Građevinski materijali i konstrukcije
Building Materials and Structures
journal homepage: www.dimk.rs

https://doi.org/10.5937/GRMK2300015R

Original scientific paper

Enhancing mechanical properties and crack resistance of earth-sand building materials through alfa fiber reinforcement: an experimental investigation

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Article history

Received: 17 November 2023
Received in revised form:
21 December 2023
Accepted: 26 December 2023
Available online: 07 February 2024

Keywords

Earth construction;
Alfa fiber;
Shrinkage;
Mechanical strength;
SEM

ABSTRACT

This paper investigates enhancing the mechanical properties and crack resistance of earth-sand building materials by incorporating Alfa fibers, derived from the Alfa plant. Earth-based construction materials, known for their sustainability, face challenges in mechanical performance and cracking. The study explores a composite of earth (60 wt%) and sand (40 wt%) reinforced with Alfa fibers of varying lengths and rates. Tensile strength and water absorption of the fibers were assessed, and prismatic specimens (40x40x160 mm^3) with different cutting lengths were tested. Results inform the potential of Alfa fibers for improving earth-based material performance.

Incorporating 2% wt of Alfa fibers reduced the unit weight of the composite from 1849 kg/m^3 to 1632 kg/m^3, resulting in a slight material weight decrease. Compared to unreinforced adobe specimens, fibrous samples exhibited lower linear shrinkage rates and improved mechanical behavior, with 2% wt of 3 cm fibers showing optimal performance. The fibers effectively impeded crack propagation, with both length and content influencing crack attenuation. However, microstructural observation revealed poor fiber/matrix adhesion, negatively impacting adobe specimen compactness despite enhanced mechanical properties.

1 Introduction

Around the world, buildings are constructed from a wide variety of materials. When access to concrete, timber, and crushed stone is limited, the most commonly used material is soil. For thousands of years, earthen houses have been built around the globe [1].

In recent years, there has been a lot of interest in the use of vegetable fibers as a possible reinforcement in adobe as a building material. Several fibers [2]–[7] have been incorporated to improve the properties of bricks [8] and also to gradually change out conventional construction materials in an attempt to decrease building large carbon footprints. The addition of this kind of material negatively impacts the compressive strength characteristics of the composite. Nevertheless, the incorporation of a minor quantity of fibers with short lengths could be used as reinforcement and effectively address this shortcoming with a significant increase in strength [9], [10].

Given the fact that natural soil is the most eco-friendly material that is typically used to produce bricks, combining vegetable fibers with it could be deemed one of the most promising methods for greening the construction sector. Several researchers around the globe are inspired to try creating intelligent, lightweight, and alternative materials with this basic mixture because it takes advantage of the earth´s high thermal mass and the substantial influence of agro-aggregates on the hygrothermal efficiency of adobe bricks [11]. Additionally, the utilization of vegetable fibers is more advantageous in developing countries, where they are available at a low cost and their manufacture requires a small amount of energy. Besides, they do not contribute to pollution.

A series of experimental studies have been conducted on the physical and mechanical properties of earth brick composite. They have shown the benefits of the incorporation of vegetable fibers (coconut, straw, jute, flax, bamboo, cane, etc.) [2], [3], [5]–[7], [9], [12]–[15]. Also, in order to create theoretical analytical models for earth composites [16], [17], the impact of synthetic fibers on the soil matrix has also been investigated [18]–[20]. The primary factors that significantly impact the properties of earth composites are the kind, durability, water absorption, and tensile strength of the fibers, in addition to their length and weight percentage replacement in the composite [2].

The type of fiber has a significant impact on the impermeability of the bricks, which depends on the percentage of lignin in the fiber. The impermeability of vegetable fiber increases with its lignin content. The brick shrinkage that occurs during the drying process of adobe

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samples could vary greatly depending on the earth mixture and the addition of fibers to the soil matrix to prevent the formation of shrinkage cracks [21]. Less shrinkage occurs when fibers with higher bonds are more resistant [8]. Furthermore, the crack resistance of earth reinforced with fibers is directly related to the tensile strength of the fibers [22]. This paper does not address the long-term stability of this aspect, but it does investigate the physical and mechanical properties of adobe bricks reinforced with Alfa fibers. The length of the fiber directly influences the reinforcement force, which is equal to or less than the fiber tensile strength, by determining the pullout resistance of the incorporated fiber in the earth matrix. Several studies support this statement. A study by Mustapha et al. used both experiments and computer simulations to look into how natural fibers pull away from an earth-based matrix. They discovered that the interfacial crack driving force is equal to the interfacial fracture toughness, which changes non-linearly with the internal crack lengths and the elastic properties of the materials. This means that the fiber pull-out loads probably won't depend linearly on the fiber embedment length [23]. The total weight ratio of fibers controls the reinforcement's intensity; for small quantities, the reinforcement's strength goes up as the number of fibers increases. However, as the fibers become so widespread randomly they weaken the matrix, decreasing the strength of reinforced adobe composites [2], [3]. Finally, other studies have highlighted that incorporating natural fiber increases the ductility, fracture resistance, and energy absorption properties of earthen materials [24], [25]. The fiber length was also found to have a notable influence on ductility and the post-fracture response of the material for large deflection levels of the material [24].

