents a promising step toward sustainable construction practices. It enhances material efficiency, reduces environmental impact, and supports the valorization of wood waste into high-value building materials.

5.2 As Fiber Reinforcement

Beyond its use as a filler or aggregate replacement, sawdust can also function effectively as a natural fiber reinforcement in cementitious composites. When incorporated in chopped form typically 5–10 mm in length and added at 1–5% by volume, sawdust fibers enhance the ductility and toughness of mortar and concrete mixes. These fibers act as micro-reinforcements that bridge microcracks, delaying their propagation and thereby improving post-cracking behavior and energy absorption (Gil *et al.*, 2017; Cheng *et al.*, 2024).

At lower dosages (around 1–2%), the flexural and tensile strengths of the composite tend to increase significantly due to effective stress transfer between the cement matrix and the wood fibers. However, as the fiber content rises beyond optimal levels, issues such as poor dispersion, increased void content, and weak interfacial bonding can lead to a reduction in overall mechanical strength. This behavior highlights the importance of maintaining an appropriate balance between workability and reinforcement efficiency when designing sawdust fiber–reinforced mortars.

Recent studies have also demonstrated that combining sawdust fibers with alkali-activated or geopolymeric binders can further enhance performance. Such hybrid composites exhibit 10–20% higher tensile and flexural capacities compared to conventional Portland cement mixes, owing to improved fiber–matrix adhesion and reduced brittleness (Hikmet, 2024). Moreover, the natural lignocellulosic composition of sawdust contributes to internal curing and improved crack resistance, making it an attractive reinforcement material for sustainable, low-carbon construction systems.

The incorporation of sawdust as a fiber reinforcement material offers a low-cost and eco-friendly strategy for improving toughness, ductility, and durability in green concrete. Its use aligns with circular economy objectives by transforming a common wood waste into a valuable functional additive within the construction industry.

5.3 Biochar from Sawdust

Another innovative valorization pathway for sawdust lies in its thermal conversion into biochar through pyrolysis. When sawdust is subjected to controlled heating in the absence of oxygen, it produces a highly porous, carbon-rich residue that can serve as an

effective microfiller and functional additive in cementitious composites. Incorporating pyrolyzed sawdust biochar at modest dosages (typically 1–5% by weight of binder) has been shown to refine pore structure, improve particle packing, and enhance the internal hydration environment of cement matrices (Karunarathna *et al.*, 2025).

The porous surface morphology of biochar facilitates water absorption and gradual release during curing, thereby improving the degree of cement hydration by 16–22% and reducing autogenous shrinkage by up to 25%. This internal curing effect helps mitigate early-age cracking, leading to better dimensional stability and enhanced long-term durability of the material. Furthermore, the high specific surface area and reactive functional groups of biochar contribute to the nucleation of hydration products, promoting denser microstructures and improved mechanical integrity (Zhao *et al.*, 2024; Salem and Fen-Chong, 2025; Jeon *et al.*, 2025).

Pre-soaking biochar before mixing has been reported to further optimize its performance, particularly in low-water or arid environments where cement hydration is limited (Korba *et al.*, 2025). The pre-saturated biochar releases stored moisture gradually, acting as a micro-reservoir that sustains hydration reactions and minimizes self-desiccation.

From a sustainability perspective, sawdust-derived biochar represents a carbon-negative additive, as it permanently locks atmospheric carbon within its stable aromatic structure. Its integration into concrete production thus contributes to carbon sequestration and circular economy (CE) objectives transforming wood waste into a high-value construction input while reducing the overall environmental footprint of traditional cement systems (Khadka, 2022; Senadheera *et al.*, 2023; Liu *et al.*, 2023).

In essence, the incorporation of biochar from sawdust not only improves the physical and mechanical performance of cement-based materials but also aligns with global efforts toward low-carbon and resource-efficient construction practices.

VI. MECHANICAL AND DURABILITY PROPERTIES

Cementitious materials incorporating sawdust and biochar exhibit a range of mechanical and durability characteristics that reflect the balance between sustainable material use and structural performance. Compressive strengths typically vary between 17 and 50 MPa under optimal conditions. For instance, a 10% sawdust replacement often achieves around 27 MPa after 28 days of curing. However, increasing sawdust content beyond 15% can lead to significant strength reductions up to 50–70% loss primarily due to increased porosity and reduced particle packing (Gwarah *et al.*, 2019; Abdul Awal *et al.*, 2021; Rakshith and Dharshan, 2023).

