Earth Building Blocks Reinforced with Jute and Banana Fiber

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***Abstract*—In developing countries, earth construction is economically the most efficient means to solve housing problems, particularly in case of low cost housing units, with the least demand of resources. The availability of local soil as raw material, the low energy consumption and the simplicity of the production process justify their extensive usage as primary housing material. Fibre inclusion enhances the strength and performance of the earth blocks. Natural fibre such as Jute fibre, Banana fibre were used and investigated experimentally with different percentages of fibre 0.25 %, 0.50 %, 0.75 % and 1 % by weight of earth. A series of test were conducted using soil with and without addition of fibre. Physical properties, mechanical properties and durability properties namely density test, water absorption by capillarity test, linear shrinkage, compressive test , split tensile test, wearing test and erosion test were conducted and compared with different fibre ratio to determine the optimum fibre content in each mix order to produce blocks that will provide the maximum strength.**

Keywords*— *Reinforced Earth Blocks; Banana fibre; Jute fibre; mechanical properties; durability properties

I. INTRODUCTION

The oldest building material in the world is earth/soil, but it's suppressed with the discovery of recent building materials like concrete, steel and burnt bricks. Material earth has many advantages, such as cost, less impact on environment and its easy accessibility. Construction using earth is still common today specially in region of suitable climate conditions and about one third to one half of the world's population is surveyed to live in houses constructed of unbaked earth. In the past decade, effort has been considerably directed towards using solid wastes[1] and enormous natural fibres[2, 3] as reinforcement in soil blocks for producing low effective cost building materials. Soil building blocks reinforced with agricultural waste are the common alternate building material that have resulted in environmental and economical sustainable buildings with different aspect ratio using coconut, bagasse, oil palm fibre[4]. Many other agricultural waste fibres such as coir, barley straw[5, 6], and date palm[7] have been investigated for its performance in soil building blocks. Industrial wastes such as saw dust, steel fibre[8], coal by-products[9], blast-furnace slag[10], natural and phosphogypsum[11], rubber[12] and plastic[13] also been studied on soil building blocks. Animal wastes such as cow dung, wool[14], flora fibres such as hibiscus cannabinus fibre[15] have also been used as reinforcement in soil blocks. There is lack of studies on synthetic fibres as reinforcement in soil building blocks.

The properties of soil building blocks reinforced with two fibres, namely Banana fibre, Jute fibre with different mix proportions were investigated. The physical, mechanical and durability properties of the fibre reinforced soil building blocks were measured to determine the optimum fibre content.

II. MATERIALS

A. Materials

The physical work was carried away in kallaperambur, thanjavur district were surplus amount of earth resources were taken for making bricks. To ensure this study, fibres were selected from widely available range. Banana fibre and Jute fibre are the basic material used for the experiment of soil building blocks. The properties of the soil (TABLE 1) indicate that the choice of soil is low plasticity clay (CL).

TABLE 1: Properties of Soil

Properties	Value
Optimum moisture content (%)	10
Maximum dry density (Mg/m^3)	1.940
Liquid limit (%)	18
Plastic limit (%)	18.41
USCS	CL

Reinforcement in soil building blocks is achieved by using Banana fibre and Jute fibre. Jute fibre has a modulus of elasticity to absorb shrinkage stresses before cracks, high tensile strength with no health hazards. Banana fibre is added in soil building blocks due to the increase in ductility, impact resistance, and toughness with inert to chemical reaction. The properties of Banana fibre and Jute fibre were listed from previous research (TABLE 2).

TABLE 2: Properties of Fibres

Fibre	Banana fibre	Jute fibre
Length (mm)	60-70	60-70
Range of diameter (mm)	0.04-0.10	0.8-1
Tensile strength (Mpa)	259-274	216-225

III. METHODS

B. Methods

Physical, mechanical and durability properties of soil building blocks were tested by conducting density, water absorption by capillarity, linear shrinkage, compressive strength, indirect tensile stress, wearing and erosion. For each test, blocks from each mix ratio were selected and used.

C. Preparation of blocks

Soil building blocks of 215x105x65 mm were prepared by using Banana fibre and Jute fibre as fibre reinforcement with the different mix ratