RICA – v. 9, n. 14, 2025
Revista Interdisciplinar de Ciência Aplicada
ISSN: 2525-3824

Development of Sustainable Cement Composites Reinforced with Peanut Shell Fibers

Mohamed Leulmi (d.mohleu@gmail.com)
National School of Engineers of Tunis ENIT, University of Tunis El Manar.

Rachid Nasri (rachid.nasri@enit.utm.tn)
National School of Engineers of Tunis ENIT, University of Tunis El Manar.

Fairouz Chouit (f.chouit@univ-skikda.dz)
20 Aout 1955 University Skikda

DOI: 10.18226/25253824.v9.n14.08

Submetido em: 04/21/2025 **Revisado em:** 08/24/2025 **Aceito em:** 08/25/2025

Abstract: This study addresses global environmental challenges by recycling agricultural waste into sustainable construction materials. It investigates the use of fiber from peanut shells as reinforcement in mortars, evaluating the effect of incorporation rates on mechanical performance. Mortar samples were prepared by replacing sand mass with 0.5 wt.%, 1.0 wt.%, and 2.0 wt.% fiber from peanut shells and tested for flexural and compressive strength. Results indicate that low dosages (0.5% – 1.0 wt.%) enhance flexural strength by up to 47 %, while higher amounts (2.0 wt.%) reduce effectiveness. The findings highlight the potential of fiber from peanut shells as a sustainable reinforcement when used at optimal rates.

Keywords: Composite Materials, Mortar, Mechanical Characterization, Peanut Shells.

Resumo: Este estudo aborda os desafios ambientais globais por meio da reciclagem de resíduos agrícolas em materiais de construção sustentáveis. Investiga-se a utilização de fibras de casca de amendoim como reforço em argamassas, avaliando o efeito de taxas de incorporação (0,5 %, 1,0 % e 2,0 % em massa de areia) no desempenho mecânico. Os resultados demonstram que dosagens baixas (0,5 % – 1,0 % m/m) aumentam a resistência à flexão em até 47 %, enquanto quantidades superiores (2,0 % m/m) reduzem a eficácia. Conclui-se que as fibras de casca de amendoim apresentam potencial como reforço sustentável quando utilizadas em proporções otimizadas.

Palavras-chave: Materiais compósitos, Argamassa, Caracterização mecânica, Cascas de amendoim.

1. 1. INTRODUCTION

The global construction sector faces mounting pressure to reduce its environmental footprint, being responsible for approximately 38 % of worldwide CO_2 emissions and nearly 50 % of raw material consumption [1]. This urgent challenge has accelerated research into sustainable material alternatives that can maintain structural performance while addressing ecological concerns. Among promising solutions, the valorization of agricultural byproducts as construction materials has gained significant attention, offering simultaneous waste reduction and resource efficiency benefits [2-3].

Plant-based fibers have emerged as particularly viable reinforcements for cementitious composites, combining renewable sourcing with advantageous mechanical properties. Fibers derived from peanut shells present unique opportunities in this context, given their global abundance from annual peanut production exceeding 45 million tons [4]. These lignocellulosic materials typically contain 40 – 45 % cellulose, 30 % lignin, and 15 % hemicellulose by mass – a composition that provides both tensile strength and flexibility while remaining fully biodegradable [5]. Their incorporation into building materials aligns with multiple United Nations Sustainable Development Goals (SDGs), particularly SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption and Production) [6].

Recent advances in agro-waste composites have demonstrated several successful applications. Ajayi and Lateef [7] documented comprehensive valorization pathways for peanut shells, highlighting their potential conversion from agricultural waste to high-value construction materials. Parallel research by Echeverría-Maggi et al. [8] developed hybrid composite panels combining banana fibers and peanut shells, achieving 30 % improvements in thermal insulation properties while maintaining structural integrity. Ekpenyong et al. [9] further established that groundnut shell composites can enhance flexural strength by approximately 20 % compared to conventional materials. However, these studies primarily focused on either binder modification or thermal properties, leaving critical gaps in understanding aggregate replacement strategies.