Flexural and tensile properties follow a similar trend. While higher sawdust ratios generally result in 20–40% decreases in bending and tensile strengths, incorporating biochar can counteract some of these losses, with studies reporting up to 21% improvements in these mechanical properties (Karunarathna *et al.*, 2025). This synergy highlights biochar's role not only as a sustainable filler but also as a performance-enhancing additive.

Durability assessments provide additional insights. Sawdust and biochar composites show enhanced sulfate resistance, attributed to pozzolanic reactions that refine the pore structure. However, these materials remain susceptible to freeze-thaw damage if no supplementary additives are used. Thermal performance is more promising, with strength losses staying below 25% even at 500°C (Hikmet, 2024). Furthermore, these composites exhibit excellent sound absorption properties, with coefficients ranging from 0.65 to 0.979, making them strong candidates for acoustic panels and noise-reducing applications.

Overall, sawdust and biochar-modified cementitious materials demonstrate a delicate trade-off: moderate sawdust replacement can enhance sustainability without heavily compromising strength, while biochar offers a route to boost both mechanical performance and durability.

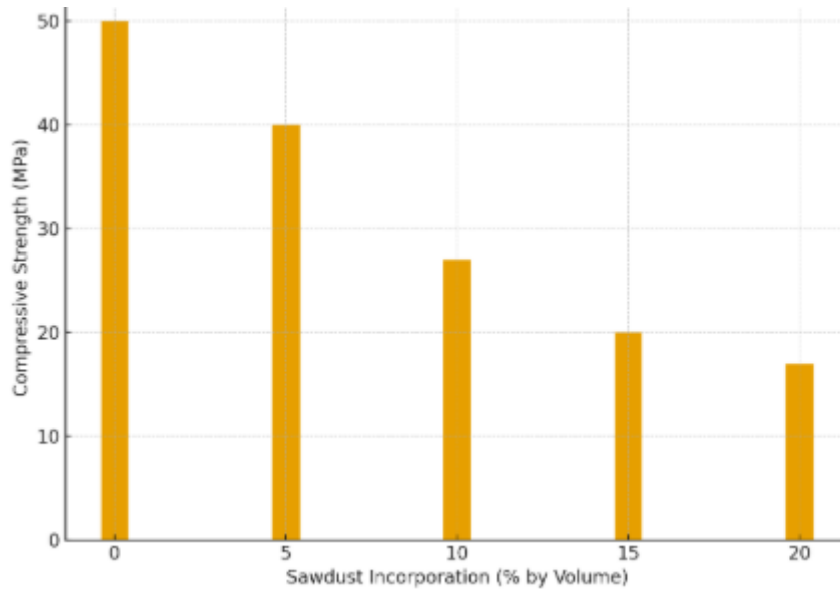


Figure 2. Relationship between Sawdust Incorporation and Compressive Strength of Blocks

As shown in Table 3, increasing sawdust content reduces density and compressive strength due to the lightweight, porous nature of sawdust, which limits matrix compaction and cement hydration (Ahmed *et al.*, 2018; Olaiya *et al.*, 2023). Conversely, thermal conductivity and sound absorption improve with

higher sawdust levels, indicating enhanced insulation and acoustic performance (Maier, 2023). These results suggest that moderate sawdust inclusion ($\leq 10\%$) offers an optimal balance between strength, energy efficiency, and sustainability in lightweight, non-load-bearing construction applications

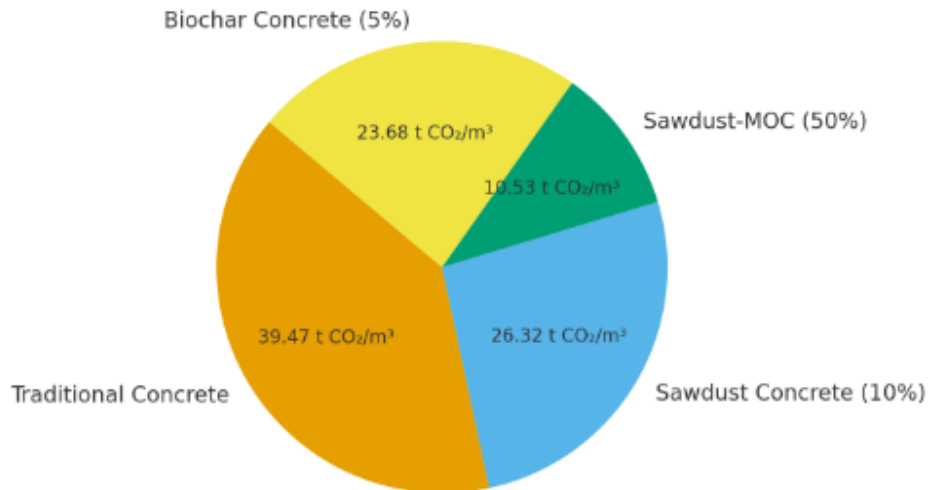
Table 3. Selected Physical and Mechanical Properties of Sawdust-Modified Blocks

