Use of seagrass fibres in adobe bricks

BAMB BUILDINGS AS MATERIAL BANKS

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Abstract. The main aim of the present study is to measure the capability the "Posidonia Oceanica" as fibre reinforcement for adobe bricks. This sea-plant is distributed in the Mediterranean coast, considered as a solid marine by-product. To analyse the performance, prismatic earthen specimens with seagrass fibres were compared with the most traditional additives for this purpose; straw fibres. Both fibres were included with different lengths and quantities. Previously, in order to understand their behaviour, the fibres themselves were evaluated. Tensile strength and water absorption tests were performed. Meanwhile bricks themselves were subjected to mechanical tests. Concerning the biomass fibres, results show that straw fibres present higher tensile resistance than the seagrass leafs while they are more fragile to breakage than seagrass; on the other hand, they have higher water absorption than seagrass. Mechanical results show variations depending on their fibre content and length. Nevertheless, bricks with long seagrass fibres present a characteristic good behaviour in terms of flexural and compressive strength. Generally, adobe bricks with both types of fibres achieve similar mechanical properties, generating favourable results in terms of comparison between them.

Keywords: Earthen bricks, compressive strength, flexural strength, biomass, seagrass, straw

1. Introduction

The IEA (International Energy Agency) identifies the building envelopes as one of the main points to take into consideration to reduce the energy consumption in buildings [1]. The choice of materials implemented for that purpose influence the needed energy to reach heating and cooling conditions as well as their embodied energy during the manufacturing process. Earth as a construction material can achieve good purposes in terms of energy saving during its production, since it is a sustainable material easily available, as well as due to its thermal inertia during the building use [2]. Previous studies highlighted the use of biomass into earthen materials, achieving some improved results in terms of comfort conditions [3-5]. This study evaluates the use of Posidonia Oceanica fibres as an additive for adobe bricks.. Posidonia Oceanica, a seagrass widely distributed along coastlines of the Mediterranean sea, leaves residues that reaching the coasts represents a significant economic, and hygienic problem in all coastal zones [6-9]. Hence, beached leaves of Posidonia Oceanica were proposed as a renewable and low cost material for the production of value-added products [6,10,11]. Differently, to our knowledge the potential use of Posidonia Oceanica fibres for adobe bricks have not yet been evaluated. As a reference, straw as brick additive was also evaluated.

2. Materials

The mixture of different soil particle sizes and water compose adobe bricks, which can be stabilized in order to improve their properties. In this experiment, clay, sand and gravel, conforming small and large particle sizes, were the different components mixed with straw or seagrass fibres.

The clay was commercialised by Ceràmica Almacelles S.A. meanwhile the sand and gravel were supplied by Nordvert of Grup Sorigué. Straw fibres came from Farratges La Noguera S.L. and sea-plant fibres were treated by CNR-ITAE Institute for Advanced Energy Technologies "Nicola Giordano".

The Mediterranean sea-plant Posidonia Oceanica is disposed as narrow independent leafs, which were collected from the southwest coast of Sicily region (Italy). To remove the sea salt that they content, all leafs were washed before with both running and distilled water. After the cleaning process, fibres were dried in an oven at 80ºC during 24 hours.

Straw fibres, an additive popularly used in earth brick constructions, were taken into consideration in the study as a reference material.

3. Methodology

3.1. Sample preparation

Prismatic samples of 4x4x16 cm were developed in standardized moulds varying the rate and length of the fibres. The inclusion of biomass fibres increased from 0% to 0.5, 1.5 and 3%, allowing to compare non-fibrous and fibrous specimens. Both straw and seagrass fibres were cut at 3 cm of length, meanwhile the natural flexibility of the seagrass allowed inserting them with their original length (up to 19 cm.) differently from the rigid appearance of the straw. All samples were left to dry in normal laboratory conditions (21-23 ºC, 40-50% RH.) during approximately 28 days.

