Investigating the effect of various lengths of bamboo straw on the mechanical properties of adobe

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Abstract. Adobe buildings are popularly used in different universe regions and comprise an important characteristic of the worldwide cultural heritage. Moreover, in recent years, ecological construction materials like bricks of adobe have become more economically vital. The advantages of using adobe as a main construction material include environment, economy, friendliness, good thermal with sound insulation, and perfect indoor air quality. Therefore, it is vital to investigate the adobe's mechanical properties. This research aims to investigate the effect of different sizes of bamboo straw on adobe bricks, which is considered a process of seeking high-performance bricks in terms of compressive strength and flexural strength. The mixture utilized in this experimental research contains sand, clay, silt, and bamboo straw. Adobe bricks with bamboo straw were prepared along with a control mix. The brick size is 227 x 115 x 75 mm which consists of different percentages of bamboo straw 0.5%, 1%, and 1.5%. Meanwhile, the bamboo straw has different lengths of 30 mm, namely, short bamboo and 60 mm as long bamboo. 70 samples were tested out of which, 35 bricks samples were tested for compressive strength, whereas 35 bricks samples were tested for flexural test. By adding the bamboo straw reinforcement, the adobe compressive strength increased also the addition of short bamboo straw recorded the maximum compressive strength up to 3.41 MPa. A solid conclusion can be made that the samples constructed with short bamboo straw throughout the mix performed better than the samples with long bamboo straw in compressive strength test and for flexural strength short bamboo marked the best performance to the 1.0%.

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1 Introduction

It is known that the production of cement is the second largest emission industry of greenhouse gases after the coal-powered electricity, which produces about 5% of annum anthropogenic universal production of CO_2 [1]. Indeed, the cement production issue is that a ton of CO_2 is emitted to the atmosphere for each ton of cement [2], [3]. Also, mining raw materials in large quantities like coal, clay, and limestone outcomes in top-soil loss and excessive deforestation [4]. The production process, from mining to transporting, consumes a high energy and has a negative ecological effect on the riverbeds and forested areas [5]. Adobe is locally available, cheap material, can be reused, adapted to many kinds of soil, and convinced with ambiance and sound properties [6]. Adobe construction is used worldwide, especially in the regions that have difficulty transporting construction manufactured materials or wood such as the high mountains which are often very seismic. According to [7], despite the fact that this kind of construction is considerably vulnerable, implementing it for construction perhaps the suitable approach to sustainability, acoustical, and environmental impact reveals the quality as it can be seen in the present time. According to [8], "using adobe is reducing due to the plenty of produced materials for construction but these regions suffer less mechanical resistance, especially to earthquakes as what happened in 1861 and 1945 in Mendoza and San Juan's respectively.

Adobe must be of a desired design and strength in order to avoid damages especially in bad weathering zones [9]. One of the ancient substances (Adobe) which used for construction buildings is formed by mixing clay with water and chopped straw or other fibers added to get a high amount of strength before leaving them under the sunshine to completely dry with the desired and required shape [10]. Using Adobe back to more than ten thousand years [11], it has been found in many places around the world such as the United States South- Western part since the old settlers of Spanish times, Africa, Portugal, the subcontinent of India, and regions of southern Europe, and Asia as it is the only material still used in the heart of Wadi-Hadhramaut in Shibam which the oldest skyscraper in the world using mud bricks [12].

Earth supports the interiors from the winter's cold due to its efficient isolation as well as keeps out the heating during summer both features are advantages to adobe walls which make it appealing [9], [13]. Approximately 30% of the people around the world live in ground manufactured materials for building [14], [15]. Including one-fifth of the suburban and urban population and the majority of the rural population, around 50% of the people in developing countries live in homes that were built using this type of construction [16], [17]. Recently, in Aveiro city, about 25% of the existing buildings are constructed by adobe, whereas this percentage rises to 40% for the entire district, according to information from Aveiro municipality; In fact, the vital expression of this construction approach in several areas in Aveiro region has been reported by assessments implemented presently [7], [13].

One of the main problems facing the strength of adobe is the saturation of water [19]; for example, what happened in Shibam–Hadhramaut, that is listed in the United Nations Educational, Scientific and Cultural Organization (UNESCO) heritage -, the height of the building reached 30 - 40m some buildings are influenced by the flooding in 2008, this case is has led to massive damage to the foundation of the buildings. Indeed, when the water interacts with the mud, it breaks which is considered as the weakness of the adobe particles [18]. However, the adobes of mud-brick seem to be an effective substance which could remain for centuries unless exposed earthquake [20]. The weakness is that the buildings are not reinforced since its substance possess low strength unless fiber or cement is added to the mixture for the purpose of increasing the resistance capability [21], [22].

