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Tesis

Sustainable Blocks Reinforced with Agave americana L. Fiber and Its Mechanical Properties

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Sustainable Blocks Reinforced with *Agave americana L.* Fiber and Its Mechanical Properties

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Abstract The study of sustainable construction materials is getting attention, since the materials must be ecological, recyclable and renewable to generate a positive impact on the environment as a substitute for the construction materials currently used in rural areas of Huancayo. The objective of this research is to determine a sustainable material with resistant mechanical properties, such as reinforced blocks with Agave americana L fiber. The block components were sand, clay and silt, in order to evaluate its behavior, 5 dosages of fiber were proposed: 0%, 0.25%, 0.5%, 0.75% and 1%, these were expressed with respect to the total weight of the sample, on the other hand, the fiber used was cut to obtain a length of 25mm. Strengths were evaluated using the simple compression method, the Brazilian diametral compression tensile method and the modulus of rupture method. The result for the most optimum compressive strength was given when using the dosage of 0.25% of agave fiber increasing by 13.39% (2.54MPa), while, the tensile strength increased by 39.13% (0.32MPa) using 1% of agave fiber, finally an increase of 14.29% (1.44MPa) was obtained in the flexural strength with 0.5% of *Agave americana L.* fiber. It concludes that the use of *Agave americana L.* fiber improved the mechanical strength of blocks, setting an optimum addition of 0.25% of fiber.

Keywords Brick, Mechanical Properties, Sustainability, Agave Fiber

1. Introduction

Half of the world's population that are in development have earth block houses, which is unfairly related to low-income housing or outdated technologies [1]. In these times, construction work encourages the use of materials that have lower energy consumption in their manufacture [2], due to current environmental problems [3], since they affect greenhouse gases as well as the deterioration of the ozone layer, and soil contamination due to the generation of difficult-to-degrade materials such as concrete [4], construction and demolition waste also generates an environmental risk due to its difficult decomposition over time [5, 6]. Nowadays, these pieces of earth blocks are still under study as an alternative for ecological sustainability [7]; because it has the property of being a thermoregulator in the walls, thus helping the comfort of the houses [8, 9]. The main component of block is soil, which has been used extensively in rural areas for thousands of years [10]. These benefits lie in their low economic cost, their contribution to the environment and the easy availability of their components [11, 12].

Likewise, the fiber of *Agave americana L*. has morphological plasticity which makes it possible to obtain thin fibers, and since it is treated as a material mixed with earth blocks, there is not much information about its use, which is the main purpose for this research [13]. This alternative of incorporating natural fiber in the blocks will influence the bending, tensile and compressive strength of the blocks [7,14], using 25 mm lengths for its best performance [15].

Generally, the main factors that affect the compressive strength of the blocks are: Soil properties, types of fibers as reinforcement, specimen morphology and moisture content [16]. This composition and the shape of the object help to evaluate the bending strength [14]. According to Rodriguez [17], it indicates that nowadays there is no technical consensus on the block dimensions to determine its mechanical properties; this motivates the researcher to find recommendations for the performance of these tests. This agreement [18], sets the standards to determine the mechanical characteristics of reinforced soil and to comply with the seismic-resistant design philosophy for these buildings, orienting the design, construction, reinforcement and repair.

Consequently, the purpose is to analyze the influence of the natural fiber (*Agave americana L.*) at different proportions applied in the blocks, showing variations in their mechanical properties. In other words, this research will help to optimize the use of the *Agave americana L.* on rural areas of the region of Junín. Over the years, several revision works were carried out to incorporate different block reinforcement fibers in order to improve their mechanical properties.

The investigation by Abdulla found that the behavior under compression was quite ductile, due to the presence of straw fiber, and strength gain was achieved at 28 days, representing 90% at 56 days, tensile strength was lower with respect to the pattern block [10]. On the other hand, the technical optimization of the reinforcement leads to lighter weight and higher resistance to compression [19]. For this reason, by adding paper and pulp residues as fiber increases in compressive strength of 25% and toxicity tests showed lower values within the permitted limits. A study incorporated date palm waste varying on a range of 0% to 10% in weight, which reduced its resistance to compression by 80% when using 10% of DPW (Date Palm Waste) [20]. Blocks incorporated with straw with percentages of 0.2% to 0.4% by weight help to improve bending and compression, mainly due to the good adherence of the fiber and the soil block [21].

New research on block design mixes, shapes and sizes will lead to greater flexibility and performance for reinforced block structures [22]. By using clay soil with a liquid limit of 40.4%, a plastic limit of 20.7% and a plasticity index of 19%, adding Agave angustifolia Haw fiber produced an increase in flexural strength of 7.9% and the compressive strength improved by 24.1% with respect to the pattern block, for which it was optimized with fibers of 25mm in length [15]. According to [23], to predict the block mechanical properties, the data used must be accurate, to propose mixture proportions by weight, including each component (gravel, sand, clay, silt and stabilizer). Subsequently, the compressive strength with the addition of palm fiber to a composition of gravel, sand and clay increased by 56%. For that reason, the addition of natural additives significantly helps to increase the block mechanical properties [24].

The use of hemp fiber of 9-10% by volume helped to increase the flexural tensile strength, but a Gaussian variation in compressive strength [25]. It is beneficial to use natural fibers because they help to improve the block performance like ductility, but Young's modulus is reduced. Flexural and tensile strengths are particularly dependent on the choice of the shape of the natural fibers [26].

