Budownictwo i Architektura 24(1) 2025, 147-161

DOI: 10.35784/bud-arch.6728
Received: 19.10.2024; Revised: 05.02.2025;
Accepted: 28.02.2025; Available online: 31.03.2025

Orginal Article

Evaluating the thermal insulation properties of sustainable building materials in Southern Algeria: A study on plaster and palm fibres

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Abstract: This research addresses the critical need to develop environmentally friendly building materials with effective insulation properties in Southern Algeria, a region increasingly affected by extreme natural phenomena such as intense heat. By exploring the potential of plaster, known for its excellent insulation characteristics, and palm fibres, a sustainable alternative to synthetic fibres, this study offers a promising future for the construction industry in the region. Plaster composites reinforced with 10 mm palm fibres were developed at 2%, 4%, and 6% fibre ratios and water-to-plaster (W/P) ratios of 0.8, 1, and 1.5. After 28 days, physical, mechanical, and thermal properties were evaluated. The results revealed that composites with 6% fibre and a 1.5 W/P ratio exhibited favourable physical properties, particularly a low density of 0.88 g/cm³, making them lightweight. Although the compressive strength decreased to 5.23 MPa with increasing fibre and water content, it remained within acceptable limits. The thermal conductivity decreased to 0.19 W/mK, and the specific heat increased to 1012.17 J/kg·K, highlighting the material's effectiveness as an insulator. This study demonstrates the potential of local, sustainable building materials, positioning date palm fibre-reinforced plaster composites as a viable solution for sustainable construction. The findings encourage further research on optimising these composites for broader environmentally conscious construction applications.

Keywords: plaster, date palm fibres, thermal conductivity, specific heat, density, compressive strength

1. Introduction

The severity of the current climate situation and the spread of global warming and climate change are increasingly manifested through extreme phenomena such as floods, droughts, and record temperatures [1]. These events highlight the urgent need to reduce our environmental impact. The construction sector, a significant contributor to global carbon dioxide emissions and energy consumption, plays a crucial role in this issue [2-4]. Traditional building materials, such as cement and synthetic fibres, contribute considerably to environmental challenges due to their energy-intensive production processes and disposal issues.

Our research aims to address these challenges by developing local, environmentally friendly building materials in Southern Algeria, a region abundant in resources such as gypsum and natural fibres derived from palm trees. These sustainable materials present viable alternatives to conventional cement and synthetic fibres, reducing the carbon footprint associated with material production and transportation. Gypsum, a historically significant building material, offers excellent thermal and acoustic properties and fire resistance, making it well-suited for interior applications. However, its inherent brittleness has limited its use to secondary applications such as partitions, ceilings, and finishing works. In contrast, natural fibres – particularly those obtained from palm trees – exhibit superior mechanical and thermal properties [5], making them ideal for reinforcing gypsum and enhancing its structural performance. Algeria's date palm cultivation spans approximately 160,000 hectares, yielding over 1 million tonnes of dates annually. Much of this production generates fibrous waste, often discarded or underutilised. This waste represents a valuable raw material for sustainable construction, particularly in Southern Algeria, where palm trees are widely available [5]. Integrating palm fibres with gypsum results in environmentally friendly composite materials with promising physical, mechanical, and thermal properties, offering a sustainable and efficient solution for modern construction demands.

Several studies have focused on the promising potential of natural fibres, such as palm, in enhancing the physical, mechanical, and thermal properties of gypsum-based composites. Al-Rifaie [6] investigated palm fibre-gypsum composites, revealing that while these composites offered certain advantages over fibreglass composites, their compressive strength diminished with increasing palm fibre content. Iucolano et al. [7] demonstrated that reinforcing gypsum composites with bio-degummed hemp fibres improved mechanical properties and thermal resistance, highlighting the effectiveness of fibre reinforcement in modifying gypsum properties for targeted applications. Rachedi et al. [8] explored the physical and mechanical behaviour of gypsum mortar reinforced with fibres of varying lengths and diameters, identifying an optimal fibre length and content that balanced essential properties such as workability, water absorption, and density.

Braiek et al. [9] examined the thermal behaviour of gypsum composites with fibre additions, observing a significant reduction in thermal conductivity—an effect attributed to the fibres' low intrinsic thermal conductivity and the resultant increase in porosity. Rachedi and Kriker [10] further investigated the thermal properties of gypsum composites reinforced with palm fibres, concluding that a specific fibre content and length yielded the best thermal performance. Chikhi et al. [11] utilised petiole fibres in varying lengths and percentages, finding that lower fibre percentages and specific lengths reduced porosity and improved mechanical properties. However, higher fibre loads diminished performance due to matrix–fibre incompatibility and unfavourable fibre orientation.