The current study addresses a fundamental research gap by systematically investigating peanut shell fibers as partial sand replacements in cementitious mortars. While previous work has examined fiber reinforcement generally, the specific optimization of sand substitution ratios remains underexplored despite its practical notable improvement. Sand mining operations currently extract an estimated *50 billion tons* annually worldwide, causing substantial ecological damage and resource depletion [10]. Developing viable alternatives through agricultural byproduct utilization could significantly mitigate these environmental impacts while creating new economic value streams for farming communities.

RICA – v. 9, n. 14, 2025
Revista Interdisciplinar de Ciência Aplicada
ISSN: 2525-3824

This study systematically evaluates mortar composites incorporating peanut shell fibers at 0.5 %, 1.0 %, and 2.0 % sand replacement by mass, maintaining constant water-cement (0.6) and cement-sand (1:3) ratios to isolate fiber effects. Through standardized mechanical testing.

The research specifically examines how fiber incorporation influences mortar performance, with implications for both material science and sustainable construction practices. By bridging the gap between agro-waste valorization and building material innovation, this work contributes to circular economy solutions in the construction sector while addressing global sustainability challenges.

2. EXPERIMENTAL METHODS

The study adopted a systematic approach to evaluate mortar composites reinforced with agricultural waste fibers. All materials, such as cement, sand, water, and peanut husk fibers, were obtained locally from Algeria to prepare the mortar samples, and their chemical and physical properties were characterized prior to use.

The cementitious binder consisted of Portland limestone cement CEM II/A-L 42.5, composed of clinker, gypsum, and limestone. This type of cement complies with Algerian (NA 442, 2013) and European (EN 197-1) standards, ensuring consistent quality. Its chemical composition includes essential oxides such as calcium oxide (CaO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), magnesium oxide (MgO), potassium oxide (K_2O), sodium oxide (Na_2O), sulfur trioxide (SO_3), and chloride (Cl^-), along with traces of free lime and insoluble residue. X-ray fluorescence analysis confirmed the predominant oxide composition, which is shown in Table 1.

Table (1): Oxide composition

Compound	Percentage
Calcium oxide (CaO)	62,5
Silicon dioxide (SiO_2)	20,1
Aluminum oxide (Al_2O_3)	4,3
Magnesium (Mg)	Low quantities
Iron (Fe)	Low quantities
Sulfur (S)	Low quantities

This selection was made due to its balanced performance and widespread availability in North African markets [7-8].

Fine aggregates were sourced from coastal dune deposits in the Oued Zhor Skikda region of Algeria, exhibiting a uniform granulometry with particle sizes up to 1.0 mm. The sand particles demonstrated stability, characterized by an apparent bulk density of 2.6 $g \cdot cm^{-3}$ and negligible organic content. Additionally, the aggregates contained sulfur compounds (SO_3, SO_4), calcium carbonate ($CaCO_3$), and chloride (Cl^-). These properties, particularly the low organic content, proved advantageous for maintaining workability in fiber-reinforced mixtures.

Potable tap water, which complies with standard practices, was used for mixing in this study. This choice ensured that the water quality met the necessary criteria for achieving optimal results in the mixing process.

Agricultural waste fibers were processed from peanut shells collected from local farms in Algeria. The shells were cleaned, then mechanically ground and sieved to obtain particle sizes consistent with sand. Analysis of the cellulose content showed that the fibrous material consisted of the compositions shown in Table 2.

Table (2): Fiber content analysis

Component	(wt.%)
Cellulose	40–45
Lignin	~30
Hemicellulose	~15
Other components	~10–15

This composition is particularly suitable for reinforcing cement matrices. The lightweight and strength of peanut shells make them ideal for improving mechanical properties while reducing costs and environmental impact [1, 9, 12].