The block components (sand, clay and silt) help to avoid shrinkage, cracking and void filling; water will help to make the mixture homogeneous [18]. Different natural fibers such as palm fiber, straw fiber, wood shavings and other natural fibers can be used to reinforce these earthen blocks [26], in our case, the natural fiber used was Agave americana type "L", these materials were typical to the area where the study was carried out. Finally, these additions of natural fibers to the block pieces with smaller dimensions help the coating as long as mixtures of similar block composition are used [27].

It is necessary to investigate these types of blocks, since there is very little information documented [28]. Also, for the generation of new sustainable materials, according to biodegradable parameters in their life cycles as shown in Figure 1, [29] the blocks decompose in the soil because they are composed of organic materials (clay, silt, sand and fibre); these blocks when joined with mortar form a type of adobe masonry as Type A (unfired block with mud mortar), Type B (fired block with mud mortar) and Type C (fired block with cement mortar) [30]. The purpose of the research is to improve the mechanical properties of *Agave Americana L.* fiber-reinforced blocks, generating knowledge regarding the Materials Mechanics. Old technologies that turn out to be less polluting are being rescued, giving their mechanical improvements to be currently applied, as starch-based artificial sandstone corn [31], bamboo columns reinforced with bioepoxy and furanic resins [32], biocomposites based on vegetable fibers [26], Cement soil [33], rice-based thermal insulator [34] and fiber-reinforced gypsum [35]. The elaborated dimensions of each block for the tests followed the recommendations of the Peruvian standard E080 [18].

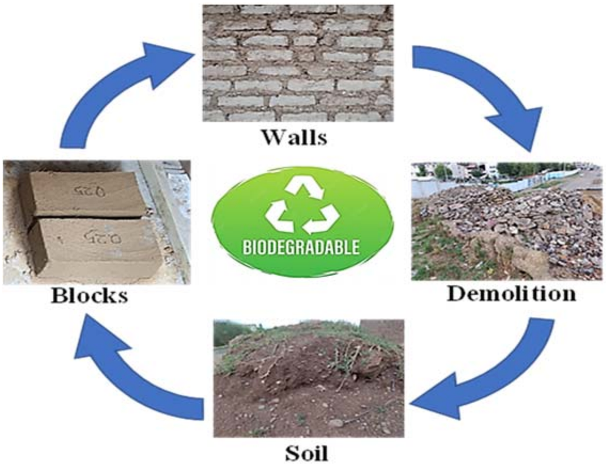

Figure 1. Block life cycle

The methodology applied is experimental because a series of tests werecarried out, identifying the properties of the composition of the materials used for the manufacture of the blocks, the way the blocks are made, the nature of the biodegradable materials and finally the mechanical behavior to be able to determine whether it is a resistant material. The results gave us a reinforced block with a small amount of agave fiber, only an optimal dosage was needed to reach the end of the problem, to reach its maximum mechanical performance.

2. Materials and Methods

In this investigation an experimental design was used [36], the materials were used for the manufacture of the blocks, the clay together with the silt was extracted from the district of Cochas that is located in the eastern zone of the city of Huancayo, and this material abounds in thedistrict. Sand was extracted from the Pilcomayo District, which is located in the western zone and finally the American Agave Fiber L from the Huamancaca district [37], since there are abundant crops of this plant, all of them were essential for the elaboration of the sustainable blocks forthey are biodegradable materials [38], as shown in Figure 2 the materials used.

2.1. Materials

Sand, Clay and Silt

For this research, nomenclatures were used, for example: Sand (S), Clay (C), Silt (L) and Agave (A%). This was subsequently tested according to MTC (Ministry of Transport and Communications of Peru) standards [39] to identify its properties. For the block, different doses of *Agave americana L.* fiber were proposed, which were 0%, 0.25%, 0.5%, 0.75% and 1% by weight of the block. The properties of the sand used are shown in Table 1. The properties of the clay and silt used are shown in Table 2.

Table 1. Sand properties

Specific weight (gr/cm3)	2.39
Liquid Limit (%)	0.00
Plastic Limit (%)	N.P.
USCS Classification	SP

Table 2. Properties of Clay and Silt

Specific weight (gr/cm3)	1.64
Liquid Limit (%)	36.70
Plastic Limit (%)	29.91
Plasticity Index (%)	6.79
USCS Classification	CL-ML

Figure 2. Components of adobe reinforced with Agave americana fiber type "L" (a: sand component, b: clay and silt component, c: Agave fiber in its natural state, d: Agave fiber component)

***Agave americana L.* Fiber**

The fiber of *Agave americana L.* from the region of Junín (Peru), used as reinforcement for the blocks, had an average length of 25 mm with a range of 10 mm to 30 mm (Figure 2), the characteristics are shown in Table 3.

Table 3. Properties of *Agave americana L.* fiber

Specific weight (gr/cm3)	7.31
Length (mm)	25
Diameter (mm)	1-4

The process of extracting the fiber of *Agave americana L.* began with the collection of the leaves, then it was struck with a mallet to expel the sap that contains leaves, then it was combed with a rake to obtain only the fiber and finally it was air-dried naturally for a month as shown in Figure 3.