Kethiri et al. [12] examined the practical implications of incorporating date palm leaflet powder (DPLP) into gypsum mortars, discovering that increased DPLP content and larger particle sizes resulted in higher porosity and water absorption while reducing mechanical strength and thermal conductivity. Esan et al. [13] provided a comprehensive review of gypsum composites, evaluating the synergistic effects of various reinforcements – including fibres, polymers, and particles – on enhancing mechanical properties as well as acoustic and thermal insulation and fire resistance. Souidi et al. [14] explored the practical use of date palm fibres (DPF) and polyester fibres (PF) in gypsum composites, finding that DPF enhanced flexural strength, while a combination of DPF and PF improved thermal conductivity and flexural strength despite a reduction in transverse compressive strength. Asefa et al. [15] studied sisal fibre-gypsum composites, noting that long unidirectional fibres provided better impact and hardness strengths than short-chopped fibres and that impact strength increased with higher fibre weight percentages.

Recent studies have further highlighted the potential of natural fibres in improving the thermal and mechanical performance of gypsum-based composites. For instance, Dan Wan et al. [16] demonstrated that incorporating paddy husk into plaster matrices significantly reduces thermal conductivity and bulk density. Similarly, Kothari et al. [17] found that date palm leaflet powder enhances the thermal insulation properties of gypsum mortars. Finally, Jedidi M. [18] investigated the incorporation of Posidonia oceanica fibres into plaster composites and observed marked improvements in their physical, mechanical, thermal, and acoustic absorption properties.

While previous studies have explored the use of natural fibres in gypsum composites, there remains a need to optimise fibre content, fibre length, and the water-to-plaster (W/P) ratio to balance thermal insulation and mechanical strength. In line with these findings, our study hypothesises that reducing the density of gypsum compounds reinforced with palm fibres will enhance their thermal insulation properties – an improvement anticipated to be particularly significant when higher fibre content, shorter fibres, and an optimised W/P ratio are employed. To address this research gap, we prepared gypsum composites reinforced with 10 mm long palm fibres at concentrations of 2%, 4%, and 6%, using varying W/P ratios of 0.8, 1.0, and 1.5. These compositions were subjected to comprehensive analyses to evaluate their physical properties (density), mechanical properties (compressive strength), and thermal properties (thermal conductivity and specific heat), thereby providing valuable insights into the development of sustainable, high-performance building materials.

The ultimate goal of this study is to reduce the environmental impact associated with the production and use of building materials by developing and revaluing local resources in Southern Algeria, such as gypsum and palm fibres. By leveraging these abundant local materials, we aim to foster sustainable construction practices that align with global efforts to mitigate climate change and promote environmental stewardship, while also potentially reducing construction costs and boosting the local economy.

2. Materials and specimens preparation

2.1. Plaster

The plaster used as the matrix in this study was produced at the reputable S.P.A Oasis Plaster factory. It is derived from natural gypsum sourced in the Ghardaia region of Southern Algeria, a region known for its high-quality gypsum. It is a white powder with the chemical formula $CaSO_4 \cdot \frac{1}{2}H_2O$, and its purity is approximately 96%, according to the NF B 12-302 standard. Table 1 presents its physical properties.

Table 1. Characteristics of plaster

bulk density	826.14
Refusal Particle size sieve (400 μm)	< 1.5%
Refusal Particle size sieve (100 μm)	< 13.20%
Fineness modulus (cm^2/g)	3518
Initial setting time (min)	8
Final setting time (min)	16

2.2. Fibres

Palm fibres, an eco-friendly reinforcing material from the Ouargla oasis in Southern Algeria, represent a sustainable alternative to conventional construction materials. These fibres, often discarded as waste during the annual harvest season, have been selected for this study due to their environmentally friendly characteristics and high availability. The potential of palm fibres to revolutionise the construction industry and contribute to a more sustainable future is promising [19]. Specifically, the study utilises surface fibres from the trunks of male date palms, as depicted in Fig. 1. These fibres were chosen for their superior mechanical properties, which have been validated in previous research by Kriker et al. [20], making them more suitable than other palm fibres.

The collected fibres undergo a meticulous preparation process, ensuring the thoroughness and reliability of the research. Initially, they are separated into individual fibres and soaked in water to eliminate impurities and dust. After drying under controlled laboratory conditions, the fibres are cut into 10 mm lengths, ready for incorporation into the plaster matrix. This attention to detail in the preparation process reinforces confidence in the quality of the research.

