REVISTA MATÉRIA V.30
ISSN 1517-7076 articles e20250583, 2025

A systematic review on stabilizing materials in adobe: performance and mechanical properties

Aldi Nestor de Souza Junior[1], Fernando Rusch[1], Juliana de Moura[1], Alexandre Santos Pimenta[2], Rafael Rodolfo de Melo[1]

[1]Universidade Federal Rural do Semiárido. Av. Francisco Mota, 572, Costa e Silva, 59625-900, Mossoró, RN, Brasil.

[2]Universidade Federal do Rio Grande do Norte. Rodovia RN 160, Km 03, s/n, Distrito de Jundiaí, 59280-000, Macaíba, RN, Brasil.

e-mail: aldi.junior@ifma.edu.br, fe_rusch@yahoo.com.br, juliana.moura@alunos.ufersa.edu.br, alexandre.pimenta@ufrn.br, rafael.melo@ufersa.edu.br

ABSTRACT

The growing demand for sustainable building materials has sparked renewed interest in blocks for construction, particularly when stabilized with natural fibers to enhance their mechanical properties. This study presents a systematic review conducted in the ScienceDirect and Scopus databases, covering publications from 2015 to 2025. The inclusion criteria considered experimental studies that analyzed adobe stabilized with plant fibers and reported their mechanical properties. A total of nine studies met the eligibility criteria. The fibers evaluated included straw, *Hibiscus cannabinus*, palm, neem, jute, seagrass, date palm, and pine needles. Overall, the addition of fibers improved mechanical performance. The best compressive strength result was obtained with neem fibers, showing a 35% increase compared to the reference block. For tensile strength, the most significant improvement was observed with palm fibers, resulting in a 19% increase compared to the control. These results confirm that controlled fiber incorporation improves adobe performance, particularly in terms of compressive and tensile strength, while maintaining its sustainable and low-cost characteristics. However, differences in soil types and experimental procedures between studies limit comparability, highlighting the need for standardized methodologies in future research.

Keywords: Fibers; Sustainable construction; Construction.

1. INTRODUCTION

Construction techniques have accompanied the development of civilizations since ancient times, helping to create environments conducive to human subsistence. Vernacular constructions played a fundamental role in this process, initially due to the simplicity of their execution and, later, to the ease of transmitting knowledge to subsequent generations. The use of earth-based construction methods in buildings dates back more than 9,000 years [1].

In recent years, with the advance of sustainability policies, earth-based construction has regained prominence due to its low environmental impact and the potential for circular economy practices. The Sustainable Development Goals (SDGs) seek, among other things, to mitigate environmental problems and promote social inclusion. SDG 11, for example, aims to make cities and communities more inclusive, safe, resilient, and sustainable. Among the goals to be achieved by 2030 is the guarantee of access to safe, adequate, and affordable housing [2].

In this context, a sustainable alternative for civil construction is using technologies based on “raw earth”, in which there is no burning during the manufacture of the blocks. This type of construction offers several advantages, such as carbon neutrality, availability of local raw materials, and thermal comfort [3]. Adobe, an example of raw earth construction, uses materials available in the region without undergoing intensive processing, making it a sustainable option, especially for low-income housing [4].

Several studies have explored the improvement of mechanical, thermal, and physical properties of blocks through the inclusion of natural or waste-based stabilizers. The addition of fibers, such as banana fiber [4; 5], and residues from paper and pulp industries [6], has shown significant potential for increasing tensile and compressive strength, as well as improving thermal performance. Likewise, the inclusion of construction waste

Corresponding Author: Rafael Rodolfo de Melo Received on 04/07/2025 Accepted on 12/09/2025

DOI: https://doi.org/10.1590/1517-7076-RMAT-2025-0583

can contribute to environmental management and the reduction of material disposal in landfills [7]. Research has also highlighted the influence of soil composition and particle size on the dimensional stability and mechanical resistance of adobe, as seen in the incorporation of kaolin and fine particles [8].

