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Characterisation of Jute Fibre Reinforced Adobe Brick and Brick masonry

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Abstract:

Adobe (sun-dried) bricks is one of the oldest and sustainable building materials. The present research involves enhancing the performance of adobe bricks by reinforcing with natural jute fibre. Adobe bricks were stabilized with different percentage (1% and 2%) of jute fibres of varied length (1cm, 2cm and 3cm). A comparative study was conducted on jute fibre reinforced and unreinforced adobe bricks. Based on test results, optimum length (2cm) and percentage of jute fibre (1%) was arrived at. Masonry prisms and triplets were cast using this particular length and percentage of jute fibers. A comparative study was conducted on unreinforced and jute fibre reinforced masonry in terms of its compressive strength and shear bond strength.

Keywords: Jute fibre, Adobe brick, Brick masonry

I. INTRODUCTION

Brick is the most commonly used building material. Adobe(sun-dried) bricks were used in ancient times during the Sumerian and Harappan civilizations. Emission of CO_2 during production of fired brick leads to environmental pollution. The utilization of adobe as a building material in the construction industry is an alternative. Due to the growing population, there is a need to provide a sustainable construction material which is eco-friendly and efficient. Some of the problems of the adobe construction are erosion of earthen walls at plinth level, shrinkage, cracking, attack by termites and pests and frequent maintenance of the structure [20]. Mainly the adobe construction is vulnerable to water absorption. The properties of bricks depend upon soil selection and process of brick making to obtain the desired strength. The suitable soil required for making adobe brick should contain adequate clay, silt and sand. The soil is mixed with water until plastic consistency is obtained.

There is growing interest in the production of adobe bricks because it is eco-friendly and a low embodied energy building material. There is a global concern, to reduce carbon dio-oxide emission due to construction materials and process.

Many researchers have commented that bricks reinforced with fibres are feasible to be used as a building material. Use of natural fibres like straw, hemp etc as a reinforcing material has been studied by many researchers. It is reported that the presence of fibres in bricks reduces brick density and shrinkage, prevents deformation and crack **[13,14,16,18,19]**. Importance of the bond between fibres and soil matrix in the bricks was studied by many researchers **[13,14,15,16,18,21,22,23,24].**

Strength and behavior of fibre reinforced adobe brick depends on the properties of both soil and fibres, hence it was decided to test both fibres and soil before manufacturing brick. A parametric study was conducted to finalize the length and percentage of jute fibre to be used in bricks.About 23-40% of greenhouse gas emission is mainly due to the building sector. The CO_2 emission from the construction industry may increase from 8.6 billion tons in the year 2004 to 15.6 billion in the year 2031 as per the international panel on climate change. Adobe is a thermal mass material, thermal mass refers to the ability of material to absorb, store the heat and release heat when required [17].

II. EXPERIMENTAL PROGRAM

A. Materials

The materials used in this study for jute fibre reinforced adobe brick production were soil that contains adequate

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amount of sand, clay and silt as main matrix; jute fibres as reinforcing materials and water.

B. Soil

Sieve analysis was conducted on the soil sample used for the manufacturing of bricks as per guidelines [4]. Particle size distribution of soil is shown in Figure 1. Further the soil was tested for Atterberg's limit, which included determination of Plastic limit, Liquid limit and Plasticity index [5]. Results obtained for properties of soil are shown in Table 1. The Chemical composition of soil is shown in Table 2.

C. Jute Fibre

Jute (bast fibre) belongs to Corchorus capsularis of Tiliaceae family [12]. Jute plant can grow to a height of 12-15 feet within 3 months. It is later soaked in water for retting process in which the inner layer of stem and the outer layer of the stem is separated.

Jute fibre is the cheapest fibre which is mostly found in India and Bangladesh [17]. It is composed of cellulose, lignin, hemicelluloses and a small amount of protein, inorganic [11]. Around 1.8 million tons of jute fibre is produced in India. Due to the presence of cellulose content, hydroxyl and other oxygen contents in jute fibre it is hydrophilic in nature [18].

The jute fibres were obtained from Srikakulam district, Andhra Pradesh. The properties of jute tested is shown in Table 3.