Property	Sawdust Content (%)	Measured Value	Reference
Density (kg/m ³)	5–15	1,120–1,920	Ahmed <i>et al.</i> , 2018; Olaiya <i>et al.</i> , 2023
Compressive Strength (MPa, 28 days)	10	27	Ahmed <i>et al.</i> , 2018; Olaiya <i>et al.</i> , 2023
Thermal Conductivity (W/m·K)	10–20	0.176–0.745	Maier (2023)
Sound Absorption Coefficient	50 (MOC boards)	0.65–0.979	Maier (2023)

VII. ENVIRONMENTAL AND ECONOMIC IMPACTS

Valorization diverts 40–60% of sawdust from landfills, slashing emissions (0.006–0.013 t CO₂/m³ saved) and enabling sequestration (870 kg/ton biochar) (Karunarathna *et al.*, 2025). MOC-sawdust composites reduce VOCs and energy use by 58%, supporting SDG 12 (Maier, 2023). Economically, costs drop 1–10% via waste offsets, with payback through insulation savings (García *et al.*, 2021; Udokpoh and Nnaji, 2023). Life-cycle analyses confirm net positives, though scaling requires policy support (Korba *et al.*, 2025).

Figure 3 shows that incorporating wood-based materials significantly reduces CO₂ emissions. Traditional concrete emits 0.15 t CO₂/m³, while sawdust concrete (10%) and biochar concrete (5%) lower emissions to 0.10 and 0.09 t CO₂/m³, respectively. The sawdust–MOC composite (50%) records the lowest at 0.04 t CO₂/m³ due to its carbon-absorbing capacity. These findings demonstrate the potential of sawdust and biochar in reducing cement dependence and promoting low-carbon construction (Maier, 2023; Karunarathna *et al.*, 2025).



Source: Updated: Maier, 2023; Karunarathna *et al.*, 2025

Figure 3: Comparative CO₂ emissions of traditional and modified concrete types

VIII. CHALLENGES AND FUTURE DIRECTIONS

Key hurdles include workability reduction (higher water demand), fire susceptibility, and quality variability, addressable via superplasticizers and standardized sorting (Hikmet, 2024). Long-term field trials and leaching assessments are needed, alongside hybrid formulations with geopolymers (Karunarathna *et al.*, 2025). Future research should prioritize AI-driven classification and global LCA frameworks to mainstream CE adoption.

IX. CONCLUSION

Sawdust valorization in cementitious materials stands as a practical demonstration of the transformative potential of the Circular Economy (CE) within the construction sector. By converting what is often regarded as waste into a valuable raw material, this approach promotes resource efficiency, waste reduction, and carbon footprint mitigation. When optimally incorporated, typically within the 5–20% range and following appropriate pretreatment methods, sawdust can produce lightweight, thermally insulating, and eco-friendly composites suitable for a wide range of non-structural applications such as blocks, panels, and mortars.

Beyond its environmental benefits, this valorization process contributes to economic sustainability by lowering material costs, reducing dependence on virgin raw materials, and creating new avenues for green innovation and job opportunities within local

wood and construction industries. However, realizing its full potential requires harmonized standards, policy support, and continuous research to optimize performance, durability, and scalability.

Ultimately, the integration of sawdust into cementitious materials represents more than a technical solution, it symbolizes a shift toward a regenerative construction paradigm, where waste is reimagined as a resource. Through collaborative innovation and standardization, this vision can lead to resilient, low-carbon, and circular built environments, contributing meaningfully to global sustainability goals and the transition to a cleaner future.