The structural behavior of fiber-reinforced adobes has been the focus of experimental studies that demonstrate improvements in performance and durability, particularly regarding crack control and shrinkage reduction [4]. These contributions highlight the importance of integrating material science with vernacular construction knowledge to enhance performance while maintaining ecological and social benefits.

In the Brazilian context, research highlights the potential of natural fibers as sustainable reinforcement in blocks, as demonstrated by studies using piassava, coconut, and sugarcane fibers in different regions of the country. For example, the incorporation of 3% piassava fibers into adobe resulted in significant gains in compressive strength and greater displacement before fracture, in addition to offering greater erosion resistance and less surface cracking [9].

This research aims to carry out a systematic analysis of the behavior of adobe, emphasizing the use of different types of stabilizers, contributing to the development of more sustainable solutions for civil construction.

2. MATERIAL AND METHODS

The review covered the period 2015 to 2025 and was conducted in the Science Direct and Scopus databases, recognized for their broad coverage of scientific publications. The search strategy used Boolean operators, employing the term "adobe AND fiber" to retrieve studies that simultaneously addressed adobe and the use of fiber as a reinforcement or stabilization element. The search was conducted exclusively in English.

After identifying the articles, the titles and abstracts were read for initial screening. Then, the full texts of the eligible articles were analyzed in detail. The extracted information was systematized in spreadsheets for later analysis.

Inclusion and exclusion criteria were defined for study selection. Articles published between January 2014 and May 2025, available in full text, and presenting experimental or analytical studies on the addition of fibers to adobe, as well as data regarding the mechanical properties of the blocks, soil characterization, and description of the fibers used, were included. Studies addressing ceramic bricks, cement, or concrete blocks, review articles without original data, and duplicate publications across the databases consulted were excluded.

After identifying the articles, the titles and abstracts were initially read for preliminary screening. The full texts of eligible studies were then analyzed in detail, and the extracted information was systematized into spreadsheets for later evaluation.

3. RESULTS AND DISCUSSION

3.1. Characteristics of vegetable fibers used as stabilizers in blocks

Adding fibers to the composition of blocks aims to improve their mechanical properties, increase thermal comfort, and reduce the appearance of cracks caused by the shrinkage process. In general, the incorporation of fibers tends to significantly increase the compressive strength of the blocks and reduce the occurrence of cracks by approximately 50% compared to simple adobe [9]. The plant fibers analyzed in the study were: *Hibiscus cannabinus*, Palm, Neem, Jute, coconut straw, seagrass, date palm, and pine needle.

Straw fibers had an equivalent diameter of 0.3 mm, tensile strength of 14.5 MPa, elongation at break of 1.5%, modulus of elasticity of 0.07 GPa, and water absorption of 300% [10]. *Hibiscus cannabinus* fibers had a diameter of 0.13 mm, natural moisture content of 6.10%, specific gravity of 1.04 g/cm^3, and average tensile strength of 1.00 GPa [11]. Palm fibers ranged in length between 10 and 60 mm, with an average diameter of 0.45 mm, average density of 1.27 g/cm^3, water absorption of 170%, ultimate strain between 4.6 mm and 18.07 mm, average tensile strength of 86 MPa, and average modulus of elasticity of 2.39 GPa [12]. Neem fibers originate from India but adapt well to tropical climates [13]. For the research, the fibers were dried in an oven for 24 hours before being mixed with the soil. The length of the fibers varied between 2 and 6 mm, with an apparent density of 0.38 kg/cm^3 (Table 1).

3.2. Characteristics of soils used in the production of adobe

For the production of adobe, the soil must have an adequate clay content, responsible for the cohesion of the material, and a sufficient proportion of sand, which contributes to dimensional stability and crack reduction [17]. Analysis of the studies revealed wide textural variation among the soils used, allowing (through the amounts of sand, silt, and clay in each of them) their categorization according to the USDA (United States Department of Agriculture).

Table 1: Characteristics of plant fibers used in the manufacture of adobe.