The motivation for this research stems from the need to develop construction materials that not only align with sustainable building practices but also exhibit improved mechanical strength and durability. By exploring the potential benefits of Alfa fiber reinforcement, we aim to contribute to the evolution of earth-based building materials into high-performance, environmentally friendly alternatives.

This experimental investigation involves a systematic exploration of the mechanical properties and crack resistance of earth-sand composites reinforced with Alfa fibers. The study encompasses evaluations of fiber characteristics, such as tensile strength and water absorption, to gain insights into their behavior within the composite matrix. Additionally, prismatic specimens with varying fiber lengths and content ratios undergo rigorous testing to assess the impact of Alfa fibers on the overall performance of the material.

The outcomes of this research are anticipated to provide valuable insights into the feasibility and effectiveness of Alfa fiber reinforcement in earth-sand building materials. Such advancements hold the potential to reshape construction practices by offering sustainable alternatives with enhanced structural attributes. As we delve into this experimental investigation, we anticipate uncovering new possibilities for the development of resilient, environmentally conscious building materials.

2 Experimental:

2.1 Characterization of raw materials

2.1.1 *Alfa fibers*

The Alfa fibers, from the StippaTenacissima L [26], thrived in the dry regions of North Africa and the South of Europe. It belongs to the graminaceous family and grows to a height of about 1m in Morocco. The Alfa plant grew in abundance in many regions, primarily in the north-eastern part of the country. The fibers used in this study were harvested from the region of "Oujda". Before their use in the composite, the fibers were cleaned to remove any dust and impurities deposited on the surface, then they were cut at different lengths (1, 2, and 3 cm). Fig. 1 shows the cut Alfa fiber studied in this paper.

According to Ajouguim [26], and A.B. Mabrouk [27], Alfa fibers are mainly composed of cellulose, hemicellulose, lignin, and extractible elements. The chemical composition of used Alfa fiber is given in Table 1, and its properties are presented in Table 2. Fig. 2 shows the structure of the Alfa plant observed through scanning electronic microscopy

Figure 1. Cut Alfa fiber

(SEM). Based on longitudinal stem observation, the SEM observations show that Alfa stems have a hairless and soft appearance with numerous dusts and impurities (wax, fat, etc.) that are located on the surface (Fig. 2b). Additionally, the SEM of the fiber cross section indicates that this plant has a cellular structure with pores (Fig. 2a). This type of vegetal fiber's void network morphology provides promise for creating Adobe composites with improved thermal performance and low unit weight. Beyond surface visualization, the SEM analysis allows us to measure the diameter as well.

The earth used in this study was collected from the 'AitOurir' (31° 33′ 54″ nord, 7° 40′ 05″ ouest) located in Al Haouz Province, at the foot of the Atlas Mountains, around 40 km east of the city of Marrakesh. This soil was used in the past by local builders to manufacture Adobe bricks, and it is characterized by its abundance and availability in the area. The mineralogical composition reveals that the soil contains dominant quartz, with other constituents including illite, augite, and plagioclase. The soil was sieved to obtain elements less than 2 mm in size. The granulometric size distribution of the soil, which was obtained by sieving and hydrometer analyses carried out following ASTM standard D422 [28], is given in Table 3a. Concerning ASTM particle size limits, the soil has 23% clay, 40.3% silt, and 36.70% sand. Table 3a reports the Density and Atterberg limits of the used soil. The soil might be classified as CL, i.e., inorganic clay with medium plasticity and medium liquid limit, in the Unified Soil Classification System [29]. Table 3b. presents the properties of crushed sand brought from a local quarry near Marrakesh city and tested according to AFNORD standard [28]. The diffractograph of the used sand reveals the dominance of quartz, together with other constituents including plagioclase and tridymite.