3. METHOD OF FORMULATION OF MORTARS WITH VEGETAL FIBERS

Four mortar formulations were developed, comprising a control mixture and three fiber-reinforced variants. Specimens were prepared under controlled laboratory conditions following European and Algerian standards for construction materials. This methodology ensured reproducible results while addressing practical considerations for potential industrial adoption.

The mortar samples were prepared using a water-to-cement ratio (W/C) of 0.6 and a cement-to-sand ratio (C/S) of 1/3, adhering to a standardized protocol. The preparation process began by thoroughly mixing cement and sand in the specified proportions. Subsequently, a slight amount of fiber from peanut shells was added as reinforcement, followed by the gradual incorporation of water until a homogeneous mixture was achieved.

Mortar specimens with dimensions of 4 cm × 4 cm × 16 cm were cast in pre-oiled metal molds, following the guidelines outlined in the standard NBN EN 1015-2 (NBN EN 1015-2, 2007). The molds were placed securely on an impact or vibrating table for uniform compaction, Elimination of Air Voids, Consistency in Results, and improved flow, and the mortar was introduced in two uniform layers to ensure consistency. After 24 h to 48 h of curing at room temperature, the specimens were demolded, marked, and stored until testing. All mechanical tests were carried out after 28 days of curing, according to international standards (ASTM, EN, ISO, etc.), because this period is internationally recognized as the standard age at which mortars reach most of their strength

RICA – v. 9, n. 14, 2025
Revista Interdisciplinar de Ciência Aplicada
ISSN: 2525-3824

and durability, which is a reliable measure of their performance. Formulation:

The experimental design focused on the partial replacement of fine sand while maintaining constant binder contents (cement and water) and evaluating the mechanical properties after standard curing periods. In this study, four types of mortar formulations were developed: a plain mortar (for comparison), a mortar reinforced with varying proportions of peanut husk fibers based on the weight of the sand, and mortar formulations with peanut husk fiber replacement at 0.5 wt.%, 1.0 wt.%, and 2.0 wt.%. These proportions were selected to ensure durability. Table 3 summarizes the detailed compositions of the mortar formulations.

Table (3): Different compositions of the mortars studied

Sample	Sand (g)	Fiber (g)	Cement (g)	Water (g)	Ratio
Witness Mortar (TM)	1350.00	-	450	270	0.6
Mortar with fiber from peanut shells (FP) 0.5 wt.%	1343.25	6.75	450	270	0.6
Mortar with fiber from peanut shells (FP) 1.0 wt.%	1336.50	13.5	450	270	0.6
Mortar with fiber from peanut shells (FP) 2.0 wt.%	1323.00	27.0	450	270	0.6

4. RESULTS

To understand the behavior of cementitious composites reinforced with vegetal fibers, destructive tests, including the flexural tensile test and the compression test, were conducted.

4.1. Flexural tensile test:

Flexural strength (R_f) tests were conducted using a three-point bending configuration on a universal testing machine. The span length between the two lower supports was fixed at 100 mm, and the load was applied at the mid-span of prismatic specimens measuring 4 cm × 4 cm × 16 cm. These specimens were prepared in accordance with the recommendations of EN 196-1, at a laboratory temperature of 25 °C. Testing was performed after a curing period of 28 days to evaluate the development of flexural tensile strength over time.

For each mix composition, the reported values represent the average of three tests. Flexural strength was determined at the appearance of the first visible crack. The following formula was used to calculate flexural strength:

$$R_f = (1{,}5 \times F_f \times L) / b^3 \qquad (1)$$

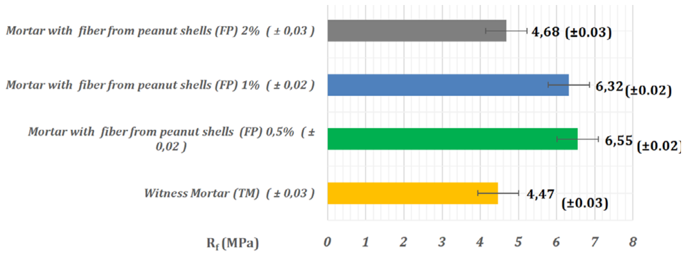
R_f: Flexural strength in (MPa);
Ff: Failure load of the specimen in bending (N);
L: Length between the two lower supports in (mm);
b: Side of the specimen in (mm).

