International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

INTERNATIONAL JOURNAL OF INNOVATION AND INDUSTRIAL REVOLUTION (IJIREV)
www.ijirev.com

GLOBAL ACADEMIC EXCELLENCE

EXPLORING THE POTENTIAL OF AGRO-WASTE IN THE DEVELOPMENT OF SUSTAINABLE, LIGHTWEIGHT, AND THERMALLY INSULATING BUILDING MATERIALS

Ammar Bello[1], Shamsuddeen Yusuf Umar [2]

[1] College of Professional Studies, Northeastern University, USA.
Email: bello.am@northeastern.edu
[2] Department of Civil Engineering, Eastern Mediterranean University, Cyprus.
Email: yusufshamsudeen1@gmail.com
[*] Corresponding Author

Article Info:

Article history:
Received date: 23.12.2024
Revised date: 31.12.2024
Accepted date: 22.01.2025
Published date: 17.03.2025

To cite this document:

Bello, A., & Umar, S. Y. (2025). Exploring The Potential Of Agro-Waste In The Development Of Sustainable, Lightweight, And Thermally Insulating Building Materials. *International Journal of Innovation and Industrial Revolution, 7* (20), 210-223.

DOI: 10.35631/IJIREV.720012

Abstract:

The construction industry is grappling with significant challenges due to the rapid expansion of urban populations and the resultant depletion of natural resources critical for producing construction materials. Overexploitation of resources such as natural and river sand, alongside agricultural by-products like paddy husks and sugarcane residues, has raised serious sustainability concerns. This review investigates the potential of groundnut shells and their derivatives as sustainable alternatives to conventional construction materials, including cement, fine aggregates, and coarse aggregates. It offers a detailed analysis of their physical properties, chemical composition, and environmental benefits, highlighting their applications in thermal insulation, lightweight construction, and sustainable building practices. The advantages of incorporating Agro-waste, such as reduced embodied energy, cost efficiency, and improved thermal insulation, are underscored, while challenges like the absence of standardized regulations and material quality inconsistencies are also addressed. Additionally, the review evaluates the physical, thermo-mechanical, methodological, and ecological impacts of Agro-waste, emphasizing its commercial viability and contributions to energy security. By providing valuable insights for researchers and professionals in construction, waste management, sustainable development, and recycling, this review aims to advance Agro-waste standards and foster sustainable construction practices.

Keywords:

Agro-Waste, Sustainable Construction Material, Building Materials, Groundnut, Shell Ash.

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

Introduction

The growing global population, projected to reach 9.7 billion by 2050, has precipitated a concomitant increase in demands on social amenities, including housing (United Nations, 2019). Consequently, this has led to a strain on the building sector, exacerbating the already pressing issue of meeting the demand for traditional materials such as cement, steel, and wood (Gartner, 2004). Furthermore, the disposal of agricultural crop waste products has emerged as a significant environmental concern, with a staggering 600 metric tons of waste reported in India alone (Gupta et al., 2015). This alarming statistic underscores the need for innovative solutions to mitigate the environmental impacts of agricultural waste. Recent studies have conclusively demonstrated that utilizing agricultural waste and by products to create building materials is a viable and viable solution (Ashraf et al., 2020). Notably, researchers have successfully harnessed agricultural crop wastes, such as peanut shells and rice husks, to create sustainable building materials that meet the stringent ASTM standards for strength and durability (Rahman et al., 2016). Moreover, natural fibres derived from wheat and barley straw have been employed to create non-toxic and sustainable building materials, thereby reducing the reliance on traditional materials (Khan et al., 2018). This paradigm shift in the construction industry has far-reaching implications for environmental sustainability.

The pigeon pea plant has also been identified as a potential source of sustainable building materials, owing to its versatility and abundance (Abdulkadir et al., 2017). However, the burning of woody stems from the plant has become a significant environmental problem, perpetuating air pollution and soil degradation (Ogundare et al., 2019). In contrast, researchers propose utilizing the woody stems to create eco-friendly building materials, thereby providing farmers with a new source of income and promoting sustainable agriculture practices (Adeoye et al., 2021). This innovative approach has the potential to revolutionize the construction industry while promoting environmental stewardship. Further research is necessitated to develop sustainable construction materials from agricultural waste, addressing the existing knowledge gaps and technical challenges (Hassan et al., 2016). Nevertheless, the strong demand for substitute materials for green building technology presents an opportunity for farmers to benefit from the use of agricultural waste as a resource, thereby promoting a circular economy (Oladipo et al., 2018). Ultimately, the successful integration of agricultural waste into the construction industry has the potential to mitigate environmental pollution, promote sustainable development, and ensure a more resilient future for generations to come.

Literature Review

Agricultural Waste Materials Application in Construction

Agro Waste Used In Concrete

Large amounts of oil palm shell (OPS), a solid waste from the palm oil industry, are found in tropical locations like Malaysia and India, and have been shown to be a viable coarse aggregate for making structural lightweight concrete (Ghazali et al., 2020). Moreover, OPS has been utilized as a lightweight aggregate to create lightweight concrete, thereby reducing the environmental impacts of traditional concrete production (Awang et al., 2019). Meanwhile, coconut shell (CS), an agricultural waste widely available in tropical nations, has been identified as a promising candidate for the development of new composite materials in concrete mix design, due to its high strength and modulus properties (Gunasekaran et al., 2011). Furthermore, perennial giant reeds and oyster shells, abundant in island nations, have also been

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012
recognized as potential sustainable materials for construction, with Taiwan's oyster shell yield alone reaching 300,000 tons over the past five years, highlighting the need for innovative solutions to mitigate environmental pollution (Chen et al., 2018).