(a) **(b)**

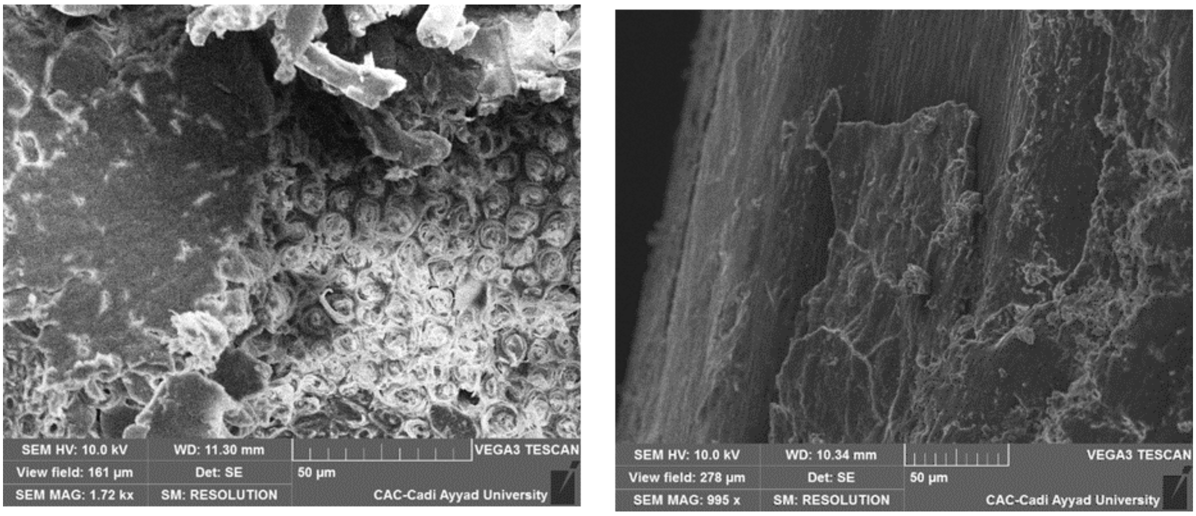


Figure 2. Structure of Alfa fiber :(a) Cross-section (b) External surface

Table 1. Chemical components of Alfa fibers [26], [27]

Cellulose (%)	Hemicellulose (%)	Lignin (%)
39.50	27.60	19.50

Table 2. Properties of Alfa fibers

Density (g/cm^3)	Young'smodulus (GPa)	Stress at break (MPa)	Strain at break (%)
1.40	21.5	247	1.96

Table 3a. Geotechnical characteristics of studied earth.

Grain size distribution	Consistencylimits	Methylene Blue Value
Clay <2µm: 23% Silt (2-63 µm):40.3% Fine Sand (0.063-0.2 mm): 36.7%	Liquid limit, LL=38% The plastic limit, PL=20% Plasticity Index, PI=18%	MBV(g/100g)= 3

Table 3b. Physical characteristics of crushed sand

Apparent density	Specificdensity	Water content (%)	Sand equivalent
1.50	2.60	1.1	85

2.2 Sample preparation

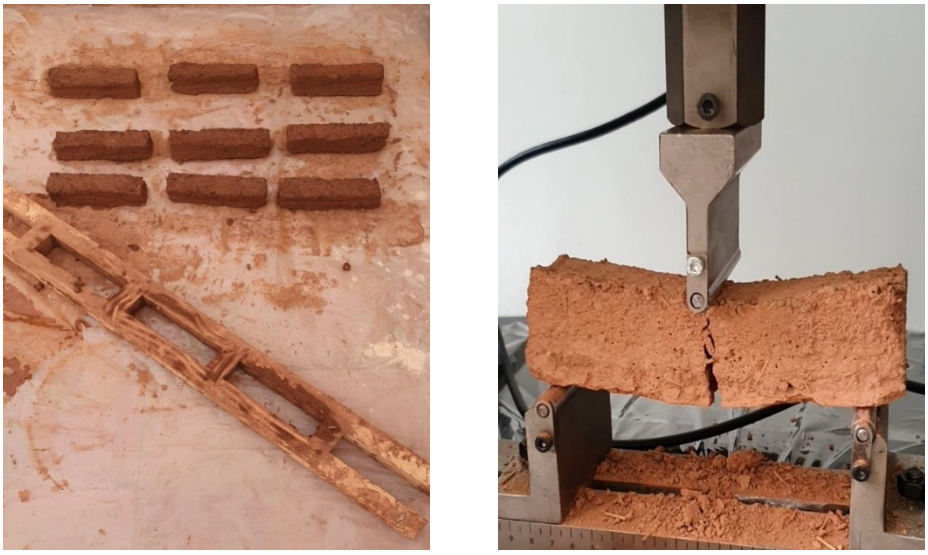
Different compositions of adobe prismatic samples were prepared by varying the content and length of the fibers. The adobe sample dimensions of 40x40x160 mm^3 justify the addition of fiber cut up to 3 cm. Additionally, previous research on the critical length and interfacial strength of fibers incorporated into an epoxy matrix also emphasized the importance of acknowledging the influence of fiber length on the interfacial strength and mechanical properties of the composite material [30]. Therefore, it is essential to address the pronounced wall effect and preferential orientation of fibers due to the specific fiber length and mold size, as this can have a substantial impact on the behavior and mechanical performance of the reinforced material. The inclusion of Alfa fibers increased from 1 wt % to 1.5 and 2 wt% (weight percentage), allowing us to compare reinforced to unreinforced specimens.