REFERENCES

- [1] Abdul Awal, A. S. M., Mariyana, A. A. K., & Hossain, M. Z. (2021). Some aspects of physical and mechanical properties of sawdust concrete. *GEOMATE Journal*, 10(21), 1918–1923. <https://geomatejournal.com/geomate/article/view/2053>
- [2] Agyemang, E., Ofori-Dua, K., Dwumah, P., & Forkuor, J. B. (2024). Towards responsible resource utilization: A review of sustainable vs. unsustainable reuse of wood waste. *PLOS ONE*, 19(12), e0312527. <https://doi.org/10.1371/journal.pone.0312527>
- [3] Ahmad, F., Rawat, S., & Zhang, Y. (2024). Magnesium oxychloride cement: development,

- opportunities and challenges. *Applied Sciences*, 14(7), 3074.
- [4] Ahmed, W., Khushnood, R. A., Memon, S. A., Ahmad, S., Baloch, W. L., & Usman, M. (2018). Effective use of sawdust for the production of eco-friendly and thermal-energy efficient normal weight and lightweight concretes with tailored fracture properties. *Journal of Cleaner Production*, 184, 1016-1027.
- [5] Akhator, P., Obanor, A.I., & Ugege, A. (2017). Nigerian Wood Waste: A Potential Resource for Economic Development. *Journal of Applied Sciences and Environmental Management*, 21, 246-251.
- [6] Alabduljabbar, H., Huseien, G. F., Sam, A. R. M., Alyouef, R., Algaifi, H. A., & Alaskar, A. (2020). Engineering properties of waste sawdust-based lightweight alkali-activated concrete: Experimental assessment and numerical prediction. *Materials*, 13(23), 5490. <https://doi.org/10.3390/ma13235490>
- [7] Backes, J. G. & Traverso, M. (2021). Application of life cycle sustainability assessment in the construction sector: a systematic literature review. *Multidisciplinary Digital Publishing Institute*. <https://doi.org/10.3390/pr9071248>
- [8] Bahar, A. A., Yulianto, A., & Astuti, B. (2024). Effect of sawdust addition on thermal conductivity of clay bricks. *Rekayasa Sipil*, 18(1), 72–77. <https://doi.org/10.21776/ub.rekayasasipil.2024.018.01.12>
- [9] Berger, F., Gauvin, F., & Brouwers, H. J. H. (2020). The recycling potential of wood waste into wood-wool/cement composite. *Construction and Building Materials*, 260, 119786. <https://doi.org/10.1016/j.conbuildmat.2020.119786>
- [10] Charai, M., Sghiouri, H., Mezrhab, A., Karkri, M., Elhammouti, K., & Nasri, H. (2020). Thermal performance and characterization of a sawdust-clay composite material. *Procedia Manufacturing*, 46, 690–697. <https://doi.org/10.1016/j.promfg.2020.03.098>
- [11] Cheng Y, Liu J, Wang W, Jin L and Yan S (2024) Preparation and property study of sawdust-modified cement mortar. *Front. Mater.* 11:1457167. doi: 10.3389/fmats.2024.1457167
- [12] Coherent Market Insights. (2025). Wood recycling market size and share analysis — growth trends and forecasts 2025-2032. 2025, February 11 <https://www.coherentmarketinsights.com/industry-reports/wood-recycling-market>
- [13] Crawford, R. H. & Cadorel, X. (2017). A framework for assessing the environmental benefits of mass timber construction. Elsevier BV. <https://doi.org/10.1016/j.proeng.2017.08.015>
- [14] European Union (2018). European wood waste statistics report for recipient and model regions. Ref. Ares (2018)5746538 - 09/11/2018. <https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bf1792ce&appId=PPGMS>
- [15] García, R., González-Vázquez, M. P., Rubiera, F., Pevida, C., & Gil, M. V. (2021). Copelletization of pine sawdust and refuse derived fuel (RDF) to high-quality waste-derived pellets. *Journal of Cleaner Production*, 328, Article 129635. <https://doi.org/10.1016/j.jclepro.2021.129635>
- [16] Gil, H., Ortega, A., & Pérez, J. (2017). Mechanical behavior of mortar reinforced with sawdust waste. *Procedia Engineering*, 200, 325–332. <https://doi.org/10.1016/j.proeng.2017.07.046>
- [17] Gwarah, L. S., Akatah, B. M., Onungwe, I., & Akpan, P. P. (2019). Partial replacement of ordinary Portland cement with sawdust ash in concrete. *Current Journal of Applied Science and Technology*, 32(6), 1–7. <https://doi.org/10.9734/cjast/2019/v32i630036>
- [18] Hikmet, N. G. (2024). An up-to-date review of sawdust usage in construction materials. *Journal of Engineering*, 30(11), 164–184. <https://doi.org/10.31026/j.eng.2024.11.10>
- [19] Jeon, I. K., Kim, Y.-R., & Bullard, J. W. (2025). Examining the Effects of Biochar Characteristics on Early-Age Hydration and Fresh Properties of Cement Paste. *Transportation Research Record: Journal of the Transportation Research Board*, 0(0),1-14. <https://doi.org/10.1177/03611981251345760>
- [20] Jonathan, C., & Onyoni, J. (2025). A feasible circularity model for construction wood wastes in developing countries: The case of Kenya and Nigeria. *Journal of Circular Economy*, 3(1), 1-24. <https://doi.org/10.55845/AGPI3177>
- [21] Karunarathna, S., Gunasekara, C., Law, D., Jayathilakage, R., Setunge, S., & Xavier, L. (2025). Timber and wood waste biochar in