FIBER	LENGTH (mm)	WIDTH OR DIAMETER (mm)	TENSILE STRENGTH (MPa)	MODULUS OF ELASTICITY (GPa)	APPARENT DENSITY (g/cm^3)	SOURCE
Straw		0.30	14,5	0.07		KHORASANI and KABIR [10]
Hibiscus cannabinus		0.13	1		1.04	MILLOGO *et al.* [11]
Palm	10–60	0.45	86	2,39	1.27	ESLAMI *et al.* [12]
Neem	2–6				0.38	BABÉ *et al.* [13]
Jute		0.152	525			CONCHA-RIEDEL *et al.* [9]
Seagrass	10–30				1.91	OLACIA *et al.* [14]
Date palm	10	0.50				KHRISSI and TILIOUA [15]
Pine needles					0.55	NASLA *et al.* [16]

Table 2: Characterization of the soil used in the manufacture of manually done adobe with different plant fibers as stabilizing materials.

COUNTRY	SAND/SILT/CLAY	LIQUIDITY LIMIT	PLASTICITY LIMIT	PLASTICITY INDEX	SOURCE
Iran	90/0/10	–	–	–	KHORASANI and KABIR [10]
France	45/30/25	38,00	20,00	18,00	MILLOGO *et al.* [11]
Iran	41/37/22	31,20	20,80	10,40	ESLAMI *et al.* [12]
Cameroon	25/13/62	36,00	22,00	14,00	BABÉ *et al.* [13]
Brazil	–	41,21	29,48	11,73	BRITO *et al.* [18]
Chile	–	29,10	17,40	11,70	CONCHA-RIEDEL *et al.* [9]
Italy	60/0/40	–	–	–	OLACIA *et al.* [14]
Morocco	62/30/8	39	23	16	KHRISSI and TILIOUA [15]
Morocco	23/25/52	35	18	17	NASLA *et al.* [16]

Table 2 summarizes the results obtained through soil characterization. The straw-added soil in Iran was composed of 90% clay and silt and only 10% sand, characterized as clayey, with liquidity and plasticity limits of 23% and 8%, respectively [10]. The soil obtained in Rochechinard (France), with 45% sand, 30% silt, and 25% clay, is classified as medium texture (clay loam), presenting liquidity limits of 38% and plasticity of 20% [11]. The soil from Iran (40.6% clay, 37.4% silt, and 22% sand) was classified as silty clayey, also within the medium texture range, with liquidity and plasticity limits of 31.2% and 20.8% [12].

The soil from Santiago (Chile) was classified as well-graded clayey sand, with liquidity and plasticity limits of 27.0% and 15.7% [19]. In the case of the soil from the Yagoua region (Cameroon), composed of 62% sand, 25% clay, and 13% silt, its classification is medium to sandy texture, with liquidity limits of 36% and plasticity of 22% [13]. This soil, when associated with neem fibers, presented outstanding performance, with a 35% increase in compressive strength, evidencing the positive influence of the combination of sand content and minimum clay content for cohesion.

The soil intended for the blocks (Brazil) presented a distinct chemical composition, rich in oxides (Al, Fe, and Si), and liquidity and plasticity limits of 41.21% and 29.48% [18], being classified as clayey. The soil from Italy, formed by 60% clay and silt and 40% sand, also qualifies as clayey, although the Atterberg limits were not reported [16].

In studies carried out in Morocco, two distinct scenarios were observed: a soil with 62% sand, 30% silt, and only 8% clay, classified as sandy, with a plasticity index of 16 [15]; and another soil from the

Rabat-Salé-Zemmour-Zaer region, with 52% sand, 25% silt, and 23% clay, classified as medium-textured (sandy loam) [16]. The first presented inferior performance due to its low clay content, while the second, with greater textural balance, showed more stable behavior when associated with fibers.