The primary characteristics of agricultural wastes that make them a viable substitute for natural aggregate are highlighted in this section. Notably, the specific gravity values of various agricultural wastes, as displayed in Table 1 (Chandra and Berntsson, 2002), reveal that oil palm shell (OPS) and coconut shell (CS) have specific gravity values ranging from 1.17–1.37 and 1.33, respectively, which are comparable to those of natural weight aggregates (Gunasekaran and Kumar, 2008). Furthermore, the water absorption percentages of OPS and CS, ranging from 9.03–33% and 8–25%, respectively, are relatively high compared to natural aggregates, but similar to each other (Gunasekaran et al., 2012). Overall, these characteristics underscore the potential of agricultural wastes as sustainable substitutes for natural aggregates in construction materials.

Table 1. Proprieties of Agricultural Wastes Material as Conventional Aggregate

Proprieties	Oil palm shell (Muthusamy & Zamri 2016)	Coconut shell (Olanipekun et al. 2006)(Reddy et al. 2014)	Oyster shell (Kuo et al. 2013)(Yang et al. 2005)(Yang et al. 2010)	Giant reed fibres (Ismail & Jaeel 2014).
Size (mm)	30	5-20	-	2.5-10
bulk density(compacted) kg/m^3	590-740	650-1900	-	535
bulk density(loose) kg/m^3	510-550	550-592	-	-
Water absorption (%)	9.03-33	8-25	2.9-7.66	-
Specific gravity	1.17-1.37	1.05-1.2	2.1-2.48	-
Fineness modulus	-	-	2-2.8	-
Moisture content (%)	8-15	4.2	-	-
Shell thickness (mm)	2-8	0.15-8	-	-

Shape, Texture, Size And Color Of Particles

Table 1 and Figure 1 illustrate the characteristics of various agricultural wastes that can potentially replace coarse aggregate entirely or partially. Notably, oil palm shell (OPS) exhibits a range of colors from dark grey to black, with a maximum size of 30mm, and its irregular shape and high absorption capacity result in a high air content in OPS concrete [29]. In contrast, waste oyster shells (WOS) vary in size and color, with a fineness modulus ranging from 2 to 2.5, and are distinguished by their spiral structure and rough surface roughness. Conversely, crushed coconut shell is limited to a maximum diameter of 12mm [30]. Overall, these characteristics highlight the potential of these agricultural wastes as sustainable alternatives to traditional coarse aggregates.

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

Figure 1: Some Agricultural Wastes,

Furthermore, the chemical reaction, carbonation depth, and thawing and freezing resistance of concrete specimens incorporating agricultural waste aggregates, such as oil palm shell (OS), have been investigated. Notably, the substitution ratio of OS did not significantly affect the weight loss of concrete specimens, although the degradation of OS concrete persisted over time (Hussein et al., 2017; Nagarajan et al., 2021). Moreover, the resistance of agro-concrete to chemical attacks was found to be unaffected by the OS substitution ratio (Nagarajan et al., 2021). Furthermore, the carbonation depth of OS concrete increased with carbonation age, and the replacement level of OS was inversely proportional to the depth of carbonation (Oluwasola et al., 2014). Additionally, the freeze-thaw resistance of concrete incorporating OS aggregates was found to be significantly impacted by the OS substitution ratio, particularly for long-term performance (Gunarathna et al., 2018).

Groundnut Shell Ash

The groundnut shell has emerged as a versatile material with a wide range of applications, extending beyond its traditional uses as animal feed and growth media. Notably, groundnut shells have been utilized as a feedstock for the production of biodiesel or bioethanol (Al-Zubaidi et al., 2019; Irfan et al., 2020), pulp (Chen et al., 2018), mulch, and activated charcoal (Okoro et al., 2016), as well as for the generation of carbon nano-sheets (Tan et al., 2020) and the degradation of dyes (Prasad et al., 2022). Moreover, researchers have explored the potential of groundnut shells as a renewable energy source, leveraging their biodegradable properties for soil enhancement applications (Akinpelu et al., 2021). Furthermore, the use of groundnut shells as a building material has gained attention, particularly as a cement substitute, with various applications illustrated in Fig. 2 (Rahman et al., 2017; Bello et al., 2019; Kumar et al., 2021). Despite these diverse applications, a significant quantity of groundnut shells remains underutilized and is discarded in landfills (Udeozor et al., 2015).

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

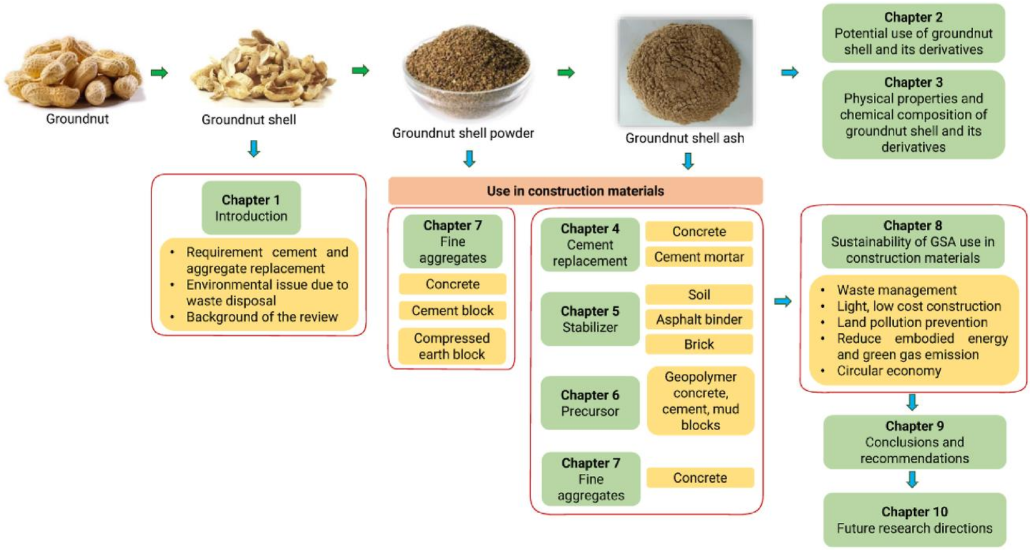

Figure 2. Groundnut Derivatives' Possible Applications As Well As An Overview Of The Review

Source: (Rahman et al., 2017; Bello et al., 2019; Kumar et al., 2021).