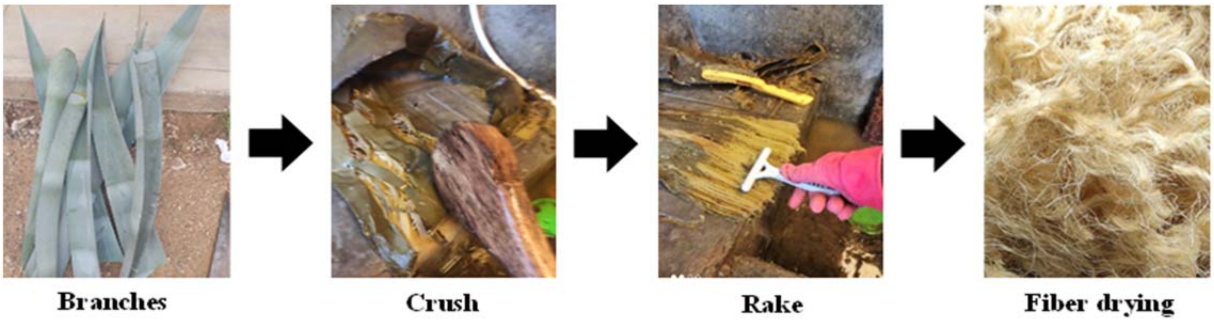

Figure 3. Fiber extraction process

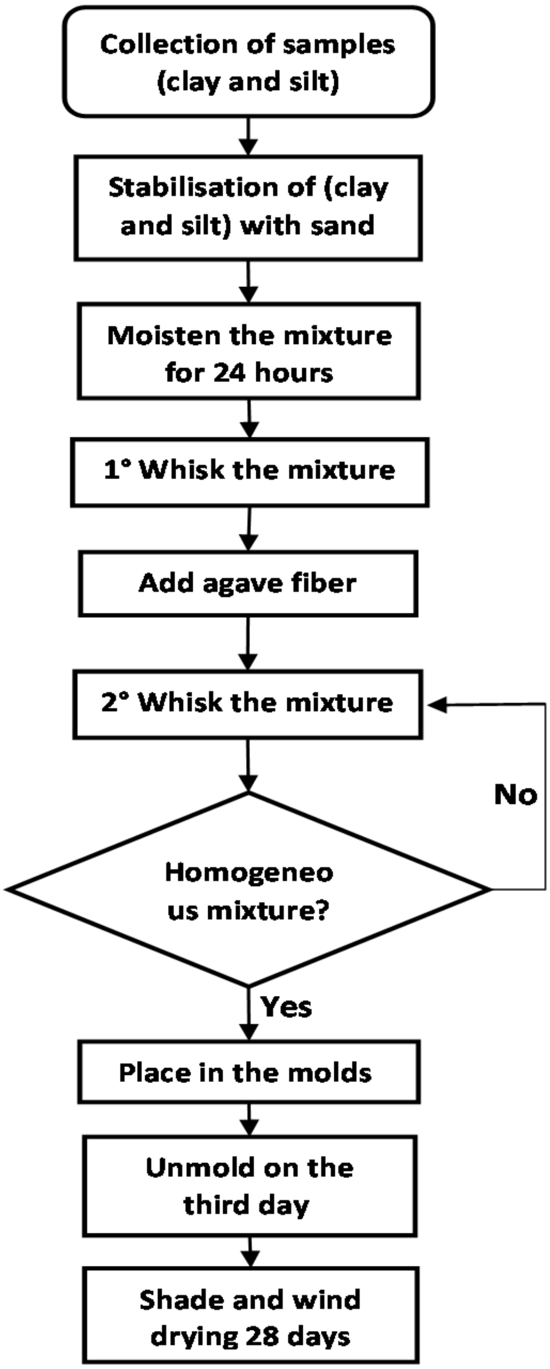

Figure 4. Flowchart of the preparation process

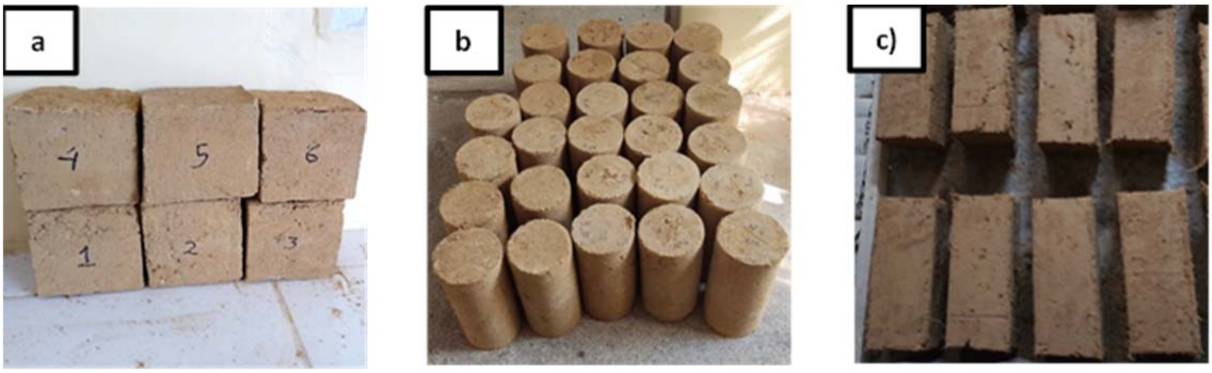

Figure 5. Test specimens (a: Sample for compression test, b: Sample for tensile test, c: Sample for flexural test)

2.2. Specimen Preparation

For the preparation of the specimens to be tested, the percentages of their components were taken into account according to standard E.080 [18], which recommends that the composition of the blocks should contain 55-70% sand, 10- 20% clay and 15-25% silt (Table 4), in order to achieve the desired composition, a stabilization of the (clay and silt) with sand was carried out [40]. To control the amount of material used, they were quantified according to the specific weight of the materials, 20% moisture was considered, then the mixture was left to stand for 24 hours to reach the desired workability according to NTP 331.201 [41]. Subsequently, the American fiber type L was added gradually in different spaces of the mixture to continue with the second beating process until the fiber was completely impregnated and uniform [42], then the mixture was placed in the different molds for each test during the day. On the third day, all our molds were demolded, and finally they were left to dry in the shade and constant wind for 28 days in environmental conditions of temperature 15°C ± 3 with the relative humidity of 55% ± 5, Figure 4 shows the whole process of the elaboration of the blocks.

