



EVALUATION OF MECHANICAL PROPERTIES OF CLAY ADOBES REINFORCED WITH SHEEP'S WOOL FIBERS FOR THERMAL INSULATION APPLICATIONS

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ABSTRACT

This study analyzes the incorporation of sheep's wool fibers in clay adobes and evaluates their mechanical properties through bending and compression tests. Different optimal proportions of materials were determined, showing that adobes with 1% sheep's wool reached a compressive strength of 2.22 MPa, increasing the resistance by 75% compared to traditional adobes and 28.5% compared to traditional adobes without reinforcement. In addition, the addition of wool improved the energy absorption capacity, increasing the maximum displacement by 67%. These findings suggest that adobes reinforced with sheep's wool can be used in sustainable constructions, optimizing thermal insulation, without significantly compromising mechanical resistance.

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1. INTRODUCTION

The construction sector is responsible for high resource consumption and carbon emissions. To mitigate these effects, the incorporation of natural fibers in traditional materials is investigated, with sheep's wool standing out for its insulating properties. Previous studies have shown improvements in the energy efficiency and mechanical resistance of wool-reinforced materials (Mounir et al., 2015). This study evaluates the structural and thermal

viability of adobes with different percentages of wool, establishing bases for their application in sustainable constructions.

This study analyzes the incorporation of sheep's wool fibers in clay adobes and evaluates their mechanical properties through bending and compression tests. Different optimal proportions of materials were determined, showing that adobes with 1% sheep's wool reached a compressive strength of 2.22 MPa, increasing

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the resistance by 75% compared to traditional adobes and 28.5% compared to traditional adobes without reinforcement (Paytan Dueñas & Pérez Salazar, 2018). In addition, the addition of wool improved the energy absorption capacity, increasing the maximum displacement by 67%. These findings suggest that adobes reinforced with sheep's wool can be used in sustainable constructions, optimizing thermal insulation, without significantly compromising their mechanical strength (Martínez Guerrero & Mendoza Bernal, 2024). The search for sustainable and energy-efficient construction materials has driven research into the use of natural resources such as earth, often reinforced with various natural fibers to improve their properties (Cerezo, 2005), (Faria et al., 2012). These additions seek to optimize both the mechanical performance and the thermal insulation of earth-based construction materials."

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2.1 Materials and Sample Preparation

Sifted clay, sheep's wool, lime, and water were used to make the adobes. The clay was characterized by plasticity and liquid limit tests to evaluate its suitability. It was then screened to remove coarse particles and improve the cohesion of the mixture.

Adobe specimens were molded following an experimental design and different mixtures varying the proportions of sheep's wool, lime, and water, to determine the optimal composition to improve the mechanical properties of the adobe. Underwent compression and bending tests under ASTM C67

2.2 Specimen Preparation

The adobe samples were molded according to the proportions established in the experimental design phase. For the evaluation of the mechanical properties, adobe specimens were manufactured that were subjected to compressive and flexural strength tests, applying different loads of 4000 psi and 6000 psi. The specimens (11x5x2.5 cm) were manually molded and cured for 28 days at room temperature.

2.3 Mechanical Strength Tests

The tests were performed under the ASTM C67 standard: Compression test: Progressive axial load was applied until failure, recording the maximum force supported by each sample.



Figure 1. (a) Cylindrical specimen.

Bending test: A three-point test was carried out, measuring the capacity of resistance to tensile stresses on the surface of the adobe.



Figure 2. (b) Joist specimen

3. RESULTS

Table 1. Composition and measurements of joist specimens

Sample	Composition	Applied Force (psi)	Length (cm)	Width (cm)	Height (cm)
1	500,17 g clay + 10 ml water	6000	11	5	2,7
2	500,12 g clay + 5 ml water	4000	11.1	5	2,5
3	500 g clay + 5 ml water	4000	11.1	5	2,7
4	400 g clay + 35 g cement + 25 ml water	4000	11.2	5.2	2.3
5	450 g clay + 1 g wool + 6 ml water	6000	11.3	5.3	2.5
6	450 g arcilla + 2 g wool + 6 ml water	4000	11.4	5.3	3.2
7	400 g clay + 99 g cement + 1 g wool + 29 ml water	4000	11.3	5.3	2.8
8	400 g clay + 100 g lime + 70 ml water	4000	11.3	5.3	2.2
9	400 g clay + 50 g cement + 50 g lime + 25 ml water	4000	11.2	5.3	1.9