3.3. Adobe

3.3.1. Production

The blocks with the addition of straw were molded with 30% humidity, and a geometric shape of 50 × 200 × 50 mm was adopted. Before testing, the blocks underwent a 28-day curing process [10]. The manufacture of blocks with the addition of *Hibiscus cannabis* fibers used 20% humidity with dimensions of 295 × 140 × 100 mm. The fibers had lengths of 30 mm and 60 mm [11].

In a study on the mechanical behavior of blocks with palm fibers, blocks measuring 200 × 200 × 50 mm were used [12]. The production was done manually by local workers, and the fibers were added in proportions of 0%, 0.25%, 0.50%, 0.75%, and 1% [12]. BURBANO-GARCIA *et al*. [19] dried the soil in an oven for 24 hours to produce the blocks.

The neem fibers were added in blocks measuring 100 x 100 x 30 mm and manually mixed with the soil in proportions of 0%, 1%, 2%, 3%, and 4% by weight of the soil. After molding, the specimens were left at room temperature for 24 hours, under 60% humidity, with a curing period of 21 days [13]. The blocks stabilized with Sisal were homogenized manually and placed in 200 × 100 × 80 mm molds, undergoing the curing process in the sun for 28 days [18]. The blocks with jute fibers were dried in an oven and homogenized manually, with a humidity of 30.7%. Fiber percentages varied between 0.5 and 2% [9].

The blocks with seagrass addition had prismatic dimensions of 40 × 40 × 160 mm. Mixing was done manually, and the blocks were cured under laboratory conditions (21–23°C, 40–50% relative humidity) for 28 days, until they reached constant weight. Fibers were added in proportions of 0%, 0.5%, 1.5% and 3% by weight [14]. The addition of date palm fibers used blocks measuring 40 × 40 × 40, homogenized manually [15]. Finally, the blocks added with pine needle fibers were molded manually, and the following measurements were adopted: 40 mm × 40 mm × 160 mm, with the percentage of fiber added being 0, 1, 2, and 3% [16]. Table 3 shows all the results related to the production of the blocks.

3.3.2. Compressive strength

The compressive strength of adobe blocks has been evaluated by several authors using different natural additives. In studies of KHORASANI and KABIR [10], the addition of straw and other materials resulted in maximum compressive strength values of 1.00 MPa. Blocks reinforced with Hibiscus cannabinus fibers reached 2.85 MPa, with the optimal fiber content being 0.4% by weight and fiber lengths of 30 mm yielding the best results [11]. The incorporation of palm fibers led to a compressive strength of 4.88 MPa with 0.25% fiber content, representing a 37% increase compared to the control block [12]. For blocks with 2% neem fibers achieved 6.35 MPa, a 35% improvement over the reference value of 4.69 MPa [13]. On the other hand, BRITO *et al*. [18] reported low compressive strength in blocks where clay was partially replaced by manure, with the highest value being 0.15 MPa at 5% substitution, slightly higher than the control value of 0.11 MPa.

An increase of 33.5% in compressive strength was observed with the addition of 2% jute fibers, with values rising from 1.49 MPa to 1.99 MPa [9]. For blocks stabilized with seagrass, the best performance was achieved using natural-length fibers at a 3% content, reaching 2.66 MPa — an increase of approximately 59%

Table 3: Characteristics of the production of adobe that adopted different vegetable fibers as stabilizing materials.

FIBER	MOISTURE (%)	DIMENSIONS (mm)	SOURCE
Straw	30,0	50 × 200 × 50	KHORASANI and KABIR [10]
Hibiscus cannabinus	20,0	295 × 140 × 100	MILLOGO *et al*. [11]
Palm	27,0	200 × 200 × 50	ESLAMI *et al*. [12]
Neem	–	100 × 100 × 30	BABÉ *et al*. [13]
Jute	–	310 × 105 × 70	CONCHA-RIEDEL *et al*. [9]
Seagrass	40-50	40 × 40 × 160	OLACIA *et al*. [14]
Date palm	–	40 × 40 × 40	KHRISSI and TILIOUA [15]
Pine needles	–	40 × 40 × 160	NASLA *et al*. [16]

Table 4: Results of compression and tensile tests on adobe that adopted different plant fibers as stabilizing materials.