- cementitious composites: a circular economy approach to performance and sustainability: a review. *Journal of Material Cycles and Waste Management*, 1-26. <https://doi.org/10.1007/s10163-025-02345-x>
- [22] Khadka, S. (2022). Addition of biochar in concrete for improved carbon sequestration: Case of Project BiBe (Bachelor's thesis). South-Eastern Finland University of Applied Sciences. https://www.theseus.fi/bitstream/handle/10024/744875/Khadka_Suman.pdf?sequence=2 42p
- [23] Korba, A., Lekawska-Andrinopoulou, L., Chatziioannou, K., Tsimiklis, G., & Amditis, A. (2025). Wood waste valorization and classification approaches: A systematic review. *Open Research Europe*, 5, 5. <https://doi.org/10.12688/openreseurope.18862.2>
- [24] Kulikova, Y., Sukhikh, S., Babich, O., Yuliya, M., Krasnovskikh, M., & Noskova, S. (2022). Feasibility of old bark and wood waste recycling. *Plants*, 11(12), 1549. <https://doi.org/10.3390/plants11121549>
- [25] Leone, R., La Scalia, G., & Saeli, M. (2025). A critical review on reuse potentials of wood waste for innovative products and applications: Trends and future challenges. *Sustainable Futures*, 10, 100869. <https://doi.org/10.1016/j.sfr.2025.100869>
- [26] Liu, J., Liu, G., Zhang, W., Li, Z., Jin, H., & Xing, F. (2023). A new approach to CO₂ capture and sequestration: A novel carbon capture artificial aggregates made from biochar and municipal waste incineration bottom ash. *Construction and Building Materials*, 398, 132472. <https://doi.org/10.1016/j.conbuildmat.2023.132472>
- [27] Maduwage, R. S., Ramachandra, T., Indikatiya, I. H. P. R., & Karunasinghe, N. S. (2025). Managing barriers affecting the implementation of sustainable construction wood waste management in Sri Lanka. *Conference Proceedings of the International Conference on Facilities Management Futures 2025*, 222–230. University of Moratuwa. <https://doi.org/10.31705/ICFMF2025.16>
- [28] Maier, A., & Manea, D. L. (2022). Perspective of using magnesium oxychloride cement (MOC) and wood as a composite building material: a bibliometric literature review. *Materials*, 15(5), 1772.
- [29] Maier, D. (2023). A review of the environmental benefits of using wood waste and magnesium oxychloride cement as a composite building material. *Materials*, 16(5), 1944. <https://doi.org/10.3390/ma16051944>
- [30] Narsinge, M., Kamble, S., Saste, J., Kolte, R., & Dethe, S. (2022). Study of composite bricks from sawdust and cement. *International Journal for Research in Applied Science and Engineering Technology*, 10(5), 4978–4983. <https://doi.org/10.22214/ijraset.2022.43523>
- [31] Nnaji, C.C. & Udokpoh, U. (2022) Sawdust waste management in Enugu timber market. *Proceedings of the International Conference on Industrial Engineering and Operations Management Nsukka, Nigeria, 5 - 7 April, 2022*
- [32] Nwiisator, D., Emerhi, E. A., Ariwaodo, J. O., & Aleru, K. (2011). Wood waste generation and lumber conversion efficiency of selected sawmills in Port Harcourt, Nigeria. *Acta Agronomica Nigeriana*, 11(1&2), 8–14. <http://www.agricolanig.org>
- [33] Olaiya, B. C., Lawan, M. M., & Olonade, K. A. (2023). Utilization of sawdust composites in construction—a review. *SN Applied Sciences*, 5(5), 140.
- [34] Oluoti, K., Megwai, G., Pettersson, A. and Richards, T. (2014) Nigerian Wood Waste: A Dependable and Renewable Fuel Option for Power Production. *World Journal of Engineering and Technology*, 2, 234-248. doi: 10.4236/wjet.2014.23025.
- [35] Owoyemi, J. M., Olawale, Z. H., & Olalekan, E. I. (2016). Sustainable wood waste management in Nigeria. *Environmental & Socio-economic Studies*, 4(3), 1–9. <https://doi.org/10.1515/enviro-2016-0012>
- [36] Oyedepo, O. J., Oluwajana, S. D., & Akande, S. P. (2014). Investigation of properties of concrete using sawdust as partial replacement for sand. *Civil and Environmental Research*, 6(2), 35–41. <https://www.iiste.org/Journals/index.php/CER/article/view/123>
- [37] Pazzaglia, A., & Castellani, B. (2023). A decision tool for the valorization of wood waste. *Environmental and Climate Technologies*, 27(1), 824–835. <https://doi.org/10.2478/rtuect-2023-0060>
- [38] Pereira, D. C., Amaral-Labat, G., & Lenze, G. F. B. S. (2019). Effect of sawdust as porosity agent on final properties of geopolymers. *Cerâmica*,