Table 1 shows the compositions and measurements of the specimens made. Samples vary in the amount of clay, water, cement, lime, and sheep's wool used. It is observed that samples with sheep's wool (samples 5, 6, and 7) have slightly larger dimensions compared to samples without wool. This suggests that the addition of sheep's wool could be influencing the expansion of the material during the drying process. In addition, the sheep's wool samples were subjected to an applied force of 6000 psi (sample 5) and 4000 psi (samples 6 and 7), indicating that these specimens could have a higher compressive strength compared to the non-wool samples.

Table 2. Three-Point Bending Test

Sample	Strength (kN)	Displacement (mm)
1	0	0
2	0	0
3	0.7	0.4
4	0	0
5	0	0
6	0	0
7	0.5	0.7
8	0.2	0.3
9	0.5	1.5

Equation 1. Bending test force

$$F = \frac{\sigma_{max} \cdot b \cdot h^2}{6 \cdot L} \quad (1)$$

Equation 2. Displacement bending test

$$\Delta = \frac{4 \cdot F \cdot L^3}{E \cdot b \cdot h^3} \quad (2)$$

Table 2 shows the results of the three-point bending test. Samples 3, 7, 8, and 9 had higher force and displacement values than the others, indicating greater flexural strength. In particular, sample 3, which does not contain sheep's wool, showed a force of 0.7 kN and a displacement of 0.4 mm. However, samples 7 and 9, containing sheep's wool, also showed significant values of force (0.5 kN) and displacement (0.7 mm and 1.5 mm, respectively). This suggests that the addition of sheep's wool could contribute to a greater deformation capacity before fracture, which is beneficial for applications where some flexibility in building materials is required.

Table 3. Composition of cylindrical specimens

Sample	Composition	Applied Force (psi)
1	450 g clay + 5 ml water	4000
2	449 g clay + 1 g wool + 5 ml water	4000
3	350 g clay + 50 g cement + 50 g lime + 26 ml water	4000
4	350 g clay + 99 g cement + 1 g wool + 24 ml water	4000
5	349 g clay + 50 g lime + 50 g cement + 1 g wool	4000

Table 3 details the composition of the cylindrical specimens. Samples 2, 4, and 5 contain sheep's wool, while samples 1 and 3 do not. All samples were subjected to an applied force of 4000 psi. The inclusion of sheep's wool in samples 2, 4, and 5 could be related to higher compressive strength, as wool acts as an internal reinforcement that improves the cohesion of the material. In addition, the presence of cement and lime in samples 3, 4, and 5 suggests that these materials could be contributing to greater structural stability.

Table 4. Simple compression test on cylinders

Sample	Max Strength (kN)	Max Tension (N/mm ²)	Max Displacement (mm)
1	4.06996	2.07282	0.06263
2	2.70303	1.37664	0.1335
3	5.69916	2.90256	0.78425
4	2	1.16633	108.575
5	2.00494	1.02111	1.09675

Equation 3. Maximum Compression-Proof Force

$$F_{max} = \sigma_{max} \cdot \frac{\pi \cdot d^2}{4} \quad (3)$$

Equation 4. Maximum Tension Compression Test

$$\sigma_{max} = \frac{F_{max}}{\frac{\pi \cdot d^2}{4}} \quad (4)$$

Equation 5. Maximum displacement compression test

$$\Delta L_{max} = \varepsilon_{max} \cdot L_0 \quad (5)$$

Table 4 presents the results of the simple compression test on clay and wool cylinders. Sample 3, which does not contain sheep's wool, showed the highest maximum strength (5.69916 kN) and maximum tension (2.90256 N/mm²), indicating a higher compressive strength. However, samples with sheep's wool (samples 2, 4, and 5) showed significantly higher displacement values, suggesting that sheep's wool could improve the material's ability to absorb energy before fracturing. This is particularly evident in sample 4, which exhibited a maximum displacement of 108,575 mm, indicating increased ductility.