FIBER	MAXIMUM COMPRESSION STRENGTH (MPa)	COMPRESSIVE STRENGTH WITHOUT FIBER ADDITION (MPa)	GAIN IN COMPRESSIVE STRENGTH (%)	MAXIMUM TENSILE STRENGTH (MPa)	TENSILE STRENGTH WITHOUT FIBER ADDITION (MPa)	GAIN IN TENSILE STRENGTH (%)	SOURCE
Straw	1.00	–	–	0,17	–	–	KHORASANI and KABIR [10]
H. cannabinus	2.50	2.45	16.33	1,30	0,52	150,00	MILLOGO *et al.* [11]
Palm	4.88	3.07	58.96	1,19	0,61	95,08	ESLAMI *et al.* [12]
Neem	6.35	4.69	35.39	0,22	0,16	37,50	BABÉ *et al.* [13]
Juta	1.99	1.49	33.56	0,88	0,37	137,84	CONCHA-RIEDEL *et al.* [9]
Seagrass	2.66	1.67	59.28	0,56	0,41	36,70	OLACIA *et al.* [14]
Date palm	3.60	1.40	157.14	1,91	1,60	19,30	KHRISSI and TILIOUA [15]
Pine needles	1.40	1.08	22.85	–	–	–	NASLA *et al.* [16]

compared to the control block (1.68 MPa) [14]. Adobe blocks reinforced with date palm fibers showed maximum strength at 3% fiber content, increasing from 1.4 MPa to 3.6 MPa; above this percentage, strength values began to decline [17]. Lastly, the addition of pine needle fibers yielded the best results at 1% content, with compressive strength increasing from 1.08 MPa to 1.40 MPa [18].

3.3.3. Tensile strength

In the tensile test, blocks with straw fibers reached a tensile strength of 0.17 MPa [10]. For blocks reinforced with *Hibiscus cannabinus*, a tensile strength of 1.3 MPa was obtained with 0.2% of 30 mm fibers [11]. Blocks with palm fibers reached 1.19 MPa with 1% fiber content, representing a 95% increase over the reference block. The use of neem fibers resulted in a tensile strength of 0.22 MPa, an increase of 37.5% compared to the blocks without fiber addition [13]. In studies of CONCHA-RIEDEL *et al*. [9], blocks with 2% jute fibers showed improved performance, with tensile strength rising from 0.37 MPa to 0.88 MPa. Blocks containing seagrass reached a maximum of 0.562 MPa with 0.5% fiber content, an increase of 36.7% over the reference value of 0.411 MPa [16]. The incorporation of date palm fibers yielded an increase of 19.3%, with values going from 1.60 MPa to 1.91 MPa; the greatest gain was observed at 3% fiber content [17]. Table 4 presents the results of the systematic compression and tensile tests.

4. FINAL CONSIDERATIONS

A wide range of soil textures was observed in the studies, according to the USDA system, ranging from sandy to clayey. However, it was not possible to establish a direct correlation between the percentage of a specific particle (sand, silt, or clay) and the increased mechanical strength of the fiber-stabilized blocks. According to GOMES *et al*. [20], adobes with higher clay content tend to have greater compressive strength, while increased sand content favors greater deformation before failure, indicating greater ductility. Therefore, further research is needed to further analyze the relationship between soil texture and mechanical performance, also considering the interaction with different types of fibers.

The systematic analysis of the literature showed that incorporating natural fibers into adobe blocks represents an effective technical strategy for improving the mechanical properties of this material, especially concerning compressive and tensile strength. The data obtained show that the controlled addition of fibers can result in significant gains in structural performance, increasing the viability of adobe as a construction solution in contexts that demand greater mechanical performance and environmental sustainability.