- 65(1), 104–109. <https://doi.org/10.1590/0366-6913201965S12607>
- [39] Priya, E., Vasanthi, P., Prabhu, B., & Murugesan, P. (2025). Sawdust as a sustainable additive: Comparative insights into its role in concrete and brick applications. *Cleaner Waste Systems*, 11, 100286. <https://doi.org/10.1016/j.clwas.2025.100286>
- [40] Rakshith, B. R., & Dharshan K. (2023). Comparative study on concrete with sawdust as a partial replacement for sand by conventional and self-curing methods. *International Journal for Multidisciplinary Research (IJFMR)*, 5(4), 1–6. <https://doi.org/10.36948/ijfmr.2023.v05i04.4698>
- [41] Salem, T., & Fen-Chong, T. (2025). Clarifying the effect of biochar on the hydration, setting, workability, and mechanical strength of cementitious materials. *Construction and Building Materials*. Advance online publication. <https://doi.org/10.1016/j.conbuildmat.2025.141892>
- [42] Senadheera, S. S., Gupta, S., Kua, H. W., Hou, D., Kim, S., Tsang, D. C. W., & Ok, Y. S. (2023). Application of biochar in concrete – A review. *Cement and Concrete Composites*, 143, 105204. <https://doi.org/10.1016/j.cemconcomp.2023.105204>
- [43] Taylor, J., & Warnken, M. (2008). Wood recovery and recycling: A source book for Australia (Project No. PNA017-0708). Forest & Wood Products Australia Limited. https://fwpa.com.au/wp-content/uploads/2008/12/PNA017-0708_Wood_Recycling_0.pdf
- [44] Titan Cement Group (2025) Use of alternative raw materials and fuels. <https://www.titan.gr/en/sustainability/environment/circular-economy/alternative-raw-materials-and-fuels>
- [45] U.S. Environmental Protection Agency. (2024). Wood: Material-specific data. 2024, November 8. <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/wood-material-specific-data>
- [46] Udokpoh, U., & Nnaji, C. (2023). Reuse of sawdust in developing countries in the light of sustainable development goals. *Recent Progress in Materials*, 5(1), 006. <https://doi.org/10.21926/rpm.2301006>
- [47] Waqar, A., Khan, M.B., Najeh, T., Almujiabah, H.R. & Benjeddou O. (2024) Performance-based engineering: formulating sustainable concrete with sawdust and steel fiber for superior mechanical properties. *Frontiers in Materials*. 11:1428700. doi: 10.3389/fmats.2024.1428700
- [48] WorkPlus NL. (2021). Wood waste statistics. WorkPlus. 2021, December 2 <https://www.workplus.nl/mobile-homes/wood-waste-statistics>
- [49] Zhao, Z., El-Naggar, A., Kau, J., Olson, C., Tomlinson, D., & Chang, S. X. (2024). Biochar affects compressive strength of Portland cement composites: A meta-analysis. *Biochar*, 6(1), 21. <https://doi.org/10.1007/s42773-024-00309-2>