The physical and chemical properties of groundnut shell ash (GSA) play a crucial role in determining its performance in construction applications. Characterized by a complex fibrous structure, groundnut shells are lignocellulosic materials comprising cellulose (40–65%), hemicellulose (3–15%), and lignin (26–36%) (Irfan et al., 2020; Kumar et al., 2021; Prasad et al., 2022). Interestingly, when groundnut shells are burned under controlled conditions, they can be used as supplementary cementitious materials. Notably, a temperature increases to 100 °C results in a 9% weight loss, primarily due to the elimination of moisture and volatile organic compounds (Bello et al., 2019). Conversely, a substantial weight loss of 55–60% occurs when the temperature rises to 450 °C, attributed to the breakdown of lignin, cellulose, and hemicellulose. Furthermore, the thermal decomposition of hemicellulose and cellulose occurs within the temperature ranges of 100–300 °C and 300–450 °C, respectively, resulting in a rapid weight loss (Kumar et al., 2021). Ultimately, the phase shifts that occur during this process result in only 27–30% of the original groundnut shell weight remaining as groundnut shell ash.

Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

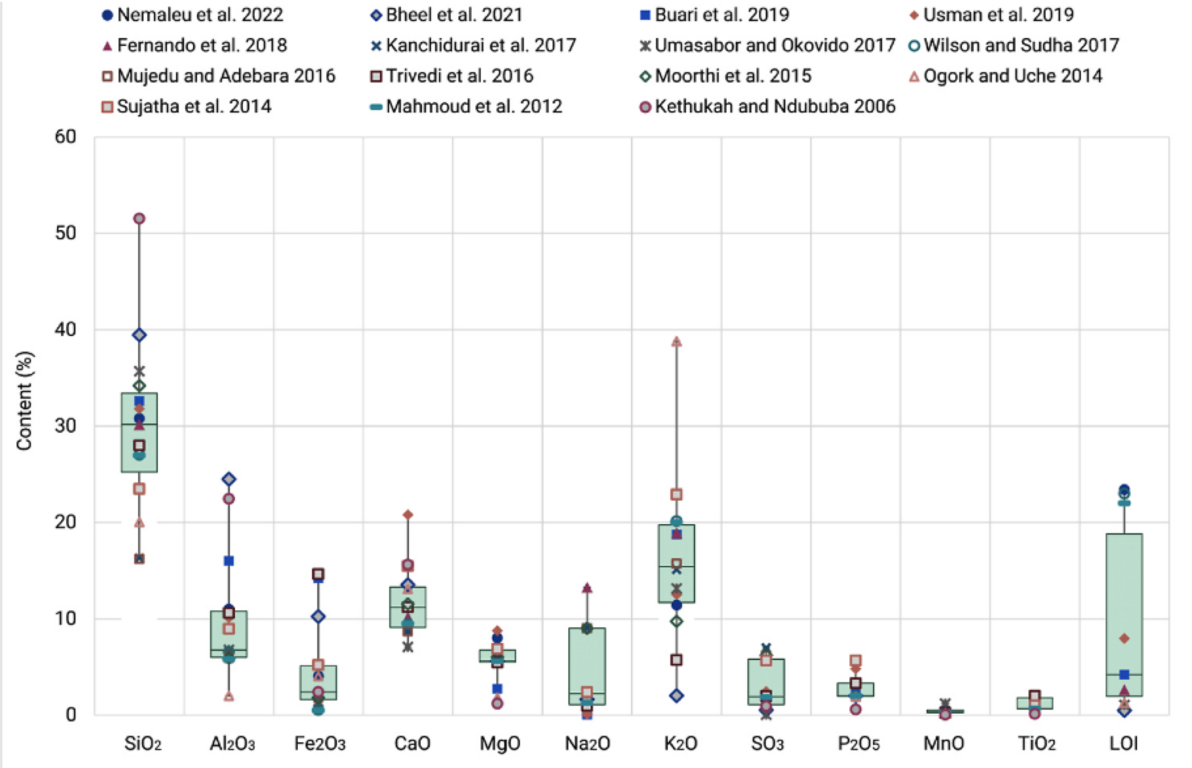

Figure 3. Chemical Composition of GSA

The chemical composition of groundnut shell ash (GSA) is illustrated in Fig. 3, based on a compilation of published literature, revealing significant variations in its chemical makeup due to the groundnut's origin and processing parameters. Notably, silica is the primary component of GSA, ranging from 16 to 51%, and can react with Ca(OH)2 to produce calcium silicate hydrate (C-S-H). Moreover, the composition of SiO2+Al2O3+Fe2O3 in GSA is generally less than 70%, which is the minimum requirement for natural pozzolanic materials according to ASTM C618. Additionally, the loss on ignition (LOI) of GSA is typically less than 10%, although higher LOI values are often correlated with unburned carbon content,