Samples were manufactured using various mix compositions, as summarized in Table 4, by first mixing the dry fibers and sand manually. The composite was then mixed with slowly added earth until a homogeneous mixture was obtained. This process allowed for a homogenous dispersion of fibers in the mixture. After mixing all the ingredients, the mixture was manually compacted in a wooden mold, as shown in Fig. 3a. This mold was first scattered inside with sand and wet with water to facilitate the removal of specimens. The moist soil was compacted into four layers and discharged when they started to gain consistency. The drying of the samples took place in normal laboratory conditions at 20 ± 2 °C with a relative humidity of 98% for approximately 28 days until constant weight. The shapes of different samples after demolding are shown in Fig. 3.

Table 4. The proportion of mixtures

Mixture designation	Earth (%)	Sand (%)	Water/Soil weight ratio	fraction	Fiber length (cm)
U (Control Specimen)	60	40	0.20	–	–
R1-1	60	40	0.20	1%	1
R1.5-1	60	40	0.20	1.5%	1
R2-1	60	40	0.20	2%	1
R1-2	60	40	0.20	1%	2
R1.5-2	60	40	0.20	1.5%	2
R2-2	60	40	0.20	2%	2
R1-3	60	40	0.20	1%	3
R1.5-3	60	40	0.20	1.5%	3
R2-3	60	40	0.20	2%	3

a: Fiber weight fraction is evaluated on the total weight of the clay-sand mix.



(a) **(b)**

Figure 3. Sample after demolding (a), three-point bending flexural-tests (b)

2.3 Experimental testing

2.3.1 *Tensile strength and water absorption of Alfa fibers*

Firstly, to be knowledgeable of certain properties of Alfa fibers and to exploit their highest potential, the fibers were evaluated in terms of tensile strength and water absorption.

The tensile strength of the long fibers was determined experimentally according to ASTM C1557 [31]. This standard test method covers the preparation, mounting, and testing of single fibers obtained either from a fiber bundle or a spool. The fibers were situated straight inside the equipment grips that produced the fiber failure. ASTM C1557 is the standard test method for determining the tensile strength and elastic modulus of fibers at ambient temperature. Therefore, the use of ASTM C1557 for determining the tensile strength of the long fibers is well-established and provides a reliable basis for the experimental determination of the fiber's tensile strength. Figure 4 presents the equipment used for this purpose. The properties of Alfa fibers are presented in Table 2. Fundamentally, vegetable fibers are characterized by their sensitivity to water [32] because of their chemical composition, as shown below. The water absorption capacity of the fibers under study was established using equation (1).

$$W = \frac{Ph - Pd}{Pd} \quad (1)$$

Where P_d is the weight of air-dried fibers and P_h is the weight of soaked fibers in drinking water. The measurement was carried out at 24-hour intervals for 18 days. The average percentages of water absorption for Alfa fibers are given in Fig 5.

Figure 4. Tensile testing of Alfa fiber

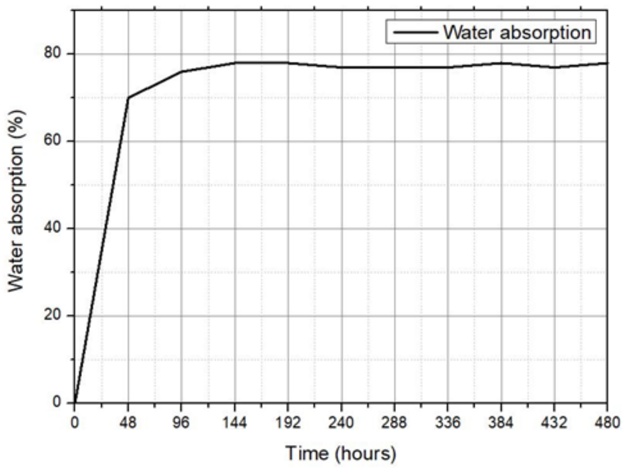


Figure 5. Water absorption of Alfa fiber

2.3.2 *Unit weight and shrinkage*

The next step after the drying process of the samples consisted of measuring the average mass and density as well as the rate of linear shrinkage. Dry density was calculated using the analytical balance. On the other hand, linear drying shrinkage was obtained by decreasing the percentage of the dried sample lengths compared with the initial length of the mold (160 mm). The reduction in the length of the specimen after drying is measured and expressed as a percentage of the original length to give the linear shrinkage, and its value is determined according to equation (2):

$$Percentage\ of\ linear\ shrinkage = \frac{1 - L_d}{L_o}$$

Where L_d is the new length of the dry specimen in mm and L_o is the original length of the specimen in mm.

2.3.3 *Flexural and compressive strength*

The flexural and compressive properties of the hardened specimens were measured after curing, according to the European Standard EN 196-1 [33]. For flexural strength, three specimens from each mix were prepared and tested with three-point bending, as shown in Fig. 3b. All tests were carried out at a controlled rate of 0.4 mm/min with the use of a closed-loop-servo-electric 5 kN tension-compression machine. Flexural strength was calculated by Equation (2):

$$\sigma_f = \frac{1,5 * F_f * L_f}{bd^2} \quad (2)$$

Where: σ_f (MPa) is the strength of the prism at the failure plan, F_f(N) is the maximum load recorded by the testing machine, b(mm) is the width of the specimen in the direction transversal to the applied force, d(mm) is the thickness of the specimen in the direction parallel to the applied force, and L_f (mm) is the distance between the holders.