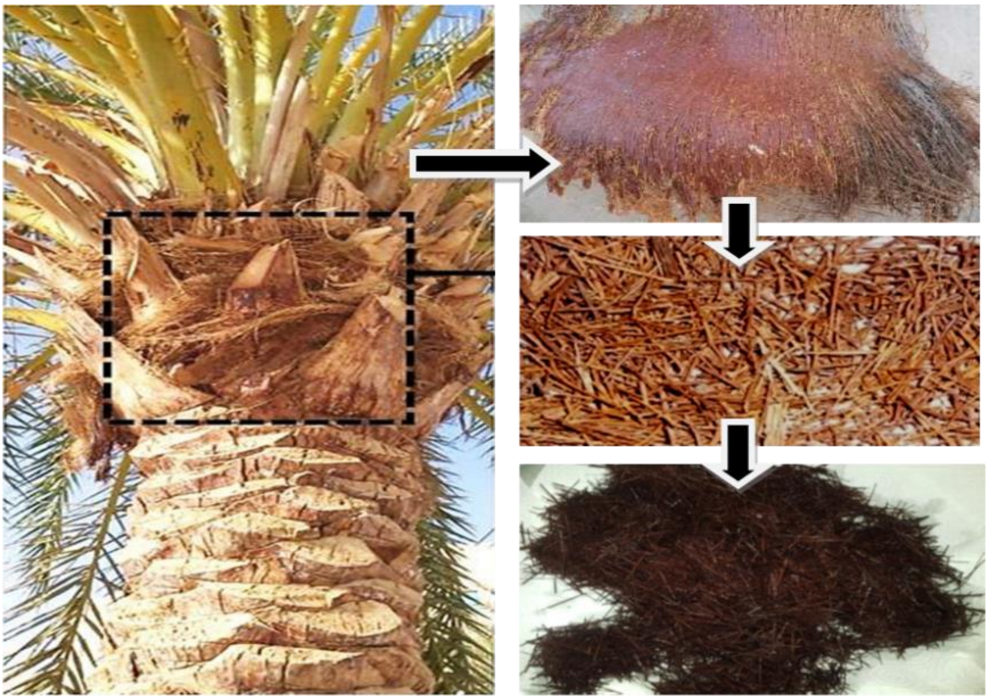

Fig. 1. Stages of palm fibre preparation and treatment

Chemical treatment, a crucial aspect recommended by various studies [10,11,21], is adopted to enhance the physical and mechanical properties of the palm fibres and to improve their adhesion to the plaster matrix. The protocol used in this study involves soaking the fibres in a 0.5% sodium hydroxide (NaOH) solution at 50°C for one hour, which helps to remove fragile layers such as lignin and hemicellulose. Following the alkaline treatment, the fibres are thoroughly washed with water to remove residual chemicals and bleached using sodium chloride (NaCl). Finally, the fibres are rewashed with water and left to dry at room temperature in the laboratory, ensuring they are optimal for use in the composite material. The physical properties of date palm fibres are presented in Tab. 2.

Table 2. Physical and mechanical properties of the fibres

Length (mm)	Diameter (mm)	Density	Humidity rate (%)	Rate of Absorption (after 24 h)	Modulus of Elasticity (GPa)	Tensile Strength (MPa)	Elongation (%)
10	0.2-1	1.32	9.82	98.22	8.43	342	8.2

2.3. Specimens preparation

To prepare the plaster composites reinforced with palm fibres, fibres of 10 mm length were used at concentrations of 2%, 4%, and 6%, with varying water-to-plaster (W/P) ratios of 0.8, 1.0, and 1.5. For comparison, pure plaster compounds were also prepared for each W/P ratio. The water used throughout the various stages of the study – including washing, mixing, and wetting—was laboratory tap water, compliant with the NF EN 1008-2003 standard, ensuring the highest quality and reliability of the research.

The preparation process, a meticulous procedure, is of paramount importance as it ensures the quality of the palm fibre-reinforced plaster samples and their compliance with predefined criteria. It begins with wetting the fibres and thoroughly mixing them with plaster. Water is gradually added during mixing to ensure an even distribution of the fibres within the plaster matrix. The mixtures are carefully poured into moulds in two stages, ensuring homogeneous packing and optimal dispersion of the fibres within the plaster matrix. This meticulous procedure is crucial in facilitating the attainment of superior physical and mechanical properties.