The groundnut shell, once considered a waste product after harvesting, poses significant environmental risks when accumulated in large quantities, including soil pollution, water contamination, and greenhouse gas emissions. However, utilizing groundnut shell ash (GSA) as a substitute for cement or fine aggregate in construction materials has been shown to offer numerous benefits, including cost-effectiveness, reduced embodied energy, and lower CO_2 emissions (Chiemela et al., 2020). By harnessing GSA, the environmental impacts associated with large-scale shell accumulation can be mitigated, while also promoting sustainable construction practices. Furthermore, the use of GSA can also reduce the need for landfills, minimize waste management costs, and create new revenue streams for farmers and rural communities. The use of GSA and groundnut shell powder (GSP) can potentially reduce embodied energy and CO_2 emissions in construction materials by substituting cement and fine aggregate (see Fig. 4). This reduction can be achieved through various stages, including cement production, which requires significant amounts of energy and results in substantial CO_2 emissions (Bath Inventory of Carbon and Energy, 2015). According to the Bath Inventory of

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012
Carbon and Energy (ICE), producing one kilogram of cement requires 4.5 MJ of embodied energy and emits 0.73 kg of CO_2. By substituting GSA for cement, the embodied energy and CO_2 emissions associated with cement production can be significantly reduced. Additionally, the use of GSP as a fine aggregate can also reduce the embodied energy and CO_2 emissions associated with aggregate production and transportation (Adekunle et al., 2019; Liu et al., 2021). Although the processing of GSA and GSP requires energy and fuel, resulting in additional CO_2 emissions, the overall eco-benefits of using these materials in construction outweigh the negative impacts (Eze et al., 2020).

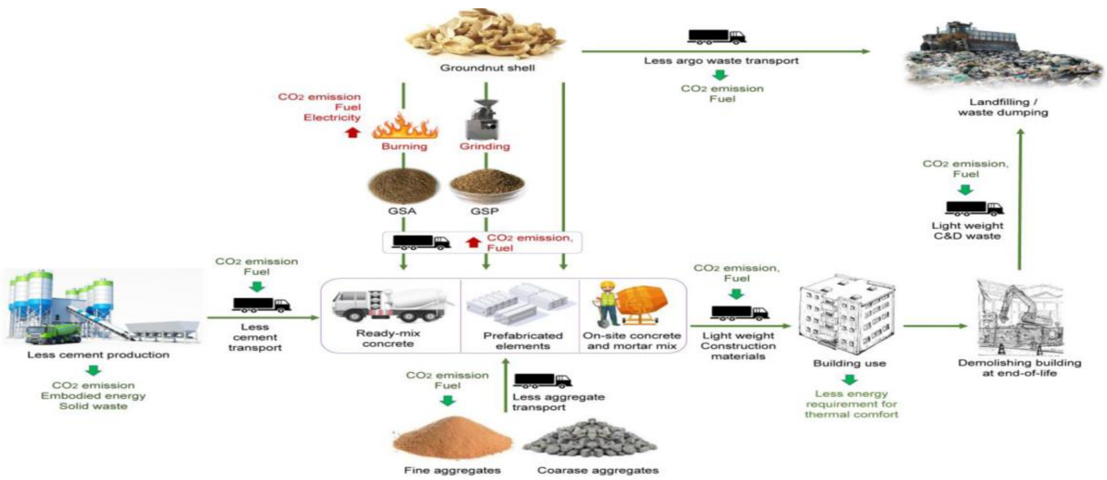

Figure 4. Potential Reduction Of CO2 Emissions And Embodied Energy Through The Use Of Groundnut Shell And Its Derivatives

Development of Alternative Material for Construction using Agricultural Residue

The growing urban population and the depletion of natural resources for construction present issues for the modern construction sector. Concerns around climate change have also prompted consideration of sustainable building materials. Another major worry is the development of agro-waste, which is produced at a rate 10–15 times higher than that of the actual products (e.g., red gram crops). Agricultural waste could be one of the suitable sustainable substitute materials to address the demand for efficient building materials (Bharath et al., 2021). This section outlines the various agricultural leftovers that have been considered as suitable sustainable alternative building materials.

Thermal Insulator

Effective thermal insulation is crucial in buildings exposed to external heat, and natural fibers have emerged as promising materials for this application. Research has demonstrated the potential of sugarcane and oil palm empty fruit bunch (OPEFB) fiber as wall thermal insulation, highlighting their ability to decrease the rate of heat transfer between surfaces with different temperatures (Kumar et al., 2020). Additionally, studies have shown that high lignocellulose and natural fiber content can be utilized as thermal insulation materials in building walls and roofing, with a decrease in thermal conductivity value observed as the amount of fiber increases (Ali & Yusuf, 2019). Moreover, the use of natural fibers and agricultural lignocellulosic materials as bio-aggregates to create bio-based insulating concretes has gained significant attention in recent research. Various studies have investigated the thermal and acoustic performance of natural fibers, including sugarcane bagasse waste (SBW) and agricultural

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012
leftovers such as palm leaves and wheat straw fibers (Rahman et al., 2020; Eze et al., 2021; Singh et al., 2021). Furthermore, the development of thermal insulating materials based on natural fibers has shown promising results, with thermal conductivity values ranging from 0.045 to 0.065 W/mK and acoustic absorption coefficients of 0.6 for frequencies above 900 Hz (Singh et al., 2021; Chiemela et al., 2022).