For all the tests, 24 hours before, 2 strips of mortar were placed on the upper and lower faces until leveling to a flat dimension so that the load applied on each sample is uniform [43].

A total of 90 samples were prepared, including 30 samples for each test (compression, tensile and flexural), thus making 6 block samples for each dosage.

Table 4. Composition of the different dosages for each test

Name of the samples	Silt (%)	Clay (%)	Sand (%)	Fiber (%)	N° of Samples
S+C+L	22.5	22.5	55	0.00	18
S+C+L+0.25A	22.5	22.5	55	0.25	18
S+C+L+0.50A	22.5	22.5	55	0.5	18
S+C+L+0.75A	22.5	22.5	55	0.75	18
S+C+L+1.00A	22.5	22.5	55	1	18

Where: S= Sand (%); C = Clay (%); L= Silt (%) and A =American agave L fiber (%)

To evaluate the compressive strength, cubic specimens of 100 mm edge were prepared, and for the flexural strength, rectangular-based prisms with a ratio of sides 1 to 2 (120 mm x 240 mm) and a height of 100 mm were prepared. Finally, to evaluate its tensile strength, cylinders with a diameter of 150 mm and a height of 30 mm were prepared.

2.3. Treatment of Results

Compressive Strength

In the regulation [18], which indicates that the minimum resistance to be reached from a total of 6 specimens, 4 of them with higher performance should be 1.0 MPa (Figure 5), 6 total samples were taken.

To calculate the resistance value, the following equation was used (1)

$$Ơc = P/A \tag{1}$$

Where: Ơc= compressive stress (MPa); P = compressive force (KN); A= Area of the face where the force is applied.

Resistance to Bending

The 4 specimens were taken from a total of 6 specimens with the best performance (Figure 5). The bending strength was evaluated under loads of 220 kg/min, locating the 3 main points of rupture [44], and the value of the resistance was calculated using the equation (2).

$$Ơf = 1.5\,FL/bd^2 \tag{2}$$

Where: Ơf = bending stress (MPa); F = compressive force (KN); L = length from center to center of its supports (m); b = base of the specimen (m); d = height of the specimen (m).

Tensile Strength

For the tensile test, 4 specimens with the highest performance were chosen from the total. In the regulations [18], which indicate that the minimum resistance that they must achieve with greater performance must be 0.08 MPa.

Also the Brazilian tensile test by diametrical compression [45] indicates that cylindrical samples should be 15.24 cm in diameter and 30.48 cm in height (Figure 5). The test was carried out with a hydraulic press at a constant speed of 0.02 mm/s so that the applied force is uniform, this load is increased until the specimen breaks [46], and the value of the resistance was calculated using the equation (3)

$$Ơt = 2P/\pi Dt \tag{3}$$

Where: Ơt = tensile stress (MPa); P = compressive strength (KN); D = specimen diameter (m); t = specimen length (m).

3. Results

Compressive Strength Results

Table 5 shows the results with the highest compressive strength performance. The compressive strength data was not taken until a complete failure of the specimens, but until a failure with the first cracks developed at a spindle speed of approximately 1.27 mm/min (Figure 6).

Figure 6. Compressive strength test

When the applied load increases in the range of 60% -70% of the maximum load, the first cracks are observed in the test specimens.

Table 5. Results of the compressive strength

Name of the sample	Dimensions			Fmax (KN)	Ơmax (MPa)
	Width (cm)	Length (cm)	Height (cm)		
S+C+L	9.99	10.25	10.43	2294.33	**2.24**
S+C+L	10.24	9.78	9.90	2492.15	**2.49**
S+C+L	10.14	10.80	10.82	2336.13	**2.13**
S+C+L	9.90	10.59	10.77	2206.63	**2.10**
S+C+L+0.25A	9.23	10.27	10.12	2402.41	**2.53**
S+C+L+0.25A	9.31	10.15	9.87	2352.45	**2.49**
S+C+L+0.25A	10.30	9.70	9.17	2576.78	**2.58**
S+C+L+0.25A	10.20	9.96	9.54	2593.10	**2.55**
S+C+L+0.5A	9.54	10.31	9.40	2356.53	**2.39**
S+C+L+0.5A	9.56	10.30	9.40	2189.30	**2.22**
S+C+L+0.5A	9.51	10.16	9.95	2142.39	**2.22**
S+C+L+0.5A	10.00	10.18	9.86	2299.42	**2.26**
S+C+L+0.75A	9.50	10.15	9.55	2134.23	**2.21**
S+C+L+0.75A	9.96	10.03	10.32	1907.86	**1.91**
S+C+L+0.75A	10.27	9.77	10.56	2137.29	**2.13**
S+C+L+0.75A	9.55	10.06	9.58	1848.72	**1.92**
S+C+L+1.00A	9.88	10.19	9.52	2077.13	**2.06**
S+C+L+1.00A	9.69	9.88	10.58	1427.58	**1.49**
S+C+L+1.00A	9.76	10.27	9.85	2240.28	**2.24**
S+C+L+1.00A	10.06	10.44	9.90	2086.31	**1.99**