As part of this study, preservation protocols for the samples intended for evaluating the composites' physical, mechanical, and thermal properties were rigorously defined to ensure reliable results. Two sample dimensions were used: 40 × 40 × 160 mm^3 for physico-mechanical tests and 40 × 80 × 160 mm^3 for thermal tests, in accordance with the FN EN 196-1 standard. After manufacturing, the samples were demoulded 24 hours after casting and stored under standardised laboratory conditions (25 ± 2°C temperature and 60 ± 5% relative humidity) to promote uniform maturation of the composite. Each test was performed in triplicate, demonstrating a commitment to ensuring the reproducibility of the measurements. The samples were then carefully kept in ambient laboratory air for 28 days, allowing for complete drying and stabilisation of the measured properties.

Fig. 2. Specimens used

3. Testing and methods

3.1. Physical Test

In this study, after thoroughly drying the samples in an oven at 50°C until their weight stabilised, we determined the physical properties of the plaster composites reinforced with palm fibre. The density (ρ) of each sample was calculated by precisely measuring the mass and apparent volume of the dried samples using the following equation:

$$\rho = \frac{M}{V} \tag{1}$$

where M (g) represents the mass of the sample, and V (cm^3) represents its apparent volume.

3.2. Mechanical test

The compressive strength of the various plaster composites, determined according to standard EN 196-1, was measured by subjecting samples, precisely cut to dimensions of 40 × 40 × 40 mm^3 from the original specimens used in the physical properties analysis, to compressive testing. These samples were placed under a hydraulic pressure machine, where a controlled load was applied at an increased rate of (2400 ± 200) $N\cdot s^{-1}$. The compressive strength (R_a, MPa) was then calculated using the following formula:

$$R_c = \frac{F_c}{A} \tag{2}$$

with: F_c: maximum load in N. A: the cross-sectional area of the specimen (A = 1600 mm^2).

3.3. Thermal test

In this study, the thermal properties of palm fibre-reinforced plaster composites were measured in accordance with the NFE 993-15 standard, using a CT-meter device, as illustrated in Fig. 3. This device operates by monitoring the temperature rise during a specified heating period, employing a probe that integrates both a temperature sensor and a heating element. The samples, precisely sized at 40 × 80 × 160 mm^3, were meticulously dried and aged for 28 days at a controlled temperature of 50°C to ensure stability. During the measurement process, the probe was inserted between two samples, enabling an accurate assessment of thermal properties. The device then directly displayed the results for thermal conductivity (λ, W/m·K) and specific heat capacity (Cp, J/m^3·K), providing crucial data for evaluating the thermal performance of the composites.

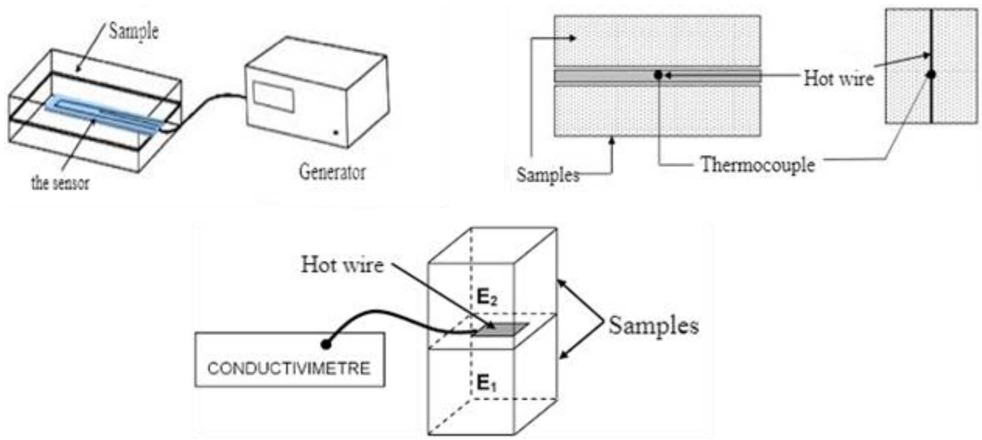

Fig. 3. Experimental setup for measuring thermal properties

4. Results and discussion

Table 3 provides a comprehensive overview of the key findings from the characterisation of the physical, mechanical, and thermal properties of plaster composites reinforced with palm fibres. These composites were prepared with 2%, 4%, and 6% fibre concentrations, using fibres of 10 mm in length and varying water-to-plaster (W/P) ratios of 0.8, 1.0, and 1.5. The results presented in this table offer a clear and immediate understanding of how fibre content and the W/P ratio influence the various properties of the plaster composites. This summary effectively highlights the study's efficiency in elucidating the role of these variables, providing valuable insights into optimising plaster composites for improved performance in construction applications.