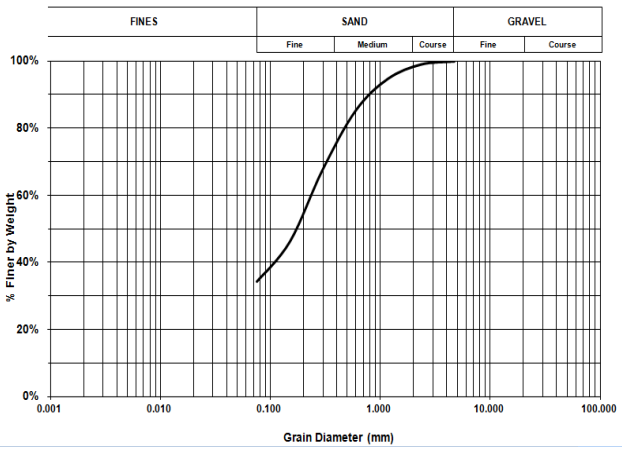

Fig. 1 Particle size distribution of soil

TABLE 1
PROPERTIES OF SOIL

Properties	
Specific Gravity (G)	2.40
Liquid Limit (%)	26.00
Plastic Limit (%)	15.00
Plasticity Index (%)	11.00

TABLE 2
CHEMICAL COMPOSITION OF SOIL

Properties		% by Mass
Silicon Dioxide.	SiO_2	67.62
Alumina.	Al_2O_3	12.18
Ferric Oxide.	Fe_2O_3	6.39
Calcium Oxide.	CaO	2.64
Magnesium Oxide.	MgO	1.57
Sulphuric Anhydride.	SO_3	0.17
Sodium Oxide.	Na_2O	1.61
Potassium Oxide.	K_2O	1.3

TABLE 3
PROPERTIES OF JUTE

Properties	
Thickness(micron meter)	50-60
Natural humidity (%)	10.20
Specific weight (KN/m³)	14.50
Water absorption (%)	270

SEM and EDS analysis of jute fibres were conducted. The diameter of jute fibres varied from 40µm-56 µm. Due to the variations of natural jute fibre maturity the three portions of jute fibres (top, middle and cutting) was found to have different thickness. SEM image of jute fibres is shown in Figure 2. Elemental composition of jute fibre is shown in Figure 3.

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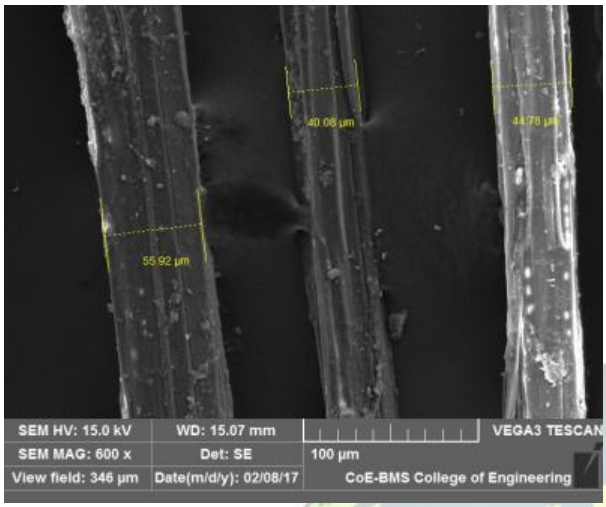

Fig.2 SEM image of jute fibres

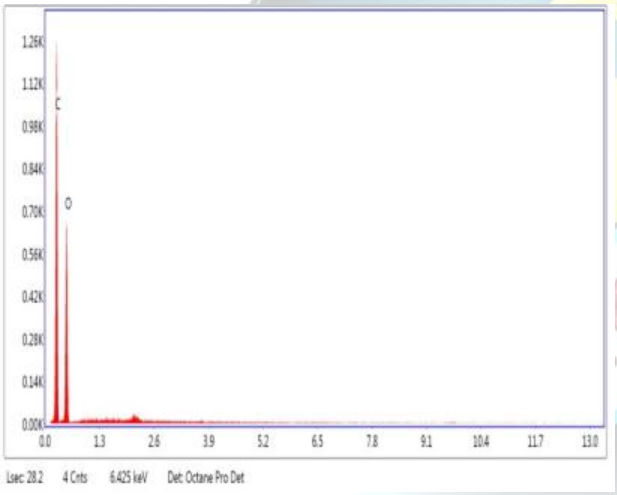

Fig.3 Elemental composition of jute fibres.

