JUTE FIBRE REINFORCEMENT OF ADOBE BRICK AS A MEANS TO PROVIDING CHEAP AND SUSTAINABLE HOUSING

Faisal Mohammed Ahmed[1], Sandra Lucas[1]
[1]University of Greenwich, Faculty of Engineering and Science, Medway Campus, Central Avenue, ME44TB, United Kingdom, F.M.Ahmed@greenwich.ac.uk

ABSTRACT

The need for sustainable construction has continued to generate momentum, in particular, finding alternative to steel reinforcement and concrete construction. In present research, the mechanical properties of adobe have been sought to serve as the alternative. In addition, several fibrous materials were combined with adobe and investigated for its strength. To ensure the long-term durability of adobe, this study investigated thoroughly the effect of jute fibre on the strength of adobe bricks and a conclusion was drawn. The developed composite shows a positive correlation between jute fibre addition and strength of adobe bricks. The compressive strength increased significantly with the addition of jute fibre and the minimum compressive strength achieved satisfied the strength requirement for adobe bricks.

1 Introduction

Adobe bricks were widely used for construction of residential houses in many countries notably in Aveiro, Portugal. The success of adobe construction in Aveiro district was mainly due to the characteristics of the existing available raw materials [1]. The main components of adobe include lime, coarse sand and argillaceous minerals. These materials were strengthen with additional clay to improve the quality of the bricks. Several researchers have proven adobe does not possess the same mechanical strength as concrete or even fired brick [2]. Therefore there is a need to exploit the possibility of strengthening these bricks to ensure their durability and increase mechanical strength. Adobe possesses a unique attractiveness, it is affordable, locally available and it is recyclable but as investigated by [3] and [4], adobe brick construction in Aveiro and Solarussa, were not properly strengthen and therefore affected the durability of the adobe structures. In the past several materials such as natural fibres mainly straws were tested and mixed with the adobe bricks to improve its strength. While reasonable improvement was achieved, there are several other fibres that can improve the strength of the bricks even more so such as jute fibres. While a number of literature have dedicated time mixing natural fibres with concrete, the objective of this paper will be to carry out an experimental investigation to study the impact of jute fibre on the mechanical properties of Adobe bricks.

Taken Adobe construction in Aveiro as case scenario, 70% of the buildings as shown by [1], are “satisfactory” and about 7% are considered “bad”. These is mainly due to poor reinforcement of the Adobe bricks.

[3] Experimented different mixtures of adobe bricks with different content of straw fibres and it was observed that as the straw fibre content increases the strain increases but the compressive strength decreases. This phenomenon is illustrated in **Fig1** (a, b). The two figures, it can be clearly observed that the compressive strength is lowering as the straw fibre content increases [3].

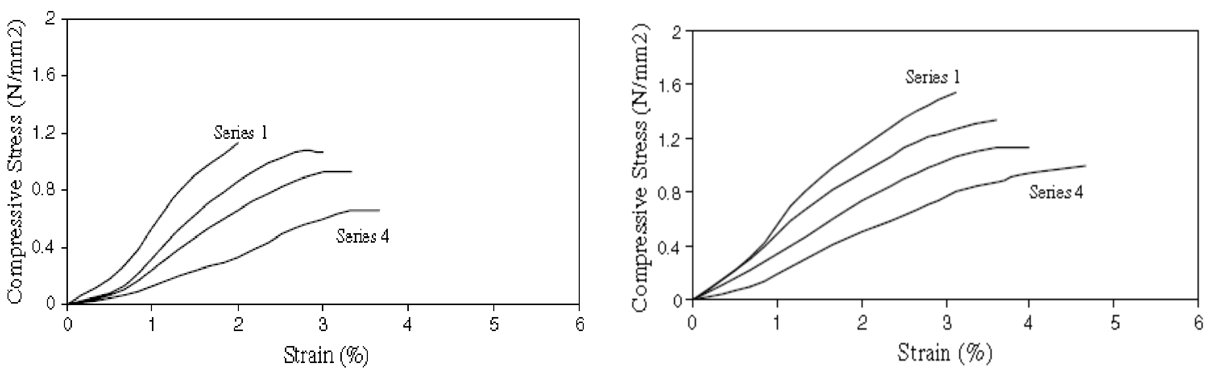

Figure 1: compressive stress strain relation for different straw fibre adobe mixtures [3]

The observation from [3] work is in clear contrast with other authors’ opinion. [5] Work shows that adding straw fibres to adobe mixture enhances the compressive strength if an optimal reinforcement ratio is used. This discrepancy might have been caused as a result of inadequate scientific experimental investigation on the balance of constituents and the optimisation of the strength for the specimens tested [6]. Therefore this paper, will improve on the methodology of these authors to find the right balance of fibre content to add to the adobe brick specimens so as to optimise its strength for construction purposes.