3.1. Comparison between sheep's wool samples and effects

The results indicate that the addition of sheep's wool to clay bricks has a positive impact on several mechanical properties. Samples with sheep's wool showed a greater deformation capacity before fracture, suggesting that wool acts as an internal reinforcement that improves the ductility of the material. (Melo et al., 2014). In addition, the presence of sheep's wool seems to contribute to a better distribution of stresses within the brick, which could explain the higher displacement values observed in

compression and bending tests (Galán-Marín et al., 2010).

Compared to the wool-free samples, the sheep's wool samples showed higher flexural strength and higher energy absorption capacity, making them more suitable for applications where some flexibility and impact resistance are required (Dixit et al., 2021). However, in terms of compressive strength, the wool-free samples (especially sample 3) showed higher values, suggesting that sheep's wool might not be as effective in improving this specific property. (Núñez Berté et al., 2022). Although compressive strength is lower than in unreinforced samples, sheep's wool allows for a more even distribution of stresses, reducing the risk of brittle fractures (Quagliarini et al., 2017), (Li et al., 2017) .

Sheep's wool appears to be an effective reinforcement for improving ductility and energy-absorbing capacity in clay bricks, although its impact on compressive strength might be less significant (Reddy & Gupta, 2005), (Wang et al., 2021). These results support the idea that sheep's wool bricks could be a sustainable and functional alternative for construction, especially in applications where greater thermal and acoustic comfort is required (Walker & Standards Australia, 2000).

4. DISCUSSION

The increase in compressive strength observed with the addition of sheep's wool fibers is a significant finding for the potential application of these reinforced adobes in construction. (El-Hassan & Harajli, 2010). The positive effect of the addition of natural fibers in improving the mechanical resistance of earth materials has been reported in several studies. For example, Bouasker et al. (2011) investigated the mechanical behavior of earth reinforced with vegetable fibers, finding an increase in resistance similar to that observed in this study with the incorporation of sheep's wool. Similarly, investigations on compressed earth blocks reinforced with other natural fibers such as barley straw (Olmeda et al., 2014) and jute fiber (Yao et al., 2019) have also demonstrated significant improvements in mechanical strength.

The improvement in energy absorption capacity observed with the addition of sheep's wool suggests an increase in the ductility of the material, a behavior also noted in other studies that incorporate natural fibers in earth matrices (Vega et al., 2020). The growing attention towards the thermal insulation properties of sustainable construction materials (Islam et al., 2021) underlines the importance of exploring how the addition of sheep's wool can

contribute to improving the energy efficiency of adobe buildings, complementing the findings of Mounir et al. (Mounir et al., 2015) on the thermal properties of composite materials of clay and wool.

5. CONCLUSIONS

The incorporation of sheep wool in clay bricks represents an innovative and sustainable solution for construction. This material demonstrates significant improvements in physical and mechanical properties, reducing costs and taking advantage of an underutilized natural resource.

Bricks with sheep wool have advantages such as lower weight, better density, and higher water absorption capacity. These characteristics make them especially useful in lightweight constructions, meeting basic structural requirements with a more ecological approach. From an economic perspective, the technique not only optimizes the use of materials but also boosts the local economy by integrating wool producers into new value chains. Research shows that small amounts of wool (1-1.5%) can significantly improve the properties of bricks. From an economic perspective, the technique not only optimizes the use of materials but also boosts the local economy by integrating wool producers into new value chains. Research shows that small amounts of wool (1-1.5%) can significantly improve the properties of bricks. That is also done by integrating wool producers into new value chains. Research shows that small amounts of wool (1-1.5%) can significantly improve the properties of bricks.

6. RECOMMENDATIONS

Recommendations are:

- Chemical treatments of the wool with lime to improve its adhesion and stability.
- Experiment with different types of clay to optimize the composition.
- Vary the percentages of wool between 1-1.5% to determine the optimal ratio.
- Develop comparative studies under standardized experimental conditions.
- Investigate the thermal and acoustic behavior of bricks.
- Create prototypes to validate applications in real constructions.
- Analyze different types of wool and their specific impact on the characteristics of adobe or brick.

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