The compressive tests have been done on each half specimen obtained after failure with the flexural test and calculated according to Equation (3). Tests were carried out in displacement control at a velocity rate of 4 mm/min

$$R_c = \frac{F_c}{S} \quad (3)$$

Where R_c (N/mm^2), F_c (N), and S (1600 mm^2) are the compressive strength, the maximum failure force, and the contact surface between the adobe element and plates used in the test, respectively.

3 Results and discussion

3.1 Apparent density of dry composite

The apparent density of an adobe brick is considered a fundamental step for building materials and engineering because it impacts material selection, structural design, safety, and serves several important purposes in the construction and building sectors.

The apparent density of an adobe brick holds paramount significance in material selection, structural design, safety, and various aspects of construction and engineering. In Fig. 6, the apparent density of composites, featuring different fiber lengths and addition ratios, is presented. The results show that increasing the fiber percentage results in a decrease in apparent density. For instance, adding 2% wt of 3 cm Alfa plant cutting reduced the density from 1849 kg/m3 (unreinforced sample, U) to 1632 kg/m3 for the R2-3 specimen, indicating a reduction of approximately 12%. This reduction could be attributed to the lower density of fibers compared to soil-sand materials. The increase in fiber quantity leads to a decrease in earth-sand content, consequently lowering the composite's apparent density. The lightening of the adobe brick can also be explained by the fibers' higher water absorption capacity, which in turn increases porosity during the drying process. Hence, the primary advantage of using vegetable fibers is the lightweight nature of the samples, aligning with findings from previous studies [15], [34]–[36]. However, a slight impact of fiber length variation is observed in the results.

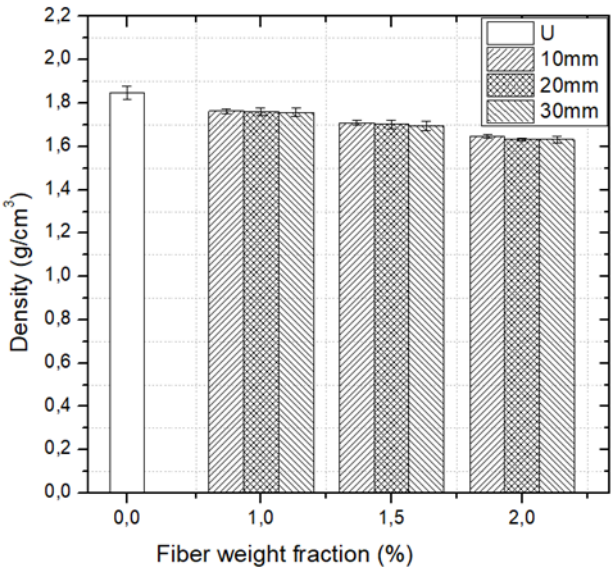


Figure 6. Apparent density of dry composite

3.2 Effect of Alfa fiber on linear shrinkage

The dimensional variation of the material due to water evaporation post-manufacture, known as linear shrinkage, was measured for all samples. In Fig. 7, the variation in linear shrinkage with different reinforcement levels is depicted. The results confirm that Alfa fibers effectively reduce shrinkage, with a 2% fiber content leading to a 68% decrease. The unreinforced samples exhibit higher shrinkage, while reinforced soil specimens resist deformation and limit contraction, which is consistent with previous studies [3], [5], and [34] . Additionally, Fig. 7 illustrates the impact of increasing fiber length to 30 mm, showing that the minimum shrinkage rate is associated with the higher fiber content of 30mm length, possibly due to long bonding between the Alfa fiber and the matrix.

The disparity in shrinkage between the reinforced and unreinforced composites can be attributed to the superior water absorption capacity of Alfa fiber and its gradual water-releasing ability. As depicted in Fig. 5, during the initial 48 hours of the drying process, the fibers absorb water and expand. This swelling action displaces the soil, and as the fibers lose humidity towards the end of drying, they contract back to their original size, leaving pores around themselves. This dynamic process during mixing and drying contributes to the observed difference in shrinkage between the reinforced and unreinforced composite materials.