D. Process of making jute fibre reinforced adobe brick

Soil was mixed with jute fibre in dry state and then soaked for 24 hours. After 24hours it was mixed to the plastic consistency. Bricks of size 230mm*105mm*75mm were prepared using mould. Hand-moulded bricks were sun dried for 2 weeks under the shade. Adobe bricks were stabilized with different percentage of jute fibres of different length as shown in Table 4.

TABLE 4
TYPES OF ADOBE BRICKS TESTED

SI. No	Mix Proportion	Percentage of Fibres (%)	Length of Fibres (cm)
1	M0	0	0
2	M1	1	1
3	M2	1	2
4	M3	1	3
5	M4	2	1
6	M5	2	2
7	M6	2	3

III. TEST METHODS

A series of mechanical tests were carried out in accordance with the recommended Indian standards to determine compressive strength of brick [7], water absorption of brick [8],Compressive strength of prism [6]. Scanning electron microscopy (SEM) was conducted to gather information about surface morphology of the bricks.

IV. RESULTS AND DISCUSSION

In the current study, jute fibre reinforced adobe bricks and brick masonry were compared with unreinforced adobe bricks and brick masonry in terms of its compressive strength. Shear bond strength test was also conducted on both reinforced and unreinforced masonry triplets.

A. Dry Compressive strength.

Based on guidelines provided by IS: 3495(Part-1)-1993[1], bricks were tested for dry compressive strength in a universal testing machine (UTM). Five bricks of each mix proportion were tested for dry compressive strength. Initially, the weight of the specimen and their dimensions was measured. The load was applied continuously till failure. Density and compression strength of brick for different mix proportions of bricks is shown in Figure 4 and 5. Failure of bricks tested shown in Figure 6 and 7.

The compressive strength of the adobe bricks was observed to have increased by 73% after stabilizing with the jute fibres of 1% and 2cm length. During compression test of jute fibre reinforced adobe bricks it was observed that even after multiple crack formation brick was able to take load, minor cracks were formed on the surface of the brick and density of brick in the central part increased considerably. The crack pattern shows that jute fibre were effective in arresting crack propagation In case of unreinforced bricks failure was observed. Compressive strength of jute fibre

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reinforced adobe brick increased with increase in percentage of fibre. The compressive strength of jute fibre reinforced adobe bricks for M2 proportion brick is 5.02 Mpa, which is 73% more than unreinforced adobe bricks. Density of jute fibre reinforced adobe brick were less than that of unreinforced bricks. [14] discussed about Microwave Semiconductor Devices such as Tunnel diode, Gunn diode and valanche transit time devices and analyzes Monolithic Microwave Integrated Circuits (MMIC)

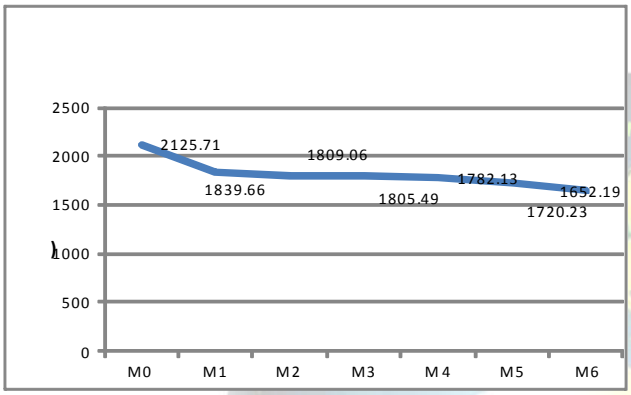

Fig. 4 Density graph for different mix proportions of bricks

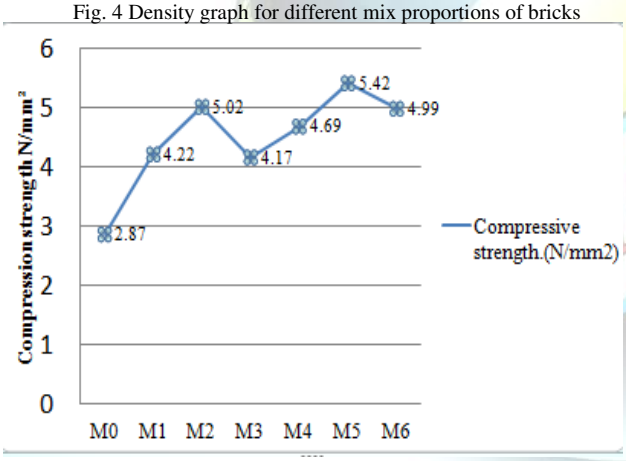

Fig. 5: Compression strength graph for different mix proportions of bricks

Fig. 6: Failure of unreinforced adobe

B. Water absorption test

Based on the guidelines provided by IS: 3495—Part2, bricks were tested for water absorption. Adobe bricks got dissolved in water within 45minutes. When adobe bricks are used for masonry construction they are to be protected from rain.