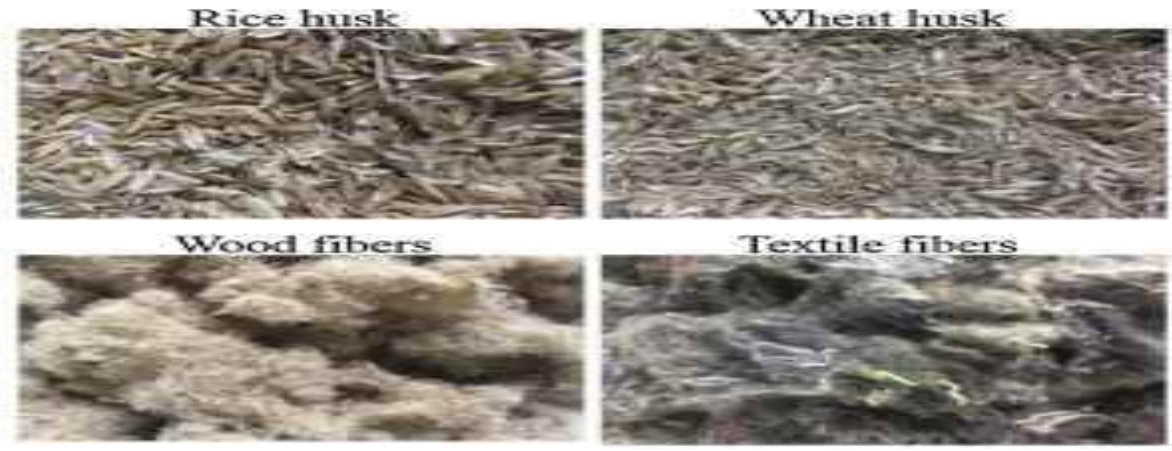

Figure. 5. Selected Husks And Fibers For The Composite Processing

The composite processing steps are shown in Fig. 6. Prior to prepare the composites, rice husk, wheat husk, wood fibers and textile fibers were dried in an oven at 80 °C overnight to eliminate moisture. The Ecovio® (15% by weight) was dissolved in chloroform (CHCl3) at room temperature, and the dissolved Ecovio® in CHCl3 was used as a binder for the selected husks and fibers to perform composites.

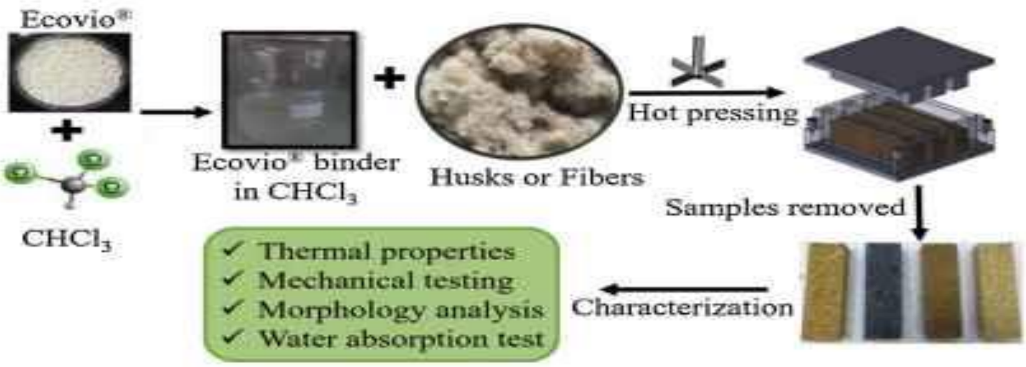

Figure. 6. Composites Processing Steps

Saturation is quite reached after 2 hours of immersion due to high absorption kinetics (Ali et al., 2020). Nevertheless, the water absorption of prepared composites remains much lower than those of particle board composites prepared from corn cob, sawdust, and larch bark (Zhang & Lin, 2019). Unlike rice husks and textile fiber composites, the composites prepared with wood fibers and wheat husks showed obvious cracks after 24 hours of immersion in water (Akinyemi et al., 2016; Kain et al., 2014). The observed cracks are due to the swelling behavior of the fibers/husks in the presence of water, as well as poor bonding between the fibers/husks and Ecovio® and insufficient binder content in the resulting composites. The high-water absorption nature of the composites is inconvenient because it leads to high shrinkage and swelling after long-term exposure to water (Rahman et al., 2020).

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

Figure. 7. Appearance Of The Prepared Composite Samples Before And After Water Absorption Test

Ceiling Tiles

Natural fibres, a significant component of global Agro-waste, have been repurposed to minimize environmental degradation. Researchers have successfully utilized wool and coconut coir to create gypsum ceiling tiles, leveraging their biodegradable and low-cost properties (Ramli et al., 2021). These natural fibres have been shown to enhance the structural qualities of gypsum-based ceiling tiles, addressing issues with moisture resistance and acoustics. Furthermore, studies have investigated the acoustic, mechanical, and thermal properties of composites made from various agricultural leftovers, such as rice husks, vine pruning, and cork, using acrylic resin (Delgado et al., 2020). The results demonstrate promising thermal resistance and acoustic absorption coefficients, highlighting the potential of these sustainable materials for green building applications, as illustrated in the process flow depicted in Fig. 8

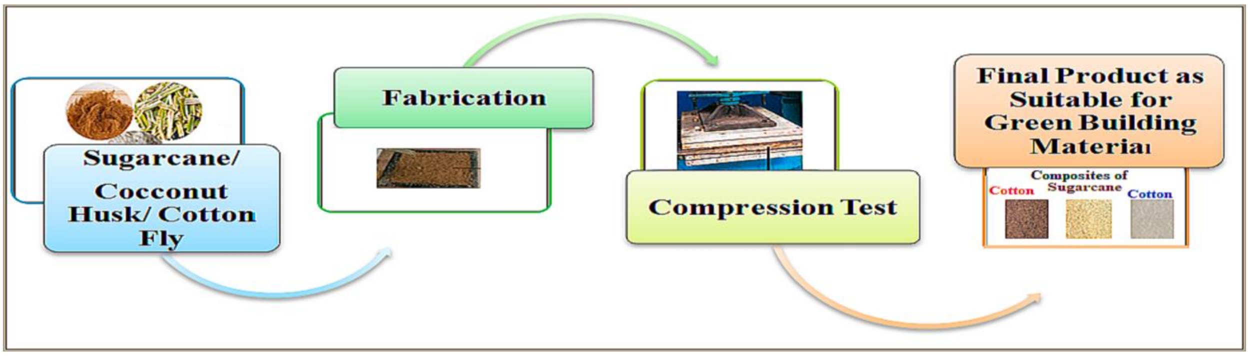

Figure 8. Green Building Materials' Sustainable Product Development Process Flow
Source: (Ali et al., 2020).