Although it was not possible to make a direct statistical comparison between the studies, some inferential trends can be highlighted. The highest compressive strength values were observed in blocks with 2% neem fibers (*Azadirachta indica*), which reached 6.35 MPa, representing an increase of 35% from the reference block (4.69 MPa). Blocks stabilized with palm fibers also stood out, reaching 4.88 MPa with 0.25% addition, an increase of 58.96% from the control (3.07 MPa). Neem fibers showed the highest compression results. Palm fibers demonstrated the most significant strength gains, with increases of approximately 150% and 157%, respectively. This result indicates that not only the fiber type but also its size and interaction with the soil matrix play a key role. The ideal fiber length is possibly between 10 and 25 mm, ensuring better bonding between particles and uniform stress distribution.

In terms of tensile strength, date palm fiber obtained the best performance, with a maximum value of 1.91 MPa (an increase of 19%), followed by Hibiscus cannabinus fiber (1.30 MPa), which presented an increase of 150% to the initial value (0.52 MPa).

The observed performance variations are directly related not only to the type and percentage of fibers used, but also to the physical and chemical characteristics of the soil, molding conditions (such as moisture and particle size), dry density, and curing processes employed. It was observed that most blocks were produced manually, generally with a moisture content of around 30%, which is appropriate for traditional practice. However, the wide diversity in manufacturing methodologies, including variations in block dimensions, molding moisture contents, and curing times and conditions, compromises the direct comparability of results across studies. This methodological heterogeneity therefore constitutes a significant limitation of this review, reinforcing the need for standardization in future research.

In terms of sustainability, using plant fibers, often considered agricultural waste, combined with using local soils without burning processes, contributes to reducing the construction industry's carbon footprint, which is in line with the Sustainable Development Goals proposed by the UN. Therefore, it is concluded that using plant fibers represents an efficient and low-cost strategy for improving construction materials, potentially combining technical performance, environmental sustainability, and socioeconomic viability. It is recommended, however, that future studies explore the influence of the length, content, and type of fibers on the durability and resistance of the blocks, especially in varied environmental conditions.

5. BIBLIOGRAPHY

[1] MINKE, G., *Manual de construção com terra: uma arquitetura sustentável*, São Paulo, B4, 2015.

[2] UNITED NATIONS, *Sustainable development goals*, https://brasil.un.org/pt-br/sdgs/11, accessed in August, 2023.

[3] WIDDER, L., "Earth eco building: textile reinforced earth block construction", *Energy Procedia*, v. 122, pp. 757–762, 2017. doi: http://doi.org/10.1016/j.egypro.2017.07.392.

[4] KAFODYA, I., OKONTA, F., KLOUKINAS, P., "Role of fiber inclusion in adobe masonry construction", *Journal of Building Engineering*, v. 26, pp. 100904, 2019. doi: http://doi.org/10.1016/j.jobe.2019.100904.

[5] MOSTAFA, M., UDDIN, N., "Experimental analysis of Compressed Earth Block (CEB) with banana fibers resisting flexural and compression forces", *Case Studies in Construction Materials*, v. 5, pp. 53–63, 2016. doi: http://doi.org/10.1016/j.cscm.2016.07.001.

[6] MUÑOZ, P., LETELIER, V., MUÑOZ, L., *et al*., "Adobe bricks reinforced with paper & pulp wastes, improving thermal and mechanical properties", *Construction & Building Materials*, v. 254, pp. 119314, 2020. doi: http://doi.org/10.1016/j.conbuildmat.2020.119314.

[7] ZENG, M.; HUANG, H.; ZHANG, X. Experiment on the Performance of Recycled Powder of Construction Waste on Adobe Materials. Buildings 2023, 13, 1358. https://doi.org/10.3390/buildings13051358

[8] CONCHA-RIEDEL, J., ANTICO, F.C., LÓPEZ-QUEROL, S., "Mechanical strength, mass loss, and volumetric changes of drying adobe matrices combined with kaolin and fine soil particles", *Construction & Building Materials*, v. 312, pp. 125246, 2021. doi: http://doi.org/10.1016/j.conbuildmat.2021.125246.