Due to its very high-water content, which content required for the workability, adobe is quick to respond to shrinkage. It is widely practiced utilizing natural fiber substances to overcome the issue during its traditional use [23]. Also, fibrous adobes supply heat - such as

fuel and energy- as savings in construction as it possesses low thermal conductivity [24]. Indeed, Adobe with added fiber leads to increase in strength flexibility, and tensile factor [25]. For this reason, in this study, there is a natural fiber added to overcome this issue which is bamboo straw. In the present time, many researchers are concentrating on improving the mechanical properties of adobe bricks, by adding fibers to increase their strength of it. However, in this study, bamboo is an additional material to the mixture due to its high mechanical properties [26]. Bamboo is earth friendly when compared to other natural fibers as it plays an important role in fixing the atmospheric carbon dioxide [27], [28]. There are more than a thousand species of bamboo and around 70 genera grow naturally in diverse climates [10], [27]. Despite the bamboo's leaves protect it against the sun meanwhile its roots keep the soil together, bamboo possess many desirable features like its lightweight, biodegradability, stiffness, and high strength [26]. This type of fiber is known as the eco-friendly functional fiber of the 21st century due to its versatility and multi-functions. Also, it is commonly disseminated worldwide, and it is easy to cultivate as it's ratio of high survival; additionally, it is reproducible and degradable without pollution [29].

In this research, 70 bricks – size of 227 mm x 115 mm x 75 mm - with different amounts of bamboo straw to notice the changes in compressive and flexural strength. These bricks are divided into 7 categories to estimate the effectiveness of adding bamboo straw to the dry bricks of adobe. Besides the control samples: 0% of bamboo straws on the dry bricks, there are 6 different categories based on the amount of long or short bamboo straws added to adobe. Then the bricks are tested and evaluated for their compressive and flexural strength based on the BS EN 12390-3:2002 and BS 1881:part118,1983, respectively.

2 Methodology

2.1 Soil classification

The samples are mixed with soil that is from highlands soil, which is categorized as Oksysls, that is known by it its composition Jaotheit, Jbsat, hematite, and hematite. It prevails on kaolin tends substantially to acidic status. Red soil, which was used in this study, comprised of heavy rain in the warm areas, dense forests, and wet air. Where most of the components are mud thus it turns from sand to mud. In fact, its origin is crystalline rocks with the features of low in dissolved salts, poor content of lime, vulnerable, and fragile. Consist of 90% insoluble substances and 1% organic materials. By using the sieve analysis, the soil was divided into clay (0.002 mm), silt (from approximately 0.002 and 0.06 mm), and sand (between almost 0.06 and 2 mm). The percentages of each soil type used are 50% sand, 30% clay, and 20% silt for all samples prepared. The specimens with natural fibers were prepared based on the previously mentioned percentages of bamboo straw with lengths of 30 mm as short straws, and 60mm as long straws. The way to use a bamboo straw for the adobe is by cutting the bamboo straw after the extracting process to the length required.

2.2 Preparation, compacting and curing process

The concrete mixer is used as less time is necessary and also to have control over the quality and the ratio of used materials. The water is added when the earth materials blending is poured gradually to ensure homogeneity. 4 kg per mixture of every substance consumed through Adobe preparation. Then, the compacting process of 0.9 MPa is conducted once the earth materials mix is ready. This is to ensure high efficiency and to keep the mix well compacted without deformations. The hydration guidelines instructions are effectively followed to avoid exposing Adobe to any influence. Indeed, 7 days in the open area and 7 days in the oven with

temperature of 106 Celsius is implemented. The preparation mix stated in table 1.

Table 1. Sample preparation mix.

Samples	Mix percentage %			
	Sand	Clay	Silt	Bamboo
Control bricks	50	30	20	5
M1	50	30	20	0.5
M2	50	30	20	1.0
M3	50	30	20	1.5

M = Mixed Bamboo Lengths

3 Results and discussions

3.1 Compressive strength

Before the test is performed, it is vital to have the side of the brick specimen's side is smooth. The values shown on the digital meter – provide the maximum load value which could be resisted by the brick prior it fails - are recorded. Based on the analysis, the samples with bamboo straw in Figure 1, the best value was marked by using short bamboo straw which contains higher strength compared to the samples without bamboo straw and other percentages. When then portion of short bamboo straw is at 1.5 percentage the compressive strength reached a highest value for the sample, which is 3.41 N/mm^2 compared to the 0.5-1.0 percentages. The samples containing long bamboo straw where positive to compare to the control samples which marked 0.83. For the long straw the best percentage is 1.0 % which marked the highest value of compressive strength test by 1.82 N/mm^2. This means that the addition of bamboo straw causes the sample to retain high compressive strength.