Fiber Reinforcement

The construction industry's increasing demand for sustainable development has driven research into alternative building materials. Natural fibres, such as coconut coir and sisal fibre, have been investigated for their potential to enhance the mechanical properties of concrete (Ramakrishna & Sundararajan, 2005). Studies have shown that the optimal proportion of coconut coir fibre to add to concrete is 1.5%, which improves its ductility and strength. Additionally, wrapping with sisal fibre has been found to increase load-bearing capacity. The effects of natural fibre reinforcement on the mechanical characteristics of concrete have also

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

been documented (Li et al., 2006). Research has explored the use of Masson Pine Needle Fibre (MPNF) to improve concrete's mechanical properties, demonstrating its potential as a sustainable reinforcement material (Kim et al., 2020). The search for sustainable alternatives to steel reinforcement has led to increased interest in natural fibres. Sisal fibre, in particular, has been studied for its potential as a reinforcement material (Akinyemi et al., 2016). Research has also investigated the autogenous self-healing potential of ultra-high-performance fibre-reinforced concrete (UHPFRC) (Li et al., 2018). Furthermore, natural fibre composite plates have been explored as a cost-effective and sustainable alternative to carbon fibre-reinforced polymer (CFRP) laminates and steel plates for shear strengthening of concrete beams (Ali et al., 2020). Experimental results have shown that beams reinforced with composite plates made of natural fibres exhibit superior ductility and failure loads compared to CFRP laminates.

Reinforcement Material for Building

Agro-wastes have been utilized in the production of building reinforcement materials, leveraging their lightweight properties. Research has shown that combining clay and agricultural waste from grape seeds and wine lees can result in lightweight bricks (Delgado et al., 2018). Similarly, studies have demonstrated that concrete panels made using groundnut shells as aggregate substitutes exhibit reduced compressive strength, making them unsuitable for heavy structural applications (Ekanayake & Ramachandran, 2020). Additionally, building insulation composites made with fibres from barley and wheat straw have been found to be naturally lightweight (Hosseini et al., 2015). The use of vegetable fibres as reinforcement in cement-based materials has also been explored, with research showing improved durability and other characteristics (Onuaguluchi & Banthia, 2016). For instance, concrete beams reinforced with bamboo rebars, a substitute for vegetable fibre, have been investigated, as shown in Figure 6.

Figure 9. Concrete Beams Reinforced With Bamboo Rebars: (A) Finished Reinforcement, (B) The Setup

Benefits and Drawbacks of Using Agricultural Waste for Building Materials

Many benefits and drawbacks are noted based on the thorough analysis of the various building materials made from agro-waste, as previously discussed in the sections. For instance, the utilization of agro-waste in the production of construction materials offers numerous benefits, categorized into two primary groups: environmental benefits and advantages in the production of construction materials. Repurposing agro-waste addresses environmental issues associated with traditional disposal methods, reduces the need for non-renewable resources, and preserves

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012
the environment by decreasing energy consumption (Akinyemi et al., 2016; Delgado et al., 2018). Additionally, agro-waste-based construction materials have been shown to be cost-effective, lightweight, and of high quality, meeting predetermined construction guidelines (Hosseini et al., 2015; Onuaguluchi & Banthia, 2016). The use of agricultural wastes as insulation materials has also demonstrated superior mechanical resistance and insulation qualities, promoting economic and social sustainability. Overall, the production of construction materials from agro-waste offers three primary benefits: social, environmental, and economic sustainability, providing maximum quality and comfort while reducing energy consumption and environmental impact (Delgado et al., 2018).

Despite the benefits of using agro-waste in construction materials, several challenges have been identified. One major drawback is the lightweight nature of the materials, limiting their use to specific structural applications (Delgado et al., 2018). For instance, bricks made from clay, sugarcane bagasse ash, and rice husk ash can only be used in situations where buildings require reduced structural loads (Onuaguluchi & Banthia, 2016). Additionally, the requirement for advanced manufacturing capabilities and pre-processing stages for certain agro-wastes can be costly and time-consuming (Ramakrishna & Sundararajan, 2005; Kim et al., 2020). The creation of sustainable building materials has also been associated with difficulties, including the lack of instructions on combining agro-waste with conventional materials (Delgado et al., 2018). Furthermore, pre-processing treatments, such as alkali treatment or burning, may be necessary to produce ash that can be combined with traditional materials (Li et al., 2006).

Results and Discussions

The world's population is projected to reach 9.7 billion by 2050, putting immense pressure on resources such as wood, steel, aluminium, and cement, and driving up construction costs. To address the growing shortage of construction materials and the challenges associated with disposing of agricultural waste, innovative approaches to sustainable building materials are necessary. Agricultural waste has shown promising prospects for use in building construction, with studies demonstrating its viability and adherence to industry standards (Ramakrishna & Sundararajan, 2005). The use of natural fibres like wheat and barley straw for reinforced bricks and the incorporation of crop leftovers into cement blocks are just a few examples of the potential applications of agricultural waste in construction.

Despite the opportunities presented by agricultural waste, its integration with conventional materials poses implementation challenges due to the lack of defined methods and policies. Further research and real-world implementations are necessary to address these challenges and create long-term solutions in the construction sector. An extensive analysis of agricultural wastes has revealed possibilities for the production of composite materials and concrete, including oil palm shell, coconut shell, waste oyster shells, and groundnut shell ash. To fully utilize the benefits of agricultural waste, ongoing research and development are necessary to overcome obstacles such as the lightweight nature of the material, complex manufacturing processes, and the lack of defined rules (Onuaguluchi & Banthia, 2016).

Conclusion and Recommendations

The utilization of agricultural waste materials, such as groundnut shell ash (GSA), in construction offers numerous benefits that contribute to a more sustainable and environmentally friendly built environment. By reducing embodied energy and CO2 emissions during construction, these materials can significantly lessen the environmental impact of building projects. Additionally, using Agro-residues instead of traditional materials like cement and fine aggregate can result in cost savings, making building projects more economically viable. The thermal insulation qualities of materials made from agricultural waste can also lower building energy usage, reducing the strain on resources and mitigating climate change. Furthermore, these materials are often lightweight, making them suitable for applications where smaller structural loads are tolerated, and promoting more efficient and sustainable construction practices. Ultimately, the adoption of agro-waste materials in construction contributes to sustainable building methods, generates new revenue streams for farmers, and benefits society and the economy as a whole, while also promoting environmental management and resource conservation.

Future prospects for the utilization of Agro-waste in building materials appear promising, yet further investigation is requisite to fully actualize their potential. The development and implementation of standardized regulations and guidelines are essential to facilitate the widespread adoption of these materials in conventional building practices. By establishing precise protocols and frameworks, the scalability and applicability of Agro-waste-based building materials can be substantially enhanced, thereby contributing to a more sustainable and environmentally conscious construction industry.

Acknowledgment
I would like to express my deepest gratitude to my co-author, Yusuf Shamsuddeen Umar, for his immense support, unwavering dedication, and invaluable contributions throughout the research process. His insightful feedback, collaborative spirit, and steadfast commitment were pivotal in shaping the success of this work, and I am truly fortunate to have had the opportunity to work alongside him. I am also profoundly grateful to Eastern Mediterranean University, where this incredible journey began. The university provided the foundation, resources, and inspiration that nurtured my passion for research and academic growth. A special thanks to Prof. Murude Çekilag for her exceptional mentorship, guidance, and encouragement throughout this endeavour. Her expertise and advice were invaluable in refining this work. My heartfelt appreciation goes to my family for their unwavering love, patience, and encouragement. Their constant support has been a source of strength and motivation throughout this journey. Finally, I extend my sincere thanks to Northeastern University for fostering an enabling environment that allowed me to focus on my research and reach my goals. The institution's resources and academic community have played an integral role in the completion of this work. To everyone who contributed to this research journey in any way, I remain deeply indebted and sincerely grateful.

References
Abdullah, A. A. (1984, November). Basic strength properties of lightweight concrete using Agricultural wastes as aggregates. In *Proceedings of international conference on low-cost Housing for developing countries*, Roorkee, India.
Adeleke, A. A., Ikubanni, P. P., Orhadahwe, T. A., Christopher, C. T., Akano, J. M., Agboola, O. O., ... & Ibikunle, R. A. (2021). Sustainability of multifaceted usage of biomass: A review. *Heliyon, 7*(9), e07864. https://doi.org/10.1016/j.heliyon.2021.e07864
Ashour, T., Korjenic, A., Korjenic, S., & Wu, W. (2015). Thermal conductivity of unfired earth Bricks reinforced by agricultural wastes with cement and gypsum. *Energy and Buildings, 104*, 139-146. https://doi.org/10.1016/j.enbuild.2015.07.027

Bagheri, A., Zanganeh, H., Alizadeh, H., Shakerinia, M., & Marian, M. A. S. (2013). Comparing the performance of fine fly ash and silica fume in enhancing the properties of concretes containing fly ash. *Construction and Building Materials, 47*, 1402-1408. https://doi.org/10.1016/j.conbuildmat.2013.05.007

Bobet, O., Nassio, S., Seynou, M., Remy, B., Zerbo, L., Sanou, I., ... & Gilles, E. (2020). Characterization of peanut shells for their valorization in earth brick. *Journal of Minerals and Materials Characterization and Engineering, 8*(4), 301-315.

Buari, T. A., Olutoge, F. A., Ayinnuola, G. M., Okeyinka, O. M., & Adeleke, J. S. (2019). Short term durability study of groundnut shell ash blended self-consolidating high performance concrete in sulphate and acid environments. *Asian Journal of Civil Engineering, 20*, 649- 658. https://doi.org/10.1007/s42107-019-00155-w

Carrasco, B., Cruz, N., Terrados, J., Corpas, F. A., & Pérez, L. (2014). An evaluation of bottom ash from plant biomass as a replacement for cement in building blocks. *Fuel, 118*, 272-280. https://doi.org/10.1016/j.fuel.2013.10.054

Chaussinand, A., Scartezzini, J. L., & Nik, V. (2015). Straw bale: A waste from agriculture, a new construction material for sustainable buildings. *Energy Procedia, 78*, 297-302. https://doi.org/10.1016/j.egypro.2015.11.159

Duc, P. A., Dharanipriya, P., Velmurugan, B. K., & Shanmugavadivu, M. (2019). Groundnut shell—a beneficial bio-waste. *Biocatalysis and Agricultural Biotechnology, 20*, 101206. https://doi.org/10.1016/j.bcab.2019.101206

Fall, D., Bakhoum, N., Fall, F., Diouf, F., Ndiaye, C., Faye, M. N., ... & Diouf, D. (2018). Effect of peanut shells amendment on soil properties and growth of seedlings of *Senegalia senegal* (L.) Britton, *Vachellia seyal* (Delile) P. Hurter, and *Prosopis juliflora* (Swartz) DC in salt- affected soils. *Annals of Forest Science, 75*(1), 1-11. https://doi.org/10.1007/s13595-018- 0747-0

Figaredo, A. T., & Dhanya, M. (2018). Development of sustainable brick materials incorporating Agro-wastes: An overview. *Development, 5*(11).