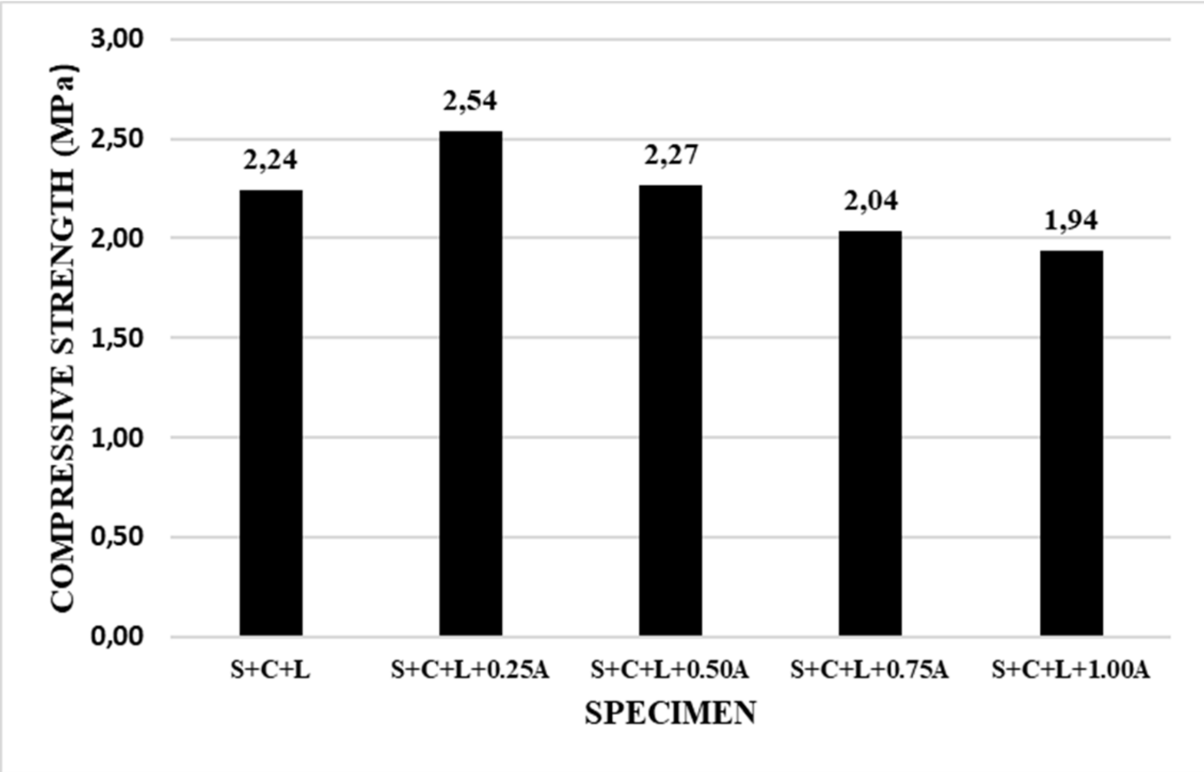

Figure 7. Average compressive strength

According to Table 5, the specimens with smaller dimensions due to exudation, they contracted on drying, showing high compressive strength values, obtaining 2.58 MPa, while the specimens that did not lose their dimensions had low resistance, obtaining 1.49 MPa. According to Figure 7, it can be observed that: The average maximum compressive strengths of the specimens were 2.27 MPa and 2.54 MPa using 0.25% and 0.5% agave fiber respectively.

On the other hand, the blocks without addition of *Agave americana L*. fiber had a value of 2.24 MPa, which is generally low strength, but higher than the minimum strength (1.0 MPa) stipulated by the E.080.

Bending Test Results

Table 6 shows the results with the highest performance in flexural strength. Figure 8 shows the failure after the flexural strength test.

Figure 8. Flexural strength test

Table 6. Bending test results for adobe blocks

Sample Name	Dimensions			Fmax (Kgf)	Ơmax (MPa)
	Base (cm)	High (cm)	Large (cm)		
S+C+L	11.93	10.09	23.48	484.36	**1.40**
S+C+L	11.73	9.35	23.58	328.34	**1.13**
S+C+L	11.84	9.87	23.51	363.01	**1.11**
S+C+L	11.84	9.77	23.43	444.59	**1.38**
S+C+L+0.25A	11.98	10.06	23.93	412.98	**1.22**
S+C+L+0.25A	11.54	9.89	24.07	442.55	**1.42**
S+C+L+0.25A	12.24	9.57	24.00	504.75	**1.62**
S+C+L+0.25A	12.00	9.94	23.89	442.55	**1.34**
S+C+L+0.5A	11.75	9.81	23.91	481.30	**1.52**
S+C+L+0.5A	11.70	9.89	23.96	497.61	**1.56**
S+C+L+0.5A	11.68	9.97	23.98	412.98	**1.28**
S+C+L+0.5A	11.64	9.64	23.84	426.23	**1.41**
S+C+L+0.75A	11.70	9.83	23.96	479.26	**1.52**
S+C+L+0.75A	11.69	9.87	23.91	376.27	**1.18**
S+C+L+0.75A	11.90	9.81	23.79	467.02	**1.45**
S+C+L+0.75A	11.63	9.98	23.90	367.09	**1.14**
S+C+L+1.00A	11.84	9.77	23.77	356.90	**1.13**
S+C+L+1.00A	11.95	10.24	23.83	443.57	**1.26**
S+C+L+1.00A	11.83	9.89	23.59	463.96	**1.42**
S+C+L+1.00A	12.01	10.04	23.99	430.31	**1.28**