2 Experimental Program

2.1 Materials

Adobe bricks, by their nature are very simple to make. Technically two materials are needed to make adobe bricks namely sand and clay. A good adobe mixture is necessary to ensure optimum capacity of its strength. Therefore the type and size of earthen materials used and the proportion of mixture matters greatly. Too much clay leads to cracks and too much water in the mix lowers the soils stiffness.

2.2 Process operation

2.2.1 Mixing of raw materials

The sand and clay were weighted to obtain the right mixture proportion with regards to it been 60/40 or 50/50 sand to clay. For the adobe cubes used for compressive test, the total weight is 2300g, therefore for 60/40 it would be 1380g of sand and 920g of clay. For 50/50, it would be 1150g of both sand/clay. For the adobe bricks used for tensile test, the total weight is 2652g, therefore for 60/40 it would be 1591g and 1060g of sand to clay. While 50/50 will be 1326g of both sand and clay. As wet clay is being used for the mixture, the percentage of water content has to be obtained to know the amount of water in the clay. Therefore, before each mix, a small chunk of clay was taken from the wet clay, dried and weighted to obtain the amount of water content in the clay mix. It was found that there is approximately 38% of water in the clay. The water content was calculated using the formula;

$$w = \left(\frac{mass\ of\ wet\ clay - mass\ of\ dry\ clay}{mass\ of\ dry\ clay}\right) \times 100$$

The mixing process include the following:

1. The clay and sand are poured into a big bucket for ease of mixture. It is carefully mixed until it becomes a paste form and ready for moulding. A bit of water was added to the mix to give the mixture plastic consistency. The paste mixture is then inserted into the mould. The moulds are properly compacted to ensure the materials binds together.
2. The moulded specimens were left for two days before demoulding it. After demoulding the specimen are left for 2 to 3 days to dry naturally. The specimens are then inserted into the oven to dry the specimen completely for about five hours at the temperature of 100 degrees.
3. After oven drying, the specimen are left to cure for 7 and 28 days respectively before the compression and tension test are been conducted.

4. The procedures involved is the same as that of the plain adobe bricks just that in this case the jute fibre are added to the mixture. 0.1% and 0.2% by weight of the content of the mixture is added. 0.1% of the mixture is 2.7g and 0.2% is 4.6g. Jute fibre was cut into sizeable length of 70mm and mixed with the sand/clay mixture before moulding**.**

2.2.2 Preparation of Adobe bricks

The state of California uniform building code specification recommends a standard of 55% to 75% sand and 25% to 45% clay, [7]. The Adobe blocks can be made almost of any size, [8]. In this work, two sizes of adobe bricks were recommended; one the standard cube size of $100mm \times 100mm \times 100mm$ and two, a standard brick size of$104mm \times 65mm \times 216mm$. The adobe cubes will be used for the compression test while the adobe bricks will be used for the tension tests. After been filled in the foregoing manner, the moulds were placed on a vibrating table and allowed to compact properly. The specimens after curing can be seen in **Fig. 2**.

Figure 2: Different sizes of Adobe fibre reinforced bricks

2.2.3 Testing of Adobe bricks

2.2.3.1 Procedure for Compression Test

The procedures involved include the following;

- Each Adobe cubes and bricks are measured first.
- The specimens are then placed in the compression machine and even contact is maintained between the plates in the machine. A sample plain Adobe cube was made in the lab for sample test **Fig.3a**.
- The width and length of the loaded area is measured.
- Then the load is applied manually to the specimen until the specimen fails (**Fig.3**b).

Figure 3 a, b: sample adobe cube undergoing compression test

2.2.3.2 Procedure for Tensile Test

The procedures involved include the following;

- The bricks samples are used for the tension test.
- The sample should be inserted in the machine and centred.
- The point load should be touching the sample brick at the centre.
- Then using the computer aided software, the test should be run until the specimen fails.
- The test set up is similar to the one shown in **Fig.4**.