In order to observe the effect that fibres produce in the earth material, a constant mixture of 60% fine clay, 40% sand-gravel and 20% water was taken into consideration. Furthermore, natural samples without any fibre addition were manufactured for this purpose.

3.2. Test methods

Both types of biomass fibres were evaluated in terms of tensile strength and water absorption to analyse their difference.

Tensile strength of the straw and seagrass fibres was determined by Zwick Roell smart pro testing machine. The fibres were positioned straight within the equipment grips, with a maximum load capacity of 200 N and a displacement of 5 mm/min that produced the fibre failure.

The water absorption of the fibres was also determined following the specifications of DIN EN ISO 62 [12]. The weight measurements were carried out at 24 h intervals during 18 days approximately using an analytical balance AG135 from Mettler Toledo. Before starting weighting, the water was removed from the surface of the fibres. The absorptance capacity of the fibres was calculated with equation 1, where w is the percentage of water absorption, and m_1 and m_2 correspond to the mass of the fibre before and after immersion in water, respectively:

$$w = \frac{m_2 - m_1}{m_1} \cdot 100 \tag{1}$$

Flexural and compressive strength in the dried samples were tested according to the Standard EN 196-1 [13] by means of PROETISA Uniaxial testing machine equipment. The slab were subjected to the flexural strength, calculated with equation 2, where R_f (N/mm^2) is the flexural strength, F_f (N) is the maximum force at break point, b (mm) is the squared section of the prism and, l (mm) is the distance between the holders. For this purpose, a load range of 2000 kg was applied with a velocity of 5 kg/s.

$$R_f = \frac{1.5 \cdot F_f \cdot l_f}{b^3} \tag{2}$$

Compressive strength was calculated with equation 3, where R_c (N/mm^2) is the compressive strength, F_c (N) is the maximum breaking force, and S (mm^2) is the surface of the plates used in the test (1600 mm^2). The load cell of the equipment was 20000 kg with a velocity of 2.40 mm/min.

$$R_c = \frac{F_c}{S} \tag{3}$$

4. Results and discussion

The main physical properties of the studied fibres are presented in table 1. Having higher density, seagrass fibres present lower break load when they are submitted to tension and therefore, lower tensile resistance. Nevertheless, although straw fibres have higher resistance to tension, they are breakable easier than Posidonia Oceanica sea-plants.. Concerning the water absorption capability, straw presents generally more percentage absorption. This could produce some problems in connection with the bonding between soil and fibres, since the water absorption generates a following retraction in fibres, producing voids around the fibre section. This fact can generate some disadvantages in the mechanical behaviours of the pieces.

Table 1. Physical properties of the biomass fibres.

Type of fibre	Density (g/m^3)	Water absorption (%)	Break load (N)	Tensile strength (N/mm^2)
Straw	0.312	365	88.18	128.19
Seagrass	0.721	293	23.59	56.01

Mechanical test results are presented in the following figures, including the average values of compressive and three-point bending tests. In all cases, sample repetitions showed an error lower than 0.1 N/mm^2, generating a good reproducibility. Observing figure 1 that shows the compressive strength of the bricks, the increasing fibre fraction produces the highest compressive resistance for 0.50% of straw fibres content, while sea-plant samples with 3 cm length and with long fibres, reach the highest values when for 1.50% content. After those fibre rates, the compressive resistance tends to decrease for 3% fibres contents. This decreasing affects much more to straw than seagrass fibres, indeed for the straw, the value is reduced by almost 50% comparing with seagrass reinforcement. Furthermore, in all cases the fact of reinforcing adobes with the biomass fibres, improve the original state of the brick without them.