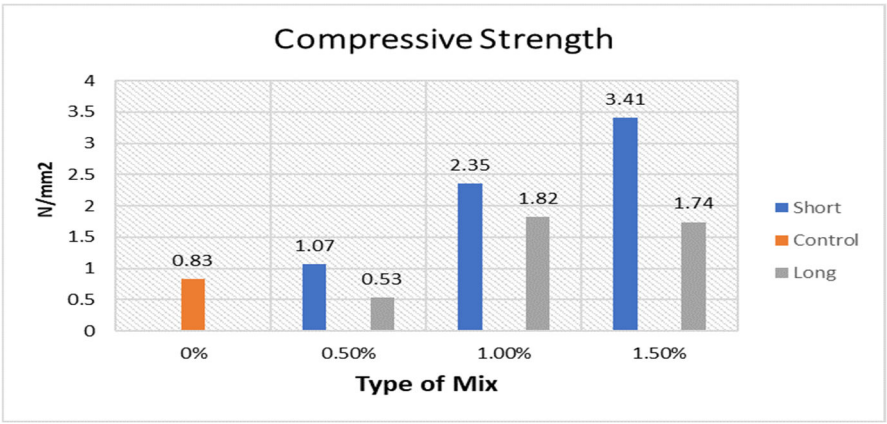

Fig. 1. Compressive Strength Test.

3.2 Flexural strength results

Depending on the results and the investigation, Figure 2 illustrates the flexural strength graph with bamboo straw. The graph proves that the usage of the bamboo straw gives the highest

stress with a sharp increment which is the (S3-S) which stand for sample3 short bamboo straw value compared to the other samples in the test. The flexural strength test has proven to show that (S3-S) sample has the highest value of all, followed by the (S1-L) as the lowest of all. In addition, the sample has recorded the highest flexural strength value compared to the other samples by 0.41 N/mm^2. Next, it's clear that the increase of the bamboo straw leads to an increase in the bricks' flexural strength as it is shown in the Fig. 2. The long straw is marked the best performance at the second mix by 1.0% of bamboo straw before its decreased at 1.5%. As it is seen the percentage 0.5 % shows the lowest strength as it was difficult to separate the straw probably in all sides due to its amount. In brief, short bamboo straw samples have recorded the highest flexural strength and mid-span deflection.

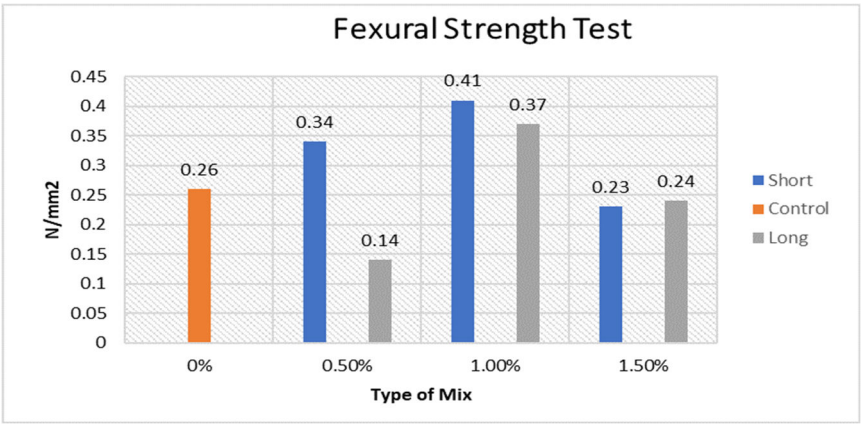

Fig. 2. Flexural Strength Test.

4 Conclusion

Based on the experimental work, a solid conclusion can be made that the samples constructed with short bamboo straw via the mix performed better than the long bamboo straw samples in compressive strength test. For flexural strength short bamboo marked the best performance to the 1.0% and then dropped down. Samples with short bamboo straw has an increment in strength because of the high rate of cohesion between the particles of the mixture which more resistible than the long bamboo straw due to easy damage of the long straw during tension which leads to reduce the connection of the particles of soil mix. This research focuses in using the short and long bamboo straw reinforced adobe clay as a construction material widely up to an extended of replacing the usage of normal clay bricks. Along with this research, it can also create a local energy, eco-friendly, high strength and develop a sustainable product. To enhance the soil mixture's workability and improve the mixture's quality, a suitable additive to the mixture needs to be searched. An added mixture needs to be found out to improve the workability of the soil mixture fasten the work and improve the quality of the mixture. Furthermore, the same study also can be repeated by increasing the percentage of the short bamboo straw to study the resulting effects.

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