Table 3. Variation of density, compressive strength, thermal conductivity, and specific heat of plaster composites based on the W/P ratio and date palm fibre content

Ratio W/P	Percentage of fibres (% by mass)	Density	Compressive strength (MPa)	Thermal conductivity (W/mK)	Specific heat (J/kg K)
0.8	0%	1.36	9.70	0.36	836.34
	2%	1.25	8.68	0.31	866.46
	4%	1.09	7.32	0.28	901.91
	6%	0.98	6.12	0.26	960.34
1	0%	1.28	9.04	0.32	861.81
	2%	1.13	8.12	0.27	893.95
	4%	0.98	6.85	0.24	937.34
	6%	0.91	5.42	0.22	986.84
1.5	0%	1.18	8.17	0.28	887.04
	2%	1.01	7.57	0.23	924.85
	4%	0.90	6.17	0.20	973.68
	6%	0.88	5.23	0.19	1012.17

4.1. Physical properties

Understanding the physical properties, particularly density, is a crucial aspect of developing new eco-friendly construction materials. Density, beyond merely indicating the lightness of a material, plays a pivotal role in determining the essential characteristics of composites. Our study, as illustrated in Fig. 4, focused on analysing the impact of various palm fibre ratios (2%, 4%, and 6%) and different water-to-plaster (W/P) ratios (0.8, 1.0, and 1.5) on the density of palm fibre-reinforced plaster composites. This analysis was conducted by preparing and testing a series of plaster composites with varying fibre and W/P ratios. A significant reduction in density was observed with an increase in fibre content and W/P ratio compared to a reference plaster. For instance, a composite with a 2% fibre ratio and a W/P ratio of 0.8 exhibited a density of 1.25, while increasing the fibre ratio to 6% at the same W/P ratio resulted in a density drop to 0.98.

Similarly, at a W/P ratio of 1.5, increasing the fibre content from 2% to 6% led to a density reduction from 1.01 to 0.88. This decrease in density can be attributed to the increased void volume due to the addition of fibres, leading to higher porosity within the composites. This reflects an inhomogeneous distribution of fibres and reduced fibre adhesion to the matrix. The alveolar structure and porous nature of palm fibres also contribute to this effect. Additionally, the high water content in our composites, exceeding what is necessary for chemical reactions, results in increased void formation as water evaporates, further reducing the density of these composites. It is important to note that our study focused on the impact of palm fibre and water-to-plaster ratios on the density of plaster composites and did not consider other factors that could influence the properties of these materials. This interpretation aligns with the findings of Djoudi et al. [22], who studied plaster concrete reinforced with palm fibres, and with the conclusions of Touil et al. [23] regarding similar plaster mortars. Ultimately, incorporating palm fibres with high water content into plaster composites is an effective strategy for reducing the density of these materials while offering potential improvements in other mechanical and thermal properties, thereby contributing to the development of high-performance eco-materials for construction.

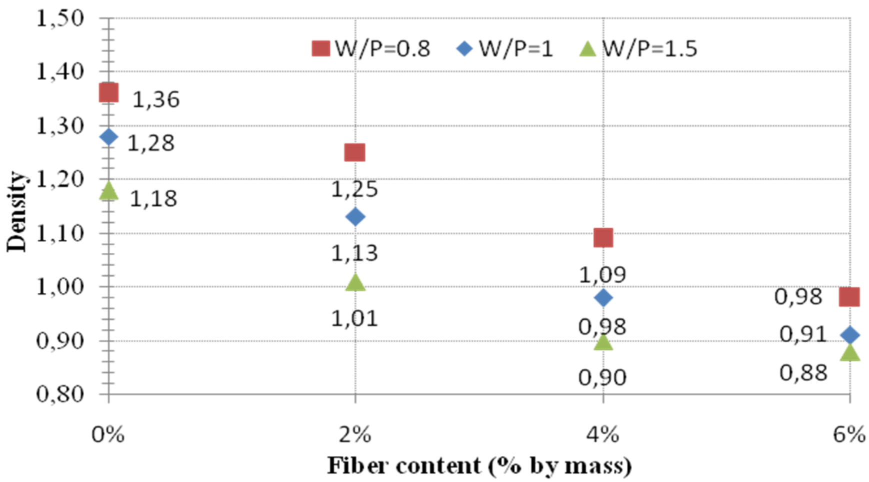

Fig. 4. Variation of the density of plaster composites based on W/P ratio and date palm fibre content

4.2. Mechanical properties

Compressive strength is a crucial parameter for evaluating the mechanical properties of construction materials, serving as an essential selection criterion for their structural applications. The results in Fig. 5 summarise the performance of palm fibre-reinforced plaster composites, highlighting the varied effects of fibre content and water-to-plaster (W/P) ratios on this mechanical property.