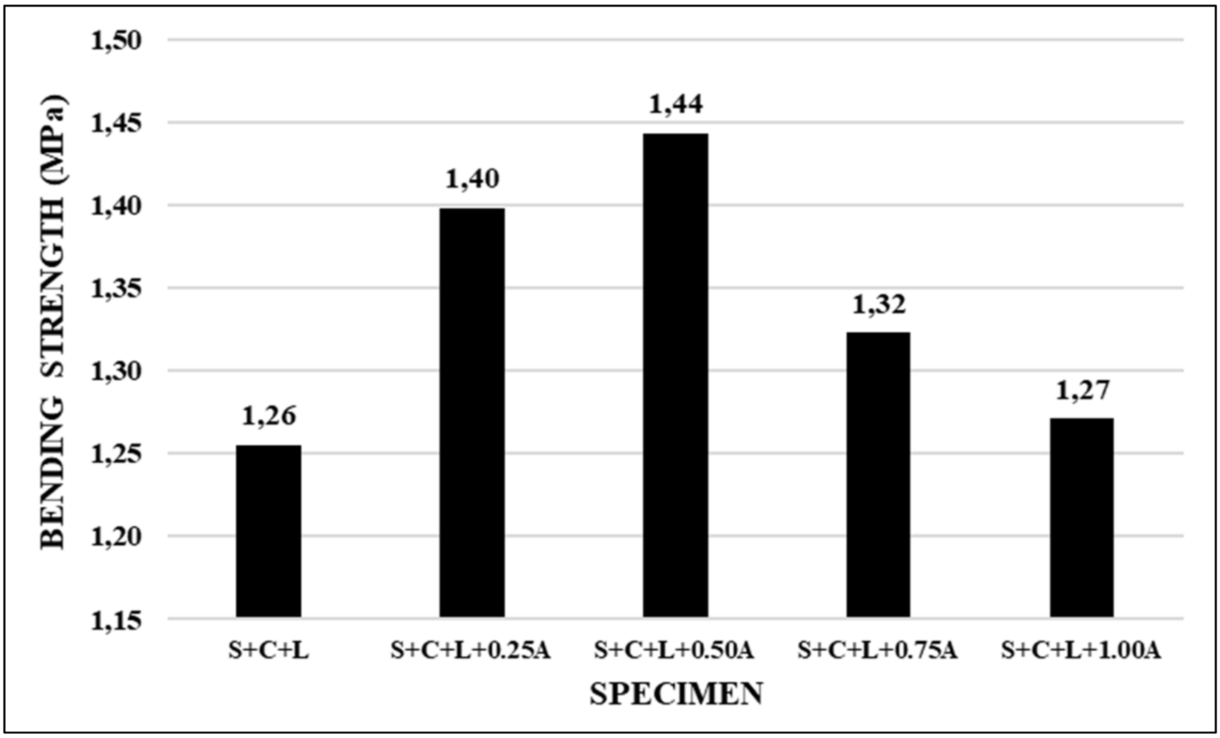

Figure 9. Average bending strength

Referring to Table 6, the specimens that had a loss in their height at the time of drying increased their bending strength, reaching 1.62 MPa, while the specimens that had little loss in their height had lower resistance, reaching 1.11 MPa. According to Figure 9, the average maximum bending strength is achieved with the addition of agave fiber, which was 1.44 MPa, and was achieved with a 0.5 of agave fiber. Likewise, the specimens with 0.5% *Agave americana L.* fiber had a better flexural strength; in addition, the blocks samples without the addition of the natural fiber had a low flexural behavior reaching 1.26 MPa.

Tensile Test Results

Table 7 shows the results with the highest tensile strength performance. Figure 10 shows the failure after the tensile strength test.

Figure 10. Tensile test

Table 7. Tensile results for cylindrical adobe blocks

Sample Name	Dimensions		Fmax (KN)	Ơmax (MPa)
	Diameter (cm)	Height (m)		
S+C+L	15.00	29.20	1531.59	**0.22**
S+C+L	14.90	29.00	1655.99	**0.24**
S+C+L	15.10	29.01	1337.85	**0.19**
S+C+L	14.10	28.10	1527.51	**0.25**
S+C+L+0.25A	15.00	29.00	1704.94	**0.25**
S+C+L+0.25A	15.00	29.40	1709.02	**0.25**
S+C+L+0.25A	14.90	29.10	1825.26	**0.27**
S+C+L+0.25A	15.00	28.70	1522.41	**0.23**
S+C+L+0.5A	14.90	29.50	1804.87	**0.26**
S+C+L+0.5A	15.00	29.00	1713.10	**0.25**
S+C+L+0.5A	15.00	29.10	1756.94	**0.26**
S+C+L+0.5A	15.10	29.30	1719.21	**0.25**
S+C+L+0.75A	15.00	29.30	1739.61	**0.25**
S+C+L+0.75A	15.00	29.90	1849.74	**0.26**
S+C+L+0.75A	15.00	29.50	1907.86	**0.27**
S+C+L+0.75A	15.00	29.20	1841.58	**0.27**
S+C+L+1.00A	15.10	30.12	2414.65	**0.34**
S+C+L+1.00A	15.20	30.12	2171.96	**0.30**
S+C+L+1.00A	14.90	29.90	2343.27	**0.33**
S+C+L+1.00A	15.00	30.20	2154.63	**0.30**