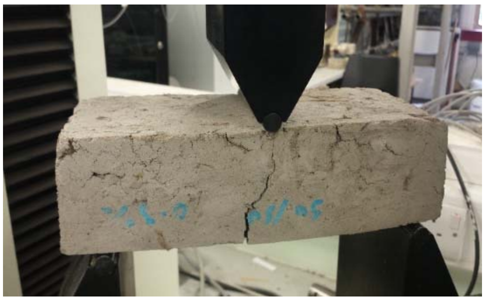

Figure 4: sample of tensile test set up

3 Results and discussion

3.1 Effect of Jute Fibre on Compressive Strength

The mean compressive strength for plain adobe specimen 50/50 ranges from 1.30 – 1.62 Mpa while for the jute fibre reinforced adobe specimen, the strength ranges from 1.38 – 1.84 Mpa depending on the content of the jute fibre reinforcement. As observed from the result, there is direct correlation between the strength and the percentage of reinforcement used (Table 1).

Table 1: Average compressive strength of Adobe bricks

	mean compressive strength (Mpa)	
Adobe specimen	7 day curing	28 days curing
Plain 50/50	1.24	1.3
plain 60/40	1.38	1.56
JFR 0.1% 50/50	1.6	1.84
JFR 0.1% 60/40	1.5	1.63
JFR 0.2% 50/50	1.38	1.44
JFR 0.2% 60/40	1.5	1.46

Adobe specimen 50/50 as can be seen from **Fig.5** does show significant improvement in strength as the curing period increased from 7 to 28 days. As observed from the graph, 0.1% JFR (jute fibre reinforced) adobe bricks increased from 1.60 Mpa to 1.84 Mpa and the 0.2% JFR adobe bricks increased from 1.38 Mpa to 1.44 Mpa. This was the case for adobe specimen 60/40 as the plain adobe bricks increased from 1.38 Mpa to 1.56 Mpa and the 0.1% JFR adobe bricks increased from 1.50 Mpa to 1.63 Mpa. However, there was an anomaly from the adobe specimens. Plain adobe specimen 50/50 compressive strength decreased from 1.62 Mpa to 1.30 Mpa as the curing period increased. The explanation of this anomaly can be attributed to the amount of water content in the mixture. The higher the moisture content the lower the workability of the bricks and therefore it is expected that compressive strength will likely reduce. Furthermore it can be observed from 0.2% JFR Adobe specimen 60/40, that there is a slight reduction in strength from 1.50 Mpa to 1.46 Mpa. This phenomenon is a result of the coherence between the fibre and the adobe layers. When the connection between the fibres and the adobe layers is somewhat loose, then the fibres cannot provide much resistance to the deformation of the adobe specimen as was witnessed in this case. Generally speaking, the jute fibre provided a marginal increase in the compressive strength of the adobe bricks and in some case it was observed that plain adobe bricks exhibited higher strength than the jute fibre reinforced specimens. In addition, the 0.1% JFR adobe bricks have provided highest resistant to the applied load, even better than the 0.2% JFR adobe bricks.