Our study reveals a negative correlation between compressive strength and fibre content. For a 2% fibre ratio with a W/P ratio of 0.8, the compressive strength decreases modestly from 9.70 MPa (for pure plaster) to 8.68 MPa. This reduction becomes more pronounced with increased fibre content and W/P ratio. For example, at a 6% fibre content and a W/P ratio of 1.5, the compressive strength significantly drops to 5.23 MPa. This observation aligns with the work of Naiiri et al. [24], who reported a decrease in compressive strength with the incorporation of palm fibres into plaster mortar, and is further supported by the studies of Djoudi et al. [22] and Amara et al. [25], who explored the benefits of palm fibres in concrete composites.

The effect of water content in the plaster is significant; higher W/P ratios lead to more substantial decreases in compressive strength for identical fibre percentages. Specifically, composites with a W/P ratio of 1.5 exhibit the lowest compressive strength across all tested fibre percentages, reaching 5.23 MPa at a 6% fibre content. The increase in porosity due to higher water content or greater fibre concentration can explain the observed deterioration in the composite's mineral skeleton, as suggested by the studies referenced in [7,8,11,13]. Additionally, the findings of Benmansour et al. [26] are consistent with our conclusions, as they also observed a significant impact of water content on the compressive strength of plaster mortar.

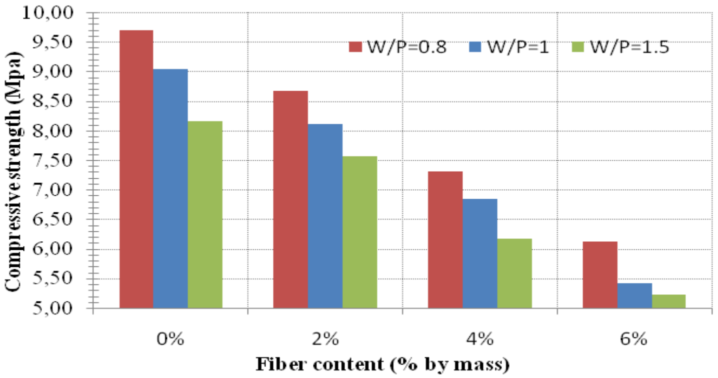

Fig. 5. Variation of the compressive strength of plaster composites based on W/P ratio and date palm fibre content

Despite the modest reduction in compressive strength observed in all tested samples, these values still fall within the permissible limits outlined in the NF EN 13670 standard. These findings further support the feasibility of producing an insulating and eco-friendly building material that can effectively meet the standards and requirements of sustainable construction.

4.3. Thermal properties

In civil engineering, optimising the thermal properties of construction materials is crucial to meeting the demands for sustainability and energy efficiency in modern buildings. Thermal conductivity, a measure of a material's ability to transfer heat, directly influences its effectiveness as an insulator. The primary goal of innovative construction composites, such as palm fibre-reinforced plaster composites, is to minimise heat loss for better indoor thermal regulation, thereby reducing energy consumption and associated costs.

The thermal conductivity results for palm fibre-reinforced plaster composites, as shown in Fig. 6, reveal a significant decrease in thermal conductivity with the introduction of palm fibres compared to standard plaster. This reduction becomes more pronounced as the fibre content and the water-to-plaster (W/P) ratio increase. For instance, at a W/P ratio of 0.8 and a fibre content of 2%, the thermal conductivity drops from 0.36 W/m·K to 0.31 W/m·K. Increasing the fibre content to 6% further reduces the conductivity to 0.26 W/m·K. Similarly, at a W/P ratio of 1.5, the thermal conductivity decreases from 0.28 W/m·K (0% fibres) to 0.19 W/m·K at a fibre content of 6%.

This reduction in thermal conductivity is primarily explained by three mechanisms related to the addition of palm fibres and the high water-to-plaster ratio:

1. Palm fibres inherently have low thermal conductivity.
2. Incorporating these fibres increases the porosity within the composites, creating more voids that hinder heat transfer.
3. The composites' high water content contributes to a further increase in void volume, which exacerbates the reduction in thermal conductivity.