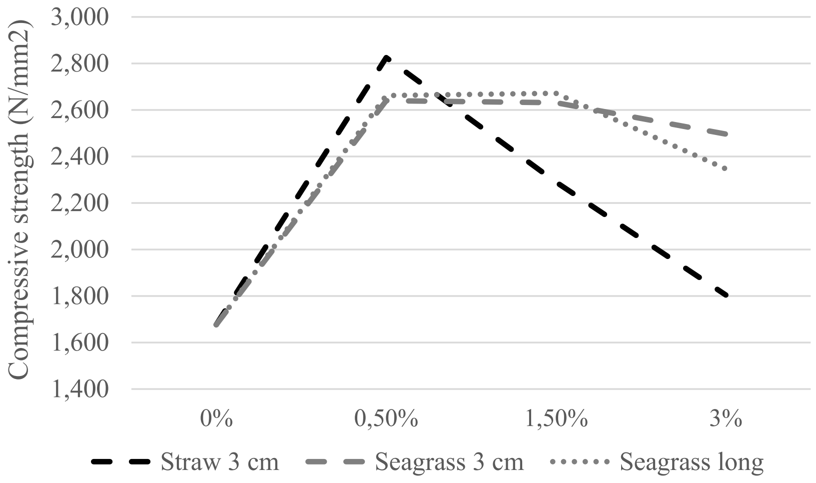

Figure 1. Compressive strength of the adobe bricks according to the fibre length (3 cm straw/seagrass, long seagrass) and fibre content (0, 0.5, 1.5, and 3%).

Figure 2 shows the flexural behaviour of the adobe bricks. In this case, bricks with Posidonia Oceanica fibres present better flexural resistance that the ones which include straw. For fibres chopped at 3 cm, the resistance tends to decrease when more content of fibres are included in adobes. However, when natural long sea-plant is incorporated, the flexural values continuously increase at increasing the fibres content, almost doubling the values achieved by the other samples. This three-point bending test allowed to observe how the complete failure of the fibre based samples did not occur; all the fibres sewed up the brick strongly. As expected, the incorporation of both fibres improved the displacement of the brick rupture, but particularly with the seagrass ones.

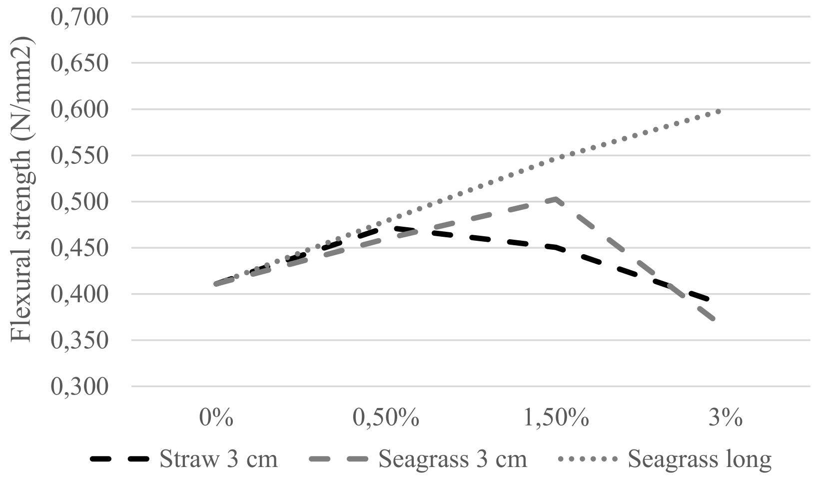

Figure 2. Flexural strength of the adobe bricks according to the fibre length (3 cm straw/seagrass, long seagrass) and fibre content (0, 0.5, 1.5, and 3%).

Therefore, comparing the mechanical behaviours of both biomass fibres, adobes with Posidonia Oceanica fibres cut at 3 cm and with its natural long length, present general better results with higher percentage of fibres than straw. Specially, bricks with long seagrass fibres reach the best results in terms of flexural resistance values. The difference with those that include straw fibres can be justified by the own nature of sea-plant. Straw has much more rigid appearance than Posidonia Oceanica, which is more flexible. This leads more fragile behaviour of the straw-based samples than the seagrass ones. Furthermore, Posidonia Oceanica fibres are more interlaced with the soil matrix than the other ones, producing less interactions fibre-soil over the piece. Furthermore, the difference of density between both fibres, where straw is lighter than seagrass, causes that, with the same weight percentage of inclusion, higher volume of straw is needed. Figure 3 exposes some sample fibre sections where it is evident that the intersection between soil-fibre is higher with straw. This fact can also contribute to the different mechanical behaviour between bricks developed with both types of fibres, since it decreases the resistance of the brick section. Furthermore, referring to the other physical properties of the fibres themselves, described in table 1, the higher water absorption of straw fibres can also be another reason worsening their mechanical behaviour, especially in compression, due to the voids produced around the biomass fibres.