Guna, V., Ilangovan, M., Rather, M. H., Giridharan, B. V., Prajwal, B., Krishna, K. V., ... & Reddy, N. (2020). Groundnut shell/rice husk agro-waste reinforced polypropylene hybrid biocomposites. *Journal of Building Engineering, 27*, 100991.

Gunasekaran, K., Annadurai, R., & Kumar, P. S. (2012). Long term study on compressive and bond strength of coconut shell aggregate concrete. *Construction and Building Materials, 28*(1), 208-215. https://doi.org/10.1016/j.conbuildmat.2011.07.024

Jaiswal, K. K., Banerjee, I., & Mayookha, V. P. (2021). Recent trends in the development and diversification of sericulture natural products for innovative and sustainable applications. *Bioresource Technology Reports, 13*, 100614.

Jaiswal, K. K., Chowdhury, C. R., Yadav, D., Verma, R., Dutta, S., Jaiswal, K. S., & Karuppasamy, K. S. K. (2022). Renewable and sustainable clean energy development and impact on social, economic, and environmental health. *Energy Nexus, 7*, 100118.

Kanchidurai, S., Nanthini, T., & Jan Shankar, P. (2017). Experimental studies on sisal fibre reinforced concrete with groundnut shell ash. *ARPN Journal of Engineering and Applied Sciences, 12*(21), 5914-5920.

Kuo, W. T., Wang, H. Y., Shu, C. Y., & Su, D. S. (2013). Engineering properties of controlled low-strength materials containing waste oyster shells. *Construction and Building Materials, 46*, 128-133. https://doi.org/10.1016/j.conbuildmat.2013.04.016

Kumar, M., Rai, D., Bhardwaj, G., Upadhyay, S. N., & Mishra, P. K. (2021). Pyrolysis of peanut shell: Kinetic analysis and optimization of thermal degradation process. *Industrial Crops and Products, 174*, 114128.

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 7 Issue 20 (March 2025) PP. 210-223
DOI 10.35631/IJIREV.720012

Li, P., Du, Z., Chang, C., Zhao, S., Xu, G., & Xu, C. C. (2020). Efficient catalytic conversion of waste peanut shells into liquid biofuel: An artificial intelligence approach. *Energy & Fuels, 34*(2), 1791-1801.

Maraveas, C. (2020). Production of sustainable construction materials using agro-wastes. *Materials, 13*(2), 262. https://doi.org/10.3390/ma13020262

Madrid, M., Orbe, A., Rojí, E., & Cuadrado, J. (2017). The effects of by-products incorporated in low-strength concrete for concrete masonry units. *Construction and Building Materials, 153*, 117-128.

Muthusamy, K., & Zamri, N. A. (2016). Mechanical properties of oil palm shell lightweight aggregate concrete containing palm oil fuel ash as partial cement replacement. *KSCE Journal of Civil Engineering, 20*, 1473-1481.

Nemaleu, J. G. D., Bakaine Djaoyang, V., Bilkissou, A., Kaze, C. R., Boum, R. B. E., Djobo, J. N. Y., ... & Kamseu, E. (2022). Investigation of groundnut shell powder on development of lightweight metakaolin based geopolymer composite: Mechanical and microstructural properties. *Silicon, 14*(2), 449-461.

Ogork, E. N., & Uche, O. A. (2014). Effects of groundnut husk ash (GHA) in cement paste and mortar. *International Journal of Civil Engineering and Technology (IJCIET), 5*(10), 88-95.

Pearlmutter, D., Theochari, D., Nehls, T., Pinho, P., Piro, P., Korolova, A., ... & Pavey, P. (2019). Upcycling agricultural residues into construction materials for low-cost housing: A project on reuse of groundnut shells for lightweight building materials. *Resources, Conservation and Recycling, 146*, 256-263.

Rangaraju, R., Shanmugavadivu, M., & Kavi, P. (2019). Green concrete from agro-industrial waste and its application for sustainable construction. *Journal of Building Engineering, 26*, 100862. https://doi.org/10.1016/j.jobe.2019.100862

Saeed, A., & Maqsood, T. (2017). Application of agro-wastes in concrete production: A Review. *Construction and Building Materials, 136*, 174-188.

Soltani, A., & Yahyapour, M. (2018). A review of the potential use of agricultural waste in concrete production. *Environmental Science and Pollution Research, 25*, 20956-20975. https://doi.org/10.1007/s11356-018-1833-9

Yilmaz, M., & Demir, A. (2020). Durability of concrete containing peanut shell ash in different curing conditions. *Construction and Building Materials, 244*, 118310. https://doi.org/10.1016/j.conbuildmat.2020.118310

Zain, M. F. M., & Mohd, N. N. (2015). The effect of waste materials on the properties of concrete. *Sustainable Materials and Technologies, 4*, 36-45. https://doi.org/10.1016/j.susmat.2015.01.001

Zhang, H., & Li, Y. (2016). Recyclable building materials for a sustainable construction industry: A review. *Renewable and Sustainable Energy Reviews, 54*, 303-315. https://doi.org/10.1016/j.rser.2015.10.063

Zuo, J., & Zhao, Z. Y. (2014). The development of a new building material made from Agricultural wastes and its application in construction. *Construction and Building Materials, 61*, 254-261. https://doi.org/10.1016/j.conbuildmat.2014.03.030