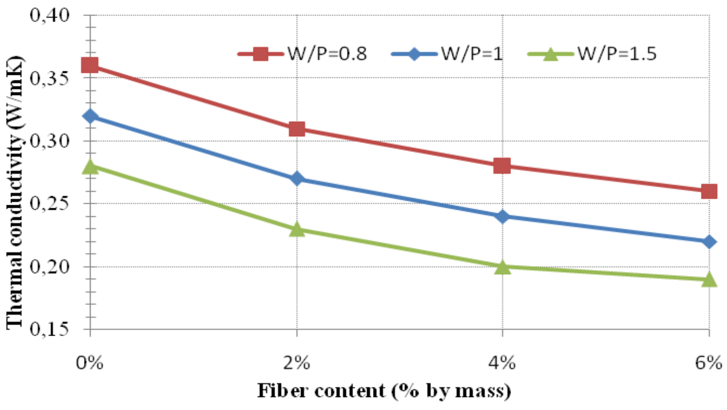

Fig. 6. Variation of the thermal conductivity of plaster composites based on W/P ratio and date palm fiber content

These findings are consistent with the observations of previous studies [8,14], which highlighted that pure plaster has a relatively low thermal conductivity and that the introduction of palm fibres, with their alveolar structure, provides additional thermal barriers. For example, the reduction in thermal conductivity observed in our palm fibre composites parallels the improvements reported by Wan et al. [16] in paddy husk composites. Moreover, the findings of studies by Kharrati et al. [27] and Ouakarrouch et al. [28] reinforce the conclusion that increasing the short fibre content and high water content leads to decreased thermal conductivity due to increased porosity.

In conclusion, the analysis of thermal conductivity confirms that palm fibre-reinforced plaster composites offer significant improvements in thermal insulation, aligning with our research objectives to develop eco-friendly construction materials. The ability of these composites to reduce thermal conductivity while maintaining essential mechanical and structural properties positions them as promising candidates for sustainable construction applications, supporting efforts to reduce the energy impact of buildings.

Specific heat is a crucial property of construction materials, as it determines their capacity to store thermal energy, which is vital for maintaining thermal regulation within buildings, contributing to thermal inertia, and stabilising indoor temperatures. Our study, aimed at developing efficient eco-materials, examined the specific heat of plaster composites reinforced with palm fibres to assess their potential to enhance thermal comfort while significantly reducing energy consumption. The results presented in Fig. 7 indicate that the specific heat of the plaster composites increases with the inclusion of palm fibres. This increase becomes more pronounced with higher fibre content and higher water-to-plaster (W/P) ratios, suggesting that these composites can store more thermal energy, thereby contributing to the thermal inertia of structures.

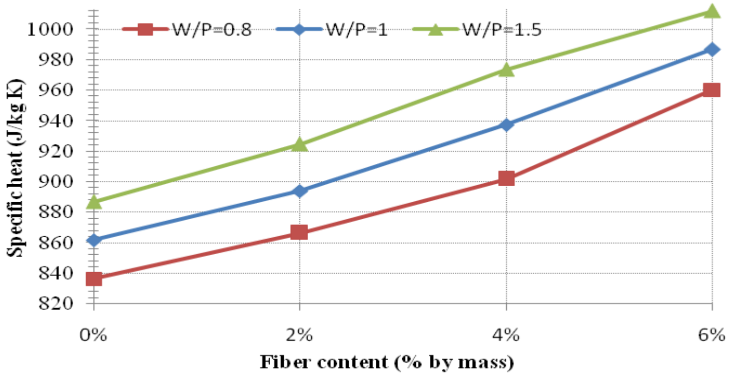

Fig. 7. Variation of the specific heat of plaster composites based on W/P ratio and date palm fibre content

For example, a composite with a 2% fibre ratio at a W/P ratio of 0.8 shows an increase in specific heat from 836.34 J/kg·K (for pure plaster) to 866.46 J/kg·K. As the fibre content and W/P ratio rise, this enhancement becomes more substantial, with the composite containing 6% fibres at a W/P ratio of 1.5 reaching a specific heat of 1012.17 J/kg·K. This improvement in specific heat can be primarily attributed to two mechanisms related to the addition of palm fibres and the increased water content in the gypsum. First, palm fibres inherently have low thermal conductivity, which reduces heat loss. Second, the higher water content in the composites leads to increased voids within the material, enhancing the composite's ability to absorb and retain heat, allowing the temperature to rise more slowly.

These findings align with a robust body of previous research. For instance, Dawood et al. [29] demonstrated that incorporating natural fibres into plaster composites enhances their heat capacity, consistent with our observations. Similarly, Jia et al. [30] found that adding palm fibres to gypsum concrete composites significantly improves the specific heat of plaster composites, further supporting our conclusions. In addition, Kethiri et al. [17] reported that incorporating date palm leaflet powder enhances the thermal insulation properties of gypsum mortars, underscoring the potential benefits of natural fibre additives in improving the thermal performance of building materials.