[9] CONCHA-RIEDEL, J., ANTICO, F.C., ARAYA-LETELIER, G., "Mechanical and damage similarities of adobe blocks reinforced with natural and industrial fibres", *Matéria*, v. 25, n. 4, e-12906, 2020. doi: http://doi.org/10.1590/s1517-707620200004.1206.

[10] KHORASANI, F.F., KABIR, M.Z., "Experimental study on the effectiveness of short fiber reinforced clay mortars and plasters on the mechanical behavior of adobe masonry walls", *Case Studies in Construction Materials*, v. 16, e00918, 2022. doi: http://doi.org/10.1016/j.cscm.2022.e00918.

[11] MILLOGO, Y., MOREL, J.-C., AUBERT, J.-E., *et al*., "Experimental analysis of Pressed Adobe Blocks reinforced with Hibiscus cannabinus fibers", *Construction & Building Materials*, v. 52, pp. 71–78, 2014. doi: http://doi.org/10.1016/j.conbuildmat.2013.10.094.

[12] ESLAMI, A., MOHAMMADI, H., BANADAKI, H.M., "Palm fiber as a natural reinforcement for improving the properties of traditional adobe bricks", *Construction & Building Materials*, v. 325, pp. 126808, 2022. doi: http://doi.org/10.1016/j.conbuildmat.2022.126808.

[13] BABÉ, C., KIDMO, D.K., TOM, A., *et al*., "Effect of neem (*Azadirachta Indica*) fibers on mechanical, thermal, and durability properties of adobe bricks", *Energy Reports*, v. 7, pp. 686–698, 2021. doi: http://doi.org/10.1016/j.egyr.2021.07.085.

[14] OLACIA, E., PISELLO, A.L., CHIODO, V., *et al*., "Sustainable adobe bricks with seagrass fibres. Mechanical and thermal properties characterization", *Construction & Building Materials*, v. 239, pp. 117669, 2020. doi: http://doi.org/10.1016/j.conbuildmat.2019.117669.

[15] KHRISSI, Y., TILIOUA, A., "Development and characterization of eco-friendly earth bricks stabilized with date palm waste fibers for sustainable construction", *Cleaner Waste Systems*, v. 11, pp. 100283, 2025. doi: http://doi.org/10.1016/j.clwas.2025.100283.

[16] NASLA, S., GUERAOUI, K., CHERRAJ, M., *et al*., "An experimental study of the effect of pine needles and straw fibers on the mechanical behavior and thermal conductivity of adobe earth blocks with chemical analysis", *JP Journal of Heat and Mass Transfer*, v. 23, n. 1, pp. 35–56, 2021. doi: http://doi.org/10.17654/HM023010035.

[17] HAN, W., WU, F., CHENG, Y., *et al*., "Compressive performance of adobe masonry strengthened with glass-fiber reinforced matrix composites", *Materials and Structures*, v. 56, n. 3, pp. 53, 2023. doi: http://doi.org/10.1617/s11527-023-02143-7.

[18] BRITO, M.R., MARVILA, M., LINHARES JUNIOR, J., *et al*., "Evaluation of the properties of adobe blocks with clay and manure", *Buildings*, v. 13, n. 3, pp. 657, 2023. doi: http://doi.org/10.3390/buildings 13030657.

[19] BURBANO-GARCIA, C., ARAYA-LETELIER, G., ASTROZA, R., *et al*., "Adobe mixtures reinforced with fibrillated polypropylene fibers: Physical/mechanical/fracture/durability performance and its limits due to fiber clustering", *Construction & Building Materials*, v. 343, pp. 128102, 2022. doi: http://doi.org/10.1016/j.conbuildmat.2022.128102.

[20] GOMES, C.D., DELUCIS, R.A., THEISEN, K.M., "Valorization of piassava fiber by its incorporation in adobe bricks", *Anais da Academia Brasileira de Ciências*, v. 96, e20240210, 2024. doi: http://doi.org/10.1590/0001-3765202420240210. PubMed PMID: 39699540.