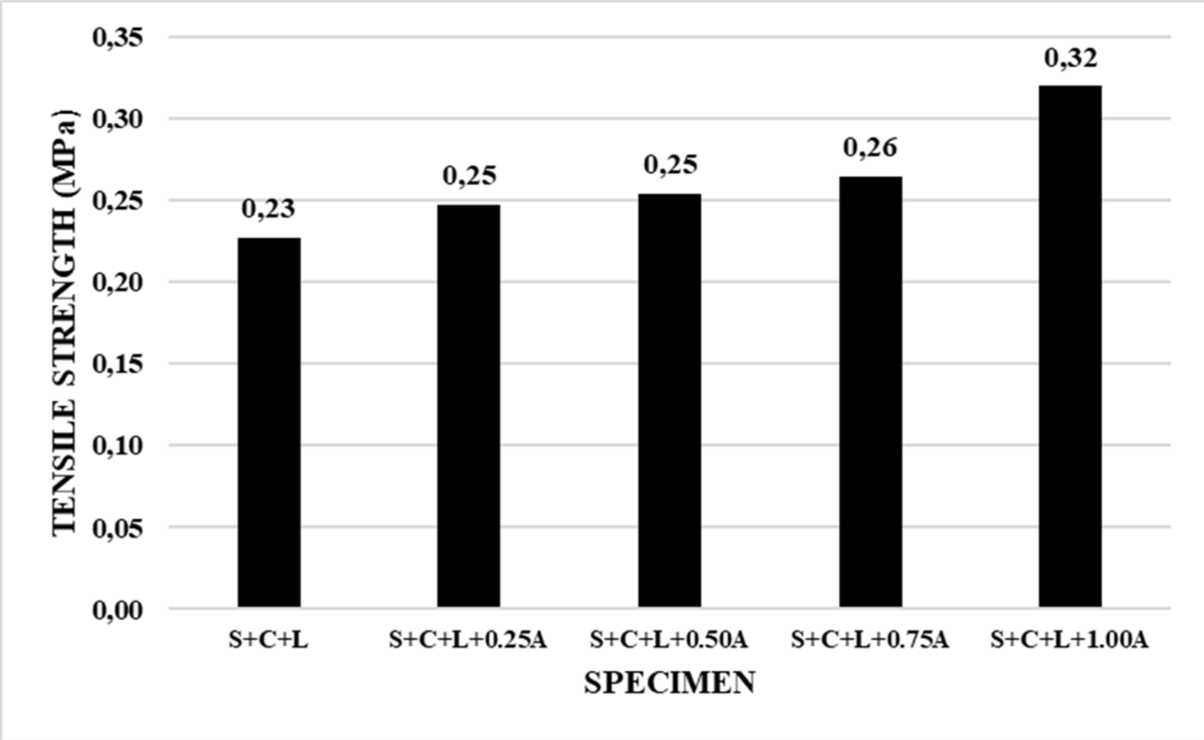

Figure 11. Average tensile strength

Referring to Table 7, the specimens that did not suffer loss in their dimensions (diameter and height) and that had a higher concentration of American L fiber, reached bending strengths up to 0.34 MPa, while the specimens with loss in their dimensions and without Americana L fiber reinforcement reduced the resistance obtaining 0.19 MPa. Figure 11 shows the average maximum tensile strengths achieved with the addition of agave fiber, they were 0.26 MPa and 0.32 MPa, which shows a great increase in strength. This agreement showed that specimens with 1% *Agave americana L.* fiber achieved better tensile strength, also blocks without the addition of natural fiber had low tensile behavior reaching 0.23Mpa.

Failure Mode

In the same way, after carrying out the respective tests, failure forms such as longitudinal and vertical were evidenced, forming cracks along their front and lateral faces (Figure 13). In the Compressive strength tests, the samples without the addition of *Agave americana L.* had a fragile behavior since the cracks spread rapidly in the specimen; on the other hand, the other samples with the addition of agave fiber suffered almost insignificant cracks in the corners of the sample (Figure 13).

Likewise, in the bending tests, the block without the addition of agave fiber (S+C+L), it was observed that it had a perpendicular type fracture, whereas the blocks added with agave fiber (S+C+L+%A), the most common fracture that occurred during the test were cracks perpendicular to the entire length of the block. Finally, the fracture of the specimen after the tensile test (0%A), had a longitudinal and vertical crack type, whereas the other amateur fiber samples, the most common fracture that occurred during the test was perpendicular to the entire cylinder length.

The cracks were counteracted with the use of the fiber of *Agave americana L.* The greater the amount of fiber, the lesser the amount of cracks, there is good adherence between the particles, the fiber acts as a union in the whole mass (Figure 12). A great force had to be induced for the fracture of the mass in two parts.