The results of the mechanical testing for flexural strength of ordinary mortar samples and mortar samples reinforced with fiber from peanut shells revealed the following key observations:

Table (4): Bending Strength Test Results (three-point bending)

Sample	F_f (N)	L (mm)	b (mm)	R_f (MPa)
Witness Mortar (TM)	1900	100	40	4.47±0.03
Mortar with fiber from peanut shells (FP) 0.5 wt.%	2800	100	40	6.55±0.02
Mortar with fiber from peanut shells (FP) 1.0 wt.%	2700	100	40	6.32±0.02
Mortar with fiber from peanut shells (FP) 2.0 wt.%	2000	100	40	4.68±0.03

Figure (1): Flexural Strength Results.



The results of the mechanical testing for flexural strength of ordinary mortar samples and mortar samples reinforced with fiber from peanut shells revealed the following key observations:

Table (4) and Figure (1) summarize the flexural strength test results for ordinary mortar and mortar reinforced with fiber from peanut shells.

The addition of fiber from peanut shells to the mortar significantly enhanced its flexural strength. The most notable improvement was observed in the mixture containing 0.5 wt.% fiber, which exhibited a 47 % increase in strength. The mixture with 1.0 wt.% fiber showed a 41.7 % increase, while the mixture with 2.0 wt.% fiber showed a 4.9 % increase.

These results indicate that incorporating low percentages of fiber from peanut shells (less than 2.0 wt.%) can markedly improve the flexural strength of mortar. This enhancement is attributed to the reinforcing effect of the vegetal fillers, which effectively absorb bending forces and distribute stress within the composite matrix.

Existing research, such as studies by Dubey et al. [10] and Ismail et al. [11], supports these findings. These works demonstrate that the addition of plant-based fillers, such as peanut shell particles, enhances the flexural strength of materials by

RICA – v. 9, n. 14, 2025
Revista Interdisciplinar de Ciência Aplicada
ISSN: 2525-3824

strengthening the structure and improving resistance to bending forces.

Overall, these findings highlight the potential of fiber from peanut shells as a sustainable reinforcement in composite materials to improve flexural strength. However, further studies are necessary to fully understand the underlying mechanisms and optimize the dosages to maximize the performance of peanut shell-reinforced composites.

Additionally, the incorporation of fiber from peanut shells was observed to limit crack propagation at the breaking point, as evidenced during the tests. This suggests that the fiber not only enhances strength but also improves the material's toughness and durability.

4.2. Compression test:

The compressive strength tests (R_c) were carried out on prismatic specimens in accordance with the NFP 18-406 standard. Prisms with dimensions of 40 mm × 40 mm × 160 mm were first tested in flexural mode, and the two half-specimens obtained from the three-point bending test were then used for compression.

Compressive tests were performed using a hydraulic testing machine equipped with flat steel plates, applying a monotonic load at a constant rate until specimen failure.

For each mortar mix composition (reference mortar and peanut-shell-reinforced mortar), three specimens were tested, and the average value of compressive strength was reported. The compressive strength (R_c), was determined using the following expression:

$$R_c = F_{c.max} / (b \times h) \qquad (2)$$

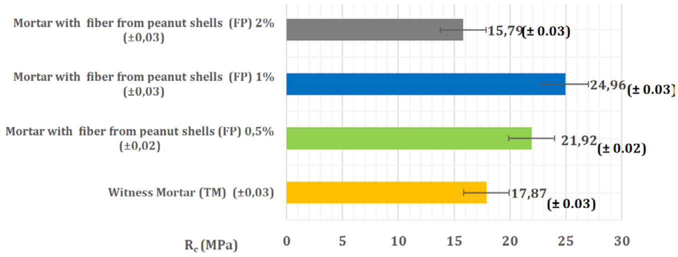
R_c: is the compressive strength of the mortar (MPa);
$F_{c.max}$: is the maximum compressive load causing failure (N);
b, h: are the width and the height of the specimen, respectively (b = h = 40 mm).