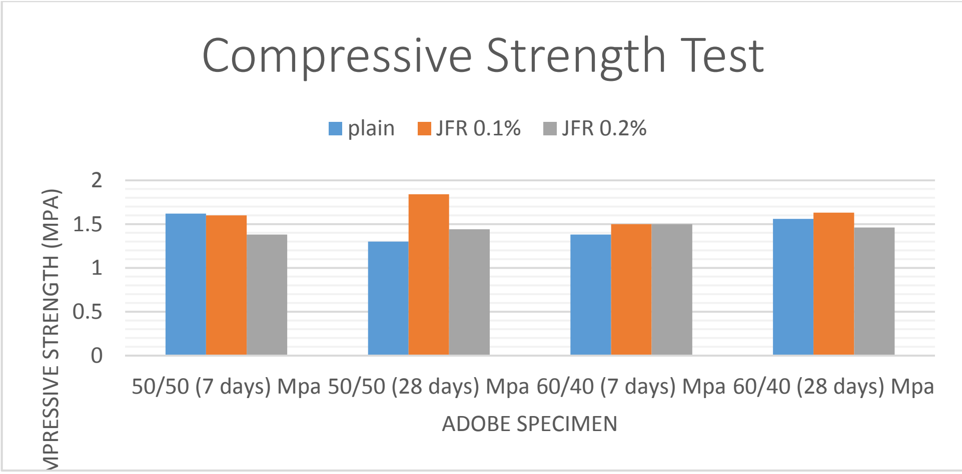

Figure 5: Comparison of compressive strength results

3.2 Adobe Tensile Strength

Fig.6 compares the tensile strength obtained from other countries (orange colour) from existing literature with the tensile strength obtained in the laboratory (green colour). It was observed that the tensile strength from the lab is much more impressive than the test conducted by other authors. For all three adobe specimens of plain, 50/50 and 60/40, the tensile strength ranges from 3.94 – 318 Mpa. The fluctuation of strength can be attributed to the interaction between the interface layers of fibrous materials and the adobe mixture. Specimen 50/50 with 28 days curing was able to achieve 318 Mpa due to the thorough drying of the specimen, which led to shrinkage increased by the bonding between the fibre, clay and sand mixture. Therefore, it was possible to achieve a higher tensile strength.

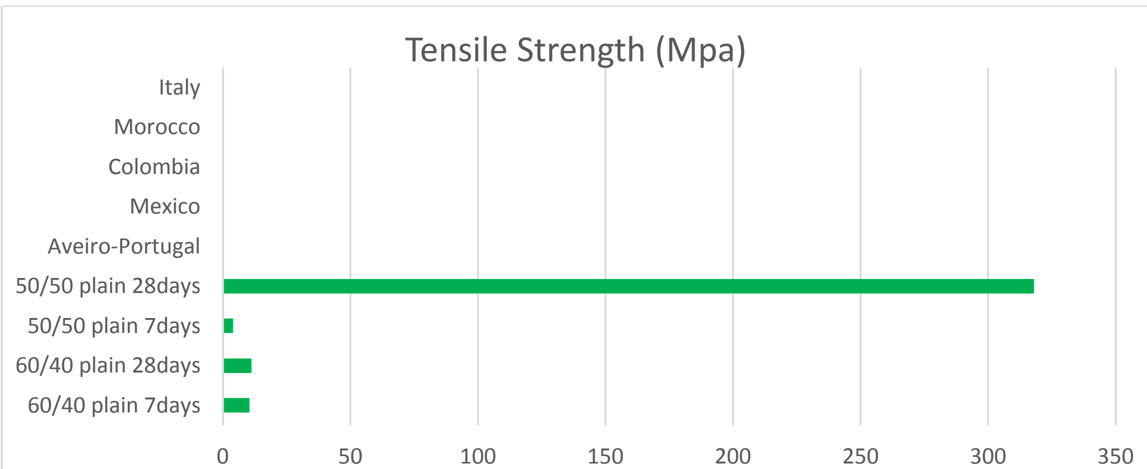

Figure 6: Comparison of Tensile Strength obtained in the lab with existing tensile strength of other countries