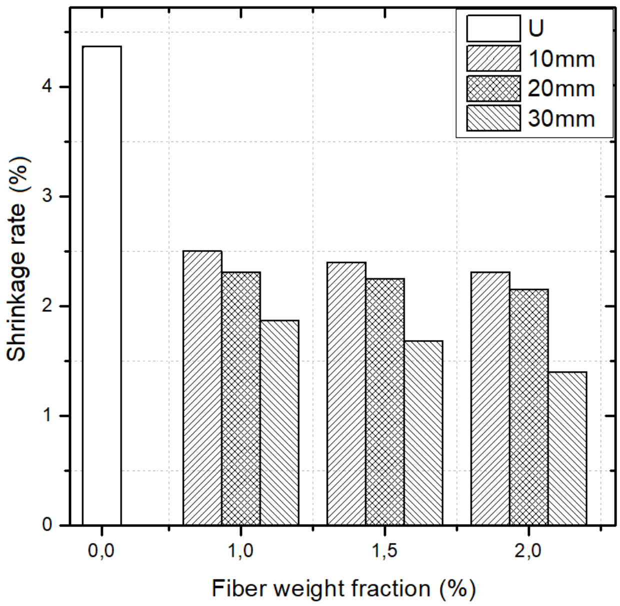


Figure 7. Average value of linear shrinkage for unreinforced and reinforced samples.

3.3 Flexural strength

Table 5 provides a summary of flexural strength results at 28 days in relation to fiber content and lengths (10, 20, and 30 mm). The finding indicates that increasing the fiber content up to 2% leads to a notable enhancement in flexural strength, ranging from 25% to 60%, depending on the specific fiber content. Additionally, it is worth mentioning that all reinforced formulations demonstrated higher flexural strength values compared to unreinforced specimens. Moreover, as illustrated in Fig. 8, it is observed that increasing fiber length from 1 to 2 cm did not significantly increase the flexural strength. However, for the 3 cm fiber length, a slight increase in flexural strength is noticeable between 1% wt and 1.50% wt. The difference becomes more prominent between 1.5% wt and 2% wt fractions, resulting in an approximately 28% increase in flexural strength. This observation indicates that, for each fiber length, higher quantities of Alfa fiber correspond to greater flexural strength. This result affirms that both increasing fiber length and addition rate have a significant impact on flexural strength. The observed findings might be attributed to the substantial contact surface between longer fibers and the matrix, enhancing adhesion forces and subsequently improving load transfer capability. The observed rise in flexural strength with the inclusion of a high fiber fraction, especially with the longest fibers, aligns with findings reported by other researchers [5], [24], and [37].

In the flexural tests, fibrous and nonfibrous samples display distinct mechanical behavior. In unreinforced samples, when a crack initiates, the fracture rapidly extends towards the upper part of the prismatic adobe, resulting in the splitting of the sample into two halves. Contrastingly, a bridging phenomenon was noted in the reinforced samples, effectively delaying the propagation of cracks. Fig. 9 illustrates the U-sample compared to the R2-3 specimen after failure, showcasing the impact of this bridging effect. It can be observed that the introduction of Alfa fibers allows better control of crack propagation, which delays the rupture phase. This behavior of the incorporation of plant fibers in composites has been highlighted by other authors [15], [24], and [38], and it could be explained by the increased toughness and because the fibers at the crack zone bear the tensile stress transferred from the ruptured section.

Table 5.Results of the mechanical properties testing.
* In italics the standard deviation

Material mix	Fibre content	Length (cm)	Density (g/cm^3)*	Compressive strength (MPa)*	Flexuralstrength (MPa)*	Ultimate deflection (mm)
U	0%	–	1,849 *(0.03)*	2.012 *(0.0221)*	0.305 *(0.0032)*	1.719 *(0.021)*
R1-1	1%	1	1.763 *(0.01)*	2.051 *(0.017)*	0.341 *(0.005)*	3.025 *(0.050)*
R1-2		2	1.761 *(0.017)*	2.102 *(0.0231)*	0.352 *(0.0052)*	3.005 *(0.042)*
R1-3		3	1.757 *(0.013)*	2.808 *(0.0271)*	0.361 *(0.0032)*	3.186 *(0.023)*
R1.5-1	1.5%	1	1.709 *(0.011)*	2.106 *(0.0143)*	0.372 *(0.0057)*	3.252 *(0.031)*
R1.5-2		2	1.703 *(0.019)*	2.304 *(0.0278)*	0.369 (0.0082)	3.205 *(0.024)*
R1.5-3		3	1.696 *(0.021)*	2.900 *(0.022)*	0.371 *(0.0037)*	3.365 *(0.055)*
R2-1	2%	1	1.647 *(0.007)*	2.250 *(0.0381)*	0.388 *(0.002)*	3.687 *(0.072)*
R2-2		2	1.633 *(0.007)*	2.300 *(0.0157)*	0.381 *(0.0031)*	3.438 *(0.024)*
R2-3		3	1.632 *(0.014)*	3.250*(0.0413)*	0.488 *(0.0021)*	4.347 *(0.031)*