The results of mechanical compressive strength tests of ordinary mortar samples and mortar samples reinforced with peanut shell fibers revealed the following key observations:

Table (5): Compression Test Results

Sample	$F_{c,max}$ (N)	h (mm)	b (mm)	R_c (MPa)
Witness Mortar (TM)	28550	40	40	17.87± 0.03
Mortar with fiber from peanut shells (FP) 0.5 wt.%	34500	40	40	21.92± 0.02
Mortar with fiber from peanut shells (FP) 1.0 wt.%	38600	40	40	24.96± 0.03
Mortar with fiber from peanut shells (FP) 2.0 wt.%	21300	40	40	15.79±0.03

Figure (2): Compressive Strength Results



The 28 days compressive strength results for mortars with fiber from peanut shells are detailed in Table (5) and Figure (2). A 0.5 wt.% addition increased strength by 22.8 %, while a 1.0 wt.% addition yielded a 39.75 % improvement. However, a 2.0 wt.% addition caused a 12 % decrease due to poor fiber distribution, increased defects, and higher porosity.

These results emphasize the need to optimize particle dosage. Lower doses (0.5 wt.% – 1.0 wt.%) enhance strength, while excessive amounts degrade performance. The 1.0 wt.% dose provided the most significant improvement.

These findings align with previous studies. Yahaya et al. [12] reported higher compressive strengths with peanut skin fibers, while Sani et al. [13] noted improvements in lightweight concrete. Conversely, Fitria et al. [9] and Namasivayam et al. [14] observed strength reductions at higher percentages, consistent with this study.

CONCLUSION

This study demonstrates that fiber from peanut shells can effectively reinforce cementitious mortars when used as partial sand replacements. Experimental results reveal that incorporation at 0.5 – 1.0 % by mass significantly enhances mechanical properties, with optimal performance observed at 1.0 wt.% fiber content (40 % increase in compressive strength and 42 % improvement in flexural strength versus control). These enhancements stem from the fibers' ability to bridge microcracks and distribute stresses within the composite matrix. However, exceeding 1.0 wt.% fiber content (e.g., 2.0 wt.%) reduces mechanical performance due to fiber agglomeration and increased porosity, underscoring the importance of dosage precision for optimal results.

From a sustainability perspective, this work offers a practical pathway to valorize agricultural waste—diverting peanut shells from landfills while reducing reliance on sand mining. The proposed formulations align with circular economy principles and support SDG targets for responsible consumption (SDG 12) and sustainable industrialization (SDG 9). For industry adoption, we recommend targeting non-structural applications (e.g., pavements, partition walls) where the 0.5 – 1.0 wt.% fiber formulations provide optimal balance between performance and workability.

RICA – v. 9, n. 14, 2025
Revista Interdisciplinar de Ciência Aplicada
ISSN: 2525-3824

Future research should focus on three key areas: (1) chemical treatments (e.g., alkali activation) to improve fiber-matrix adhesion at higher dosages, (2) long-term durability studies under environmental exposure, and (3) life-cycle assessments to quantify CO_2 savings at industrial scale. These steps will bridge the gap between laboratory-scale success and real-world construction applications.