C. SEM analysis

From the scanning electron microscopy (SEM) photos, clay morphology for different mix proportions of adobe bricks were obtained. SEM research of the surface of powdered brick specimen including external texture is shown in Figure 8. SEM analysis of different mix proportion of adobe brick samples shows the crystalline clay particles and it appears more colloidal.

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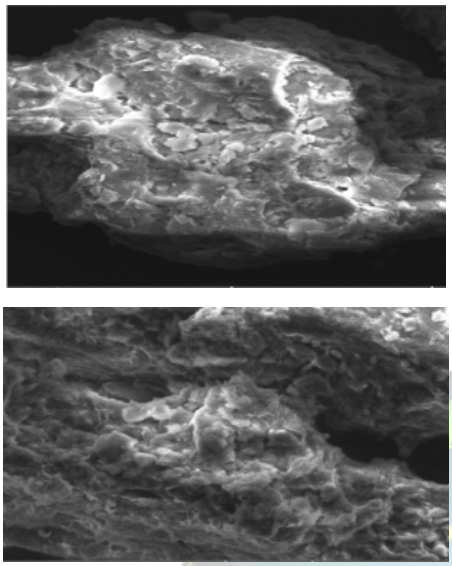

Fig. 8: SEM analysis of M0 and M2 brick

D. Compressive strength of unreinforced and jute fibre reinforced adobe brick masonry prism.

Based on compressive strength and appearance of brick, M2 (2cm length and 1%) was identified as the best bricks in this study. Unreinforced and reinforced 5 brick height masonry prisms were cast and tested as per IS:1905-1987.

Mortar reinforced with 1% of fibre of 1cm length was used in fibre reinforced adobe brick masonry. The compressive strength of jute fibre reinforced adobe brick masonry for the optimum dosage of jute fibre of 2cm length and 1% fibre is 2.08 Mpa, which is 48% more than that of unreinforced adobe brick masonry. Reinforced masonry prisms were observed to have failed after the formation of multiple cracks. This shows the effect of jute fibres in arresting cracks. Crack pattern of unreinforced and reinforced adobe brick masonry prism is shown in Figure 9.

Fig. 9: Crack pattern for unreinforced and reinforced adobe brick masonry

E. Shear Bond Strength

The shear bond strength of jute fibre reinforced and unreinforced adobe brick masonry were tested in the universal testing machine (UTM). Seven specimens were tested for shear bond strength of brick masonry. The average shear bond strength of unreinforced adobe brick masonry was 0.063 N/mm² and that of jute fibre reinforced adobe brick masonry 0.108 N/mm^2. The failure pattern is shown in Figure 10. The shear bond strength of jute fibre reinforced adobe brick masonry was 79% more than unreinforced adobe brick masonry. [19] discussed about microwave linear beam tubes including Klystrons , reflex klystrons tubes (TWTs)and it studies microwave cross field tubes such as magnetrons and microwave measurements

Fig. 10: Crack pattern for unreinforced and reinforced adobe brick masonry triplet

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V. CONCLUSION

- Compressive strength of brick increased with increase in percentage of jute fibre. When the percentage of jute fibre was increased to 3%, it was difficult to get a homogeneous mix and hence the percentage of fibre was restricted to 2%.
- Adobe bricks reinforced with jute fibres have shown higher compressive strength compared to unreinforced bricks. Bricks reinforced with jute fibres of 2cm length and 1% (M2) have shown 73% increase in compressive strength compared to unreinforced bricks.
- Including jute fibre in mortar seems to have improved the behaviour of masonry. Since the joints were of 10mm thick, 1cm length fibre of 1% was used in mortar joint in reinforced masonry.
- The compressive strength of masonry was observed to have increased by 48% after stabilizing with the jute fibres of 2cm length and 1% (M2) and by using jute fibre reinforced mortar.
- Shear bond strength of adobe brick triplet increased by 79% when jute fibre of length 2 cm and 1% was used in bricks and by using jute fibre reinforced mortar.
- The weight of jute fibre reinforced brick reduced by 10% when jute fibre of 2cm length in 1% was used.

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