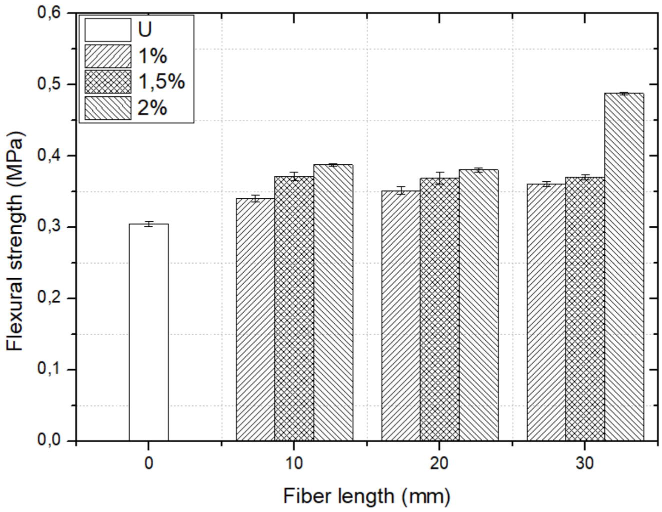


Figure 8. Flexural strength of reinforced samples with cut fibers at 28 days of curing in a laboratory environment

Figure 9. From left to right, unreinforced and reinforced sample after breaking

3.4 Compressive Strength

The effect of Alfa fiber length and quantities on the compressive strength of composites is given in Table 5. It is immediately possible to note that the highest value of compressive strength belongs to the R2-3 mixture that reached 3.25 MPa, coinciding with the mix exhibiting the highest flexural strength and the lowest shrinkage rate, thus confirming that the optimal formulation is related to 2 % wt of fiber of 3 cm length. The unreinforced samples exhibited the lowest compressive strength, barely reaching 2.012 MPa. It is noteworthy that this value aligns well with recommendations by Houben and Guillaud [39] or Binici et al. [6], which suggest a target compressive strength superior to or equal to 2 MPa. However, it is noted that all samples tested in the present study are much higher, namely 2-3.25 MPa. On the contrary, as depicted in Fig.10, it can be observed that the lengths of 10mm and 20mm did not strongly influence the compressive strength, regardless of fiber content. Nevertheless, for 3 cm of length, R1-3, R1.5-3, and R2-3 exhibit compressive strengths of 2.80 MPa, 2.90 MPa, and 3.25 MPa, respectively. These values represent higher strengths compared to other lengths by approximately 30%. This increase in compressive strength with the incorporation of plant fibers has been previously reported by other authors [6], [9], and [35].

In the case of U-samples (control specimens), the final failure occurs almost immediately after reaching the ultimate load, demonstrating a brittle behavior with large cracks, as expected. However, the presence of Alfa fiber allows for plastic deformation, which characterizes the enhancement of composite elasticity. Breaking manners were similar for all fibrous mixtures, so they do not seem to depend on fiber length and fraction. It's important to highlight that the addition of fibers results in an increase in the ultimate deflection of the material. At maximum load, the deflection ranged from 1.719 mm for the control specimen to 4.347 mm for composite materials with a higher fiber content of 2% wt of 30mm length, as indicated in Table 5.

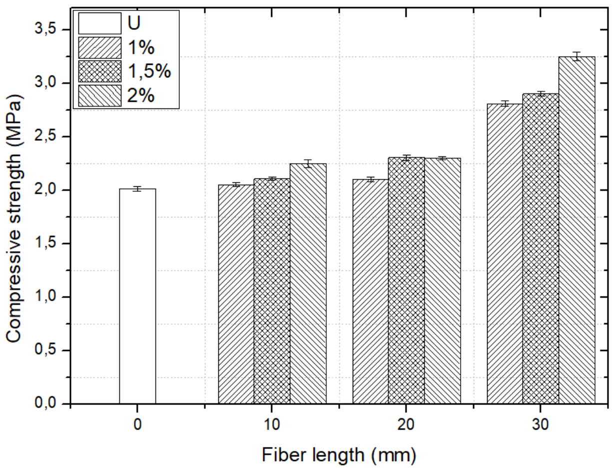


Figure 10. Compressive strength of reinforced samples with cut fibers at 28 days of curing in a laboratory environment

3.5 SEM micrographs

Fig. 11 illustrates the microscope observation of the fractured surfaces of the unreinforced composite (U). It can be observed as a heterogeneous composite, less compacted, with some apparent cracks and large voids. The structure's lower compactness might be the cause of the presence of large pores. Likewise, the interfacial zone between Alfa fiber and matrix of a higher content 2% wt of 3 cm length fibers is shown in Fig. 12. As was expected in terms of bonding, the microscope observation indicated insufficient fiber/matrix adhesion. As observed in Fig. 2, the external surface of Alfa fiber is characterized by a thick layer of dust. This finding could be attributed to the non-treatment of fibers before their addition to the mixture. Alvarez and Vázquez [40] showed that a 1 h acetylation reaction leads to better fiber/matrix adhesion. According to the authors, this better adhesion is due to the change in the morphology of fibers and the production of fibrillation. Conversely, alternative treatments, such as immersion in boiling water, decrease adhesion due to the removal of spine fibers .Moreover, these modification methods could increase the risk of chain degradation and increase production costs [15] and [41].