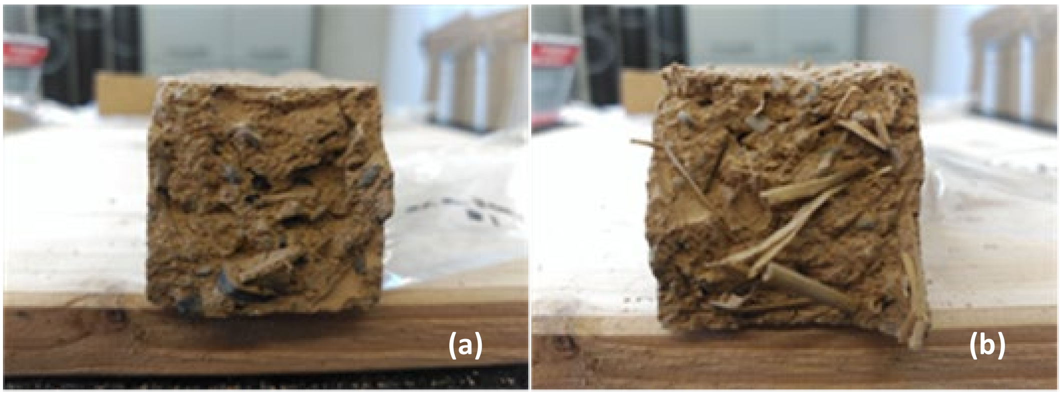

Figure 3. Seagrass (a) and straw (b) samples sections. 3% content and 3 cm fibre length.

5. Conclusions

The main purpose of the experiment was focused on evaluating Posidonia Oceanica as fibre reinforcement for adobe bricks used as sustainable building envelope material. In order to analyse their behaviour, straw fibres were considered as a reference, since they are the usually employed as additive in earthen constructions. Therefore, adobes with straw were evaluated to generate a direct comparison. Firstly, the fibres themselves were examined from a physical point of view. Density, water absorption and tensile strength were analysed, arriving to the conclusion that both types of fibres present great differences.

To develop the experimentation, earthen bricks with straw fibres were manufactured to generate a direct comparison with the innovated ones made of seagrass. After the evaluation of the bricks, as well as the investigation of different lengths and amount of fibre inclusions from both types of biomass fibres, seagrass additives on the bricks seem to be more suitable from mechanical point of view.

Concerning compressive strength, straw reinforced adobes presented the best result when the fibre content is 0.50%. Nevertheless, this result is practically reached by seagrass fibres when they are included at 1.50% rate. From flexural resistance results, when more percentage of sea-plant with its natural length is included in the bricks (3%), better mechanical performance is achieved. Therefore, both flexural and compressive strength are generally improved with higher fibre ratios when seagrass is included as additive in the bricks. Specifically, the natural length disposition of Posidonia Oceanica fibres present the best results in compression at 1.50% content and even better at 3% from flexural resistance point of view. Furthermore, comparing the fibrous samples with the non-fibrous ones, an improvement of around 50% in mechanical strength is reached when Posidonia Oceanica sea-plant fibres are included in 1.50 or 3% of content.

Regarding to the physical properties measured in both types of fibres and their relation with the bricks mechanical behaviour, density and water absorption seem to be determinant.

Therefore, it can be concluded that the inclusion of Posidonia Oceanica in adobe bricks in its natural length presents better results than the same bricks with straw fibres. Moreover, the fact of putting the fibres without cutting them into the mixture makes that the manufacturing process be much easier and cheaper.

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