3.3 Influence of Jute Fibre on Moisture Content

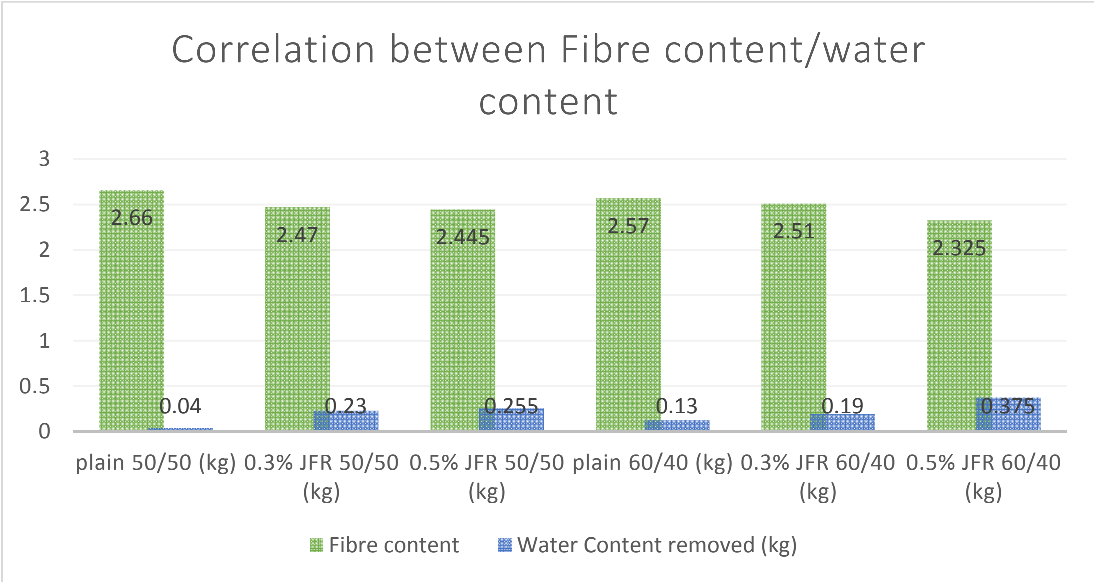

Figure7: correlation between fibre content and water content

Fig.7 shows all the different types of adobe specimen investigated with the percentage jute fibre added to the mixture. It was observed that the dry weight of the adobe specimens is decreasing with increasing content of jute fibre added to the mixture, that is drying shrinkage is greatly reduced with increasing fibre content. It was deduced from this analysis that jute fibre has a positive influence on the water added to the mix. It helps in reducing the amount of water content in the mixture by absorbing the water. This is possible through the porous nature of the fibres at a microstructural level which created more moisture paths into the matrices thereby contributing to the decreased drying shrinkage.

3.4 Influence of Jute Fibre on Load Carrying Capacity under Tensile Test

Fig.8 shows the correlation between jute fibre content and the load carrying capacity of the adobe bricks under tensile test. The relationship shows that as jute fibre content increases the load carrying capacity of the adobe specimens increases. This is because jute fibre is a strong tensile resistant material and therefore provides extra strength to carry more load subjected to the adobe bricks under tensile testing.

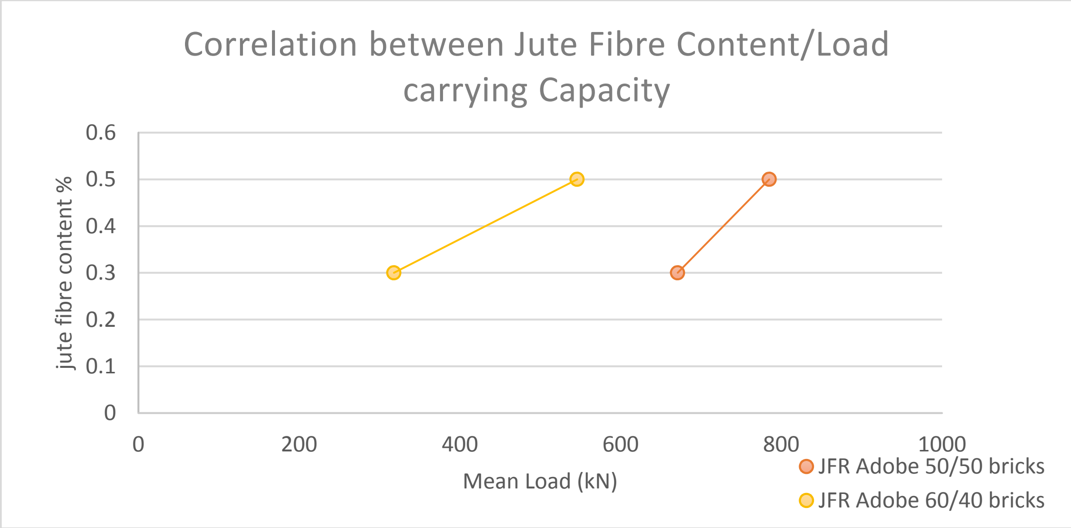

Figure 8: Correlation between jute fibre and Load carrying capacity

4 Conclusion

The mechanical properties of the adobe bricks were studied in this work. From the tests conducted it was possible to deduce the strength capacity of the adobe and in addition factors influencing the strengths of the bricks. Increase in jute fibre leads to increase in tensile strength. Also compressive strength decreases by increasing the fibre content beyond 0.1% by dry weight of content. It was also observed, the lower the moisture content, the higher the compressive and tensile strength of the adobe. Adobe construction is a fascinating technology that has existed for hundreds of years However for adobe to serve as the alternative construction material to cement/concrete construction, there is a need for further research to improve its durability and strength of the adobe.

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