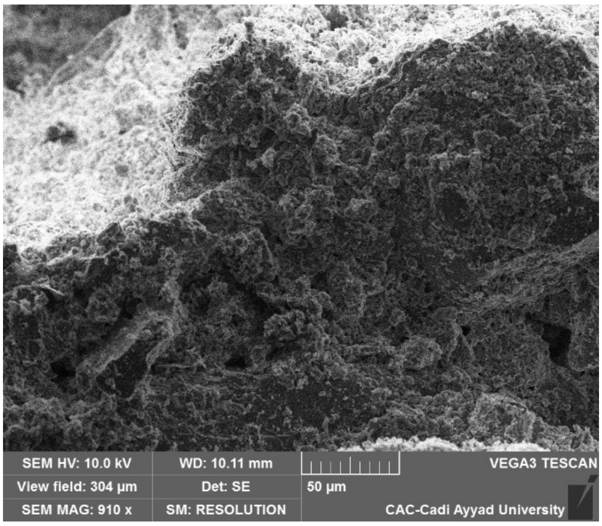


Figure 11. Microscope observation of the reference material (U)

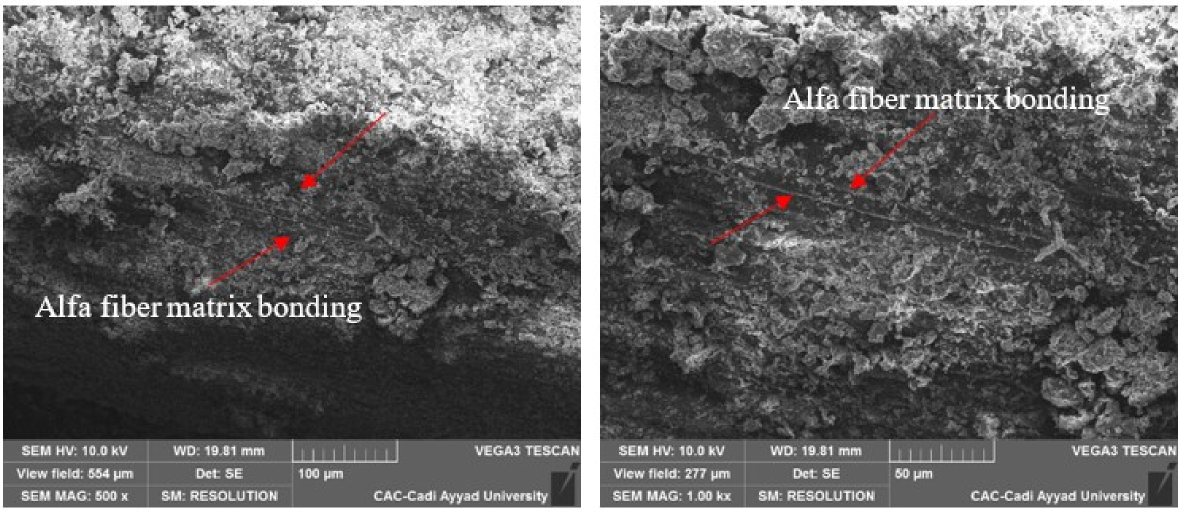


Figure 12. Microscope observation of the composite material with 2% wt Alfa fibers and length of 3 cm (R2-3)

4 Conclusion

In conclusion, this comprehensive experimental investigation has demonstrated the potential of Alfa fibers to significantly enhance the mechanical properties and crack resistance of earth-sand building materials. The incorporation of Alfa fibers, derived from the Alfa plant, into the earth-sand composite proved effective in addressing the inherent challenges associated with the mechanical performance and susceptibility to cracking of traditional earth-based construction materials. Based on the results of this experimental study, the following conclusions could be drawn:

- The study demonstrated the potential of Alfa fibers to enhance the mechanical properties and crack resistance of earth-sand building materials.
- The addition of 2% wt of Alfa fibers led to a reduction in unit weight and superior mechanical behavior compared to unreinforced adobe specimens.
- The research findings highlighted the role of Alfa fibers in preventing and delaying crack propagation, underscoring the importance of fiber length and content in attenuating cracks.
- Microstructural observations indicated poor fiber/matrix adhesion, adversely affecting the compactness of the adobe specimens.
- Further research is needed to optimize fiber-matrix adhesion and enhance the overall performance of earth-sand building composites.
- The identified optimal conditions for mechanical behavior and crack resistance pave the way for future advancements in the utilization of Alfa fibers to create environmentally friendly, resilient, and structurally sound construction materials.

Acknowledgments

The authors gratefully acknowledge Cadi Ayyad University for its support of this thesis research program.

Conflicts of interest

The authors declare no conflicts of interest.

Author contributions

Reda Sadouri: Conceptualization, Investigation, Visualisation, Methodology, Testing, Writing original draft, Writing- Review and editing.

Mustafa Benyoucef: Conceptualization, Methodology, Supervision, Validation, Writing – Review and Editing.

Hocine Kebir: Conceptualization, Methodology, Investigation, Writing – Review and Editing.

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