REFERENCES

[1] Shah, I., Li, J., Yang, S., Zhang, Y., & Anwar, A. (2021). Experimental investigation on the mechanical properties of natural fiber reinforced concrete. Journal of Renewable Materials, 10, 1307–1320. https://doi.org/10.32604/jrm.2022.017513

[2] Hussain, G., Hassan, M., Wei, H., Buhl, J., Xiao, M., Iqbal, A., Qayyum, H., Riaz, A. A., Muhammad, R., & Ostrikov, K. (2023). Advances on incremental forming of composite materials. Alexandria Engineering Journal, 79, 308–336. https://doi.org/10.1016/j.aej.2023.07.045

[3] Elfaleh, I., Abbassi, F., Habibi, M., Ahmad, F., Guedri, M., Nasri, M., & Garnier, C. (2023). A comprehensive review of natural fibers and their composites: An eco-friendly alternative to conventional materials. Results in Engineering, 19, 101271. https://doi.org/10.1016/j.rineng.2023.101271

[4] Ajayi, V. A., & Lateef, A. (2023). Biotechnological valorization of agrowastes for circular bioeconomy: Melon seed shell, groundnut shell and groundnut peel. Cleaner and Circular Bioeconomy, 4, 100039. https://doi.org/10.1016/j.clcb.2023.100039

[5] Echeverría-Maggi, E., Flores-Alés, V., Uan, J., & Martín-Del-Río, J. (2022). Reuse of banana fiber and peanut shells for the design of new prefabricated products for buildings. Revista de la Construcción – Journal of Construction, 21(2), 461–472. https://doi.org/10.7764/RDLC.21.2.461

[6] Ekpenyong, N. E., Ekong, S. A., Nathaniel, E. U., Thomas, J. E., Okorie, U. S., Robert, U. W., Akpabio, I. A., & Ekanem, N. U. (2023). Thermal response and mechanical properties of groundnut shells' composite boards. Researchers Journal of Science and Technology, 3, 42–57. https://rejost.com.ng

[7] Doughmi, K., Baba, K., & Nounah, A. (2023). Mechanical properties of eco-friendly cement-based composite mortars plastic fiber reinforced partially replaced by natural pozzolan and marble waste. Materials Today: Proceedings. Advance online publication. https://doi.org/10.1016/j.matpr.2023.07.203

[8] Abdalla, J. A., Hawileh, R. A., Bahurudeen, A., Jyothsna, G., Sofi, A., Shanmugam, V., & Thomas, B. S. (2023). A comprehensive review on the use of natural fibers in cement/geopolymer concrete: A step towards sustainability. Case Studies in Construction Materials, 19, e02244. https://doi.org/10.1016/j.cscm.2023.e02244

[9] Samsunan, Fitria, H. P., Inseun, Y. S., & Andrisman, S. (2023). Influence of groundnut shell powder on normal concrete's split tensile strength. International Journal of Engineering, 3(1), 47–51. https://doi.org/10.52088/ijesty.v1i4.410

[10] Kisan, U., Dubey, V., Sharma, A. K., & Mital, A. (2021). Synthesis of groundnut shell/rice husk hybrid composite – A review. IOP Conference Series: Materials Science and Engineering, 1116(1), 012001. https://doi.org/10.1088/1757-899X/1116/1/012001

[11] Zaaba, N. F., Ismail, H., & Jaafar, M. (2013). Effect of peanut shell powder content on the properties of recycled polypropylene (RPP)/peanut shell powder (PSP) composites. BioResources, 8(4), 5826–5841. https://doi.org/10.15376/biores.8.4.5826-5841

[12] Usman, J., Yahaya, N., & Mazizah, E. M. (2019). Influence of groundnut shell ash on the properties of cement pastes. IOP Conference Series: Materials Science and Engineering, 601(1), 012015. https://doi.org/10.1088/1757-899X/601/1/012015

[13] Tata, K. H., Sani, M., & Ekundayo, O. (2015). Feasibility study of the use of groundnut shells as fine aggregates in lightweight concrete construction. International Journal of Advanced Research in Engineering, 1(1). https://doi.org/10.24178/ijare.2015.1.1.13

[14] Tong S.E, Namasivayam S. (2023). A Study on Partially Replacing Coarse Aggregate With Peanut Shell Waste In Concrete, Constr Build Mater, Journal of Engineering Science and Technology. Vol 18 No 5. pp 2570 – 2586.