In summary, the specific heat test results confirm that plaster composites reinforced with palm fibres offer superior thermal performance compared to pure plaster, aligning with our research objectives to develop thermally efficient and sustainable construction materials. These materials, with their increased heat storage capacity, have the potential to reduce the energy demands of buildings, thereby contributing significantly to the overall reduction of the carbon footprint in construction and promoting a more sustainable future.

In line with our research objectives on eco-friendly and efficient construction materials, this study makes a significant contribution by examining plaster composites reinforced with date palm fibres. The analysis of the results reveals essential correlations between density and thermal properties, which are critical factors in assessing the performance of an insulating building material.

A particularly notable relationship was observed between density and thermal properties, as illustrated in Fig. 8. This observation aligns with the findings of Rachedi et al. [10], who demonstrated that incorporating fibres into the plaster matrix increases porosity and reduces density, with a correlation coefficient of $R^2 = 0.95$, thereby enhancing the composite's thermal insulation. Furthermore, Djoudi et al. [22] reported a direct correlation ($R^2 = 0.97$) between density and thermal conductivity, attributing this relationship to the distribution and size of fibres within the matrix. Our study found strong correlations, with $R^2 = 0.94$ for thermal conductivity and $R^2 = 0.99$ for specific heat, indicating good dispersion. These findings have important implications for sustainable materials, supporting the notion that careful selection of palm fibres and the plaster-to-water ratio can lead to the development of tailored composites that meet the specific demands of sustainable building materials. Composites with optimal densities, good thermal properties, and satisfactory compressive strength can be valuable for applications that balance thermal performance and mechanical strength. This research highlights the potential of using date palm fibres as reinforcements in plaster-based materials, offering a sustainable and environmentally friendly alternative to traditional reinforcements.

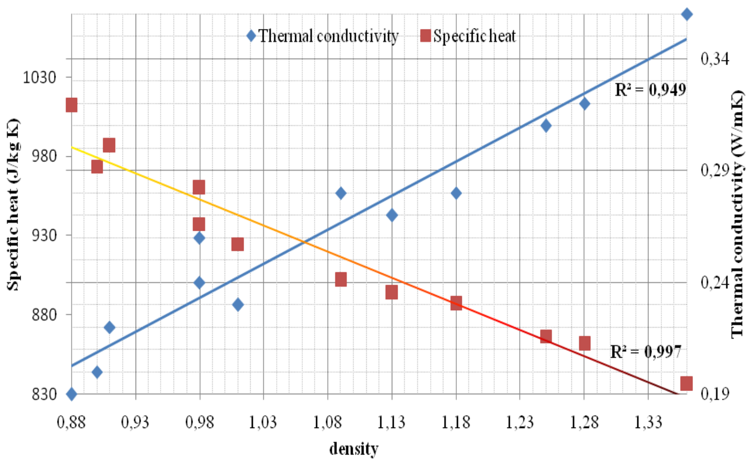

Fig. 8. Correlation between the density and thermal properties of the studied composites

5. Conclusions and comments

This study demonstrates that palm fibre-reinforced plaster composites can be developed using locally available materials in Southern Algeria, offering a sustainable alternative to conventional building materials. By incorporating 10 mm palm fibres at varying proportions (2%, 4%, and 6%) and adjusting the water-to-plaster (W/P) ratios (0.8, 1.0, and 1.5), significant modifications were achieved in the physical, mechanical, and thermal properties of the composites.

Key findings:

- Physical Properties: Increasing fibre content and higher W/P ratios consistently reduced the density of the composites. Notably, a composite with 6% fibre at a 1.5 W/P ratio reached a density of 0.88 g/cm^3, which is advantageous for lightweight construction applications.
- Mechanical Properties: Although a modest reduction in compressive strength was observed (with the 6% fibre, 1.5 W/P composite exhibiting 5.23 MPa), the values remain within acceptable limits, ensuring sufficient structural integrity.
- Thermal Properties: The addition of palm fibres significantly improved thermal insulation performance, as evidenced by a reduction in thermal conductivity to 0.19 W/m·K and an increase in specific heat capacity. These enhancements indicate a greater capacity for thermal energy storage, leading to more stable indoor temperatures and reduced heat transfer.

The results substantiate the potential of these composites to balance structural performance with enhanced thermal insulation, thereby reducing the environmental footprint associated with conventional building materials. Moreover, using locally sourced gypsum and palm fibres contributes to waste valorisation and supports sustainable construction practices tailored to arid regions.

Future research should focus on optimising fibre-matrix interactions, investigating long-term durability and fire resistance, and assessing economic feasibility in practical construction settings. Overall, this work provides a scientifically robust basis for adopting eco-friendly, energy-efficient building materials that meet the evolving demands of sustainable construction.

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