Figure 12. Fracture of the mass

Dose	Mode of failure	Cubic samples	Mode of failure	Cylindrical samples	Mode of failure	Block samples
S+C+L	Longitudinal rift		Longitudinal and vertical rift		Longitudinal rift	
S+C+L+ 0.25A	Longitudinal fissure		Longitudinal rift		Longitudinal fissure	
S+C+L+ 0.50A	Longitudinal fissure		Longitudinal and vertical rift		Longitudinal fissure	
S+C+L+ 0.75A	Longitudinal fissure		Longitudinal rift		Longitudinal fissure	
S+C+L+ 1.00A	Longitudinal and vertical fissure		Longitudinal rift		Longitudinal fissure	

Figure 13. Fracture shape in the samples

4. Discussions

The flexural strength increased by 14.29% in relation to the standard sample using a dosage of 0.5% of *Agave americana L.* fiber; however, another research [15] found that when using a dosage of 0.75% of Angustifolia Haw fiber, there was a slight increase of 7.86% in flexural strength, this difference is due to different species of agave fiber that was used in the research. In general, the fibers improve the flexibility of the blocks because there is an adhesion between the block particles and the fiber [47].

For the tests, the optimum moisture of 20% was used as Peruvian standards recommend [18], this coincides with the research [48], but differs about excess moisture, generating problems in the block manufacture.

As in the case of [49], which uses artificial fibers (polyethylene) to improve the ductility of the block, the present research obtained a similar behavior incorporating the American fiber type L, so it can be affirmed that any fiber, whether natural or artificial will improve the property of a fragile to a ductile body as shown in Figure 14.

It is evident that when using proportions of additives to manufacture earth bricks, under the compliance of Peruvian regulations [18], this helps us to ensure the minimum compressive strength of 1.0 MPa and tensile strength of 0.08 MPa, even more to achieve a significant increase in mechanical strength when using different dosages of *Agave americana L.* fiber, similarly an improvement in compressive strength is achieved, this was also met by adding any other type of natural or vegetable fiber [50]. The results shown in this research were logical with the results presented by [22], since both studies propose an improvement in compressive and tensile strength. Also, the author [26] indicates an improvement in the strength of blocks by increasing the fiber content of *Agave americana L.*, which was also shown by the results of this research. An important function of *Agave americana L.* fiber is to reduce the pores of the soil block when these are in sizes of 25 mm, giving efficient results to improve the compressive and flexural strength [51]. The soil blocks without fiber reinforcement presented a brittle failure characteristic, while the other samples with *Agave americana L*. reinforcement showed a ductile behavior. This is due to the good adhesion between the fiber and the earth blocks, since they work as a bridging effect when cracks originate [52].Clay stabilization for the manufacture of blocks is necessary to make it a ductile material. As mentioned by Mohammed [50], when there is a lot of clay, there is a brittle block.

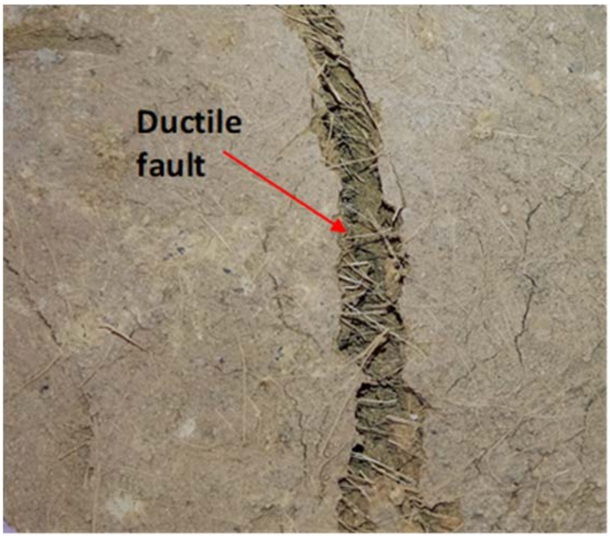

Figure 14. Ductility of the adobe

As most infrastructures are subjected to gravity loads at all times, the most important mechanical property is the compressive strength, which was therefore determined as an indicator for the most optimal dosage.

Meeting the minimum requirements for the design and elaboration of the blocks improves the mechanical properties from the standard block, and also improves the resistance of adobe masonry to gravity load effects (compressive strength) and lateral load such as winds or earthquakes (tensile and flexural strength) [53]. However, the efficient bonding of these blocks should be considered using mud mortars with tensile strength greater than or equal to 0. 012 MPa to guarantee the minimum compressive strength of 0.6 MPa and the minimum tensile strength of 0.025 MPa in adobe masonry [18].

5. Conclusions

Because the blocks were made of natural, biodegradable materials, their mechanical resistance was higher, compared to the standard simple (0%) fiber.

An optimum fiber addition was achieved to improve the mechanical properties of the block with a 0.25% addition of *Agave americana L*. fiber.

There was an increase in compressive strength of 13.39% (2.54 Mpa) compared to the standard block, also a significant increase in tensile strength by 39.13% (0.32 Mpa), and flexural strength was increased by 14.29% (1.44 Mpa) compared to the standard sample.

According to the results, the compressive strength was increased by 124% and the tensile strength by 187.5% in relation to the minimum strength values of the Peruvian standard E. 080. The fiber of *Agave americana L*. helped to control the cracks in the blocks.

Finally, this research should be used to provide additional knowledge regarding the elaboration of blocks. It is not recommended to use doses of *Agave americana L*. greater than 1%, since it is difficult to integrate the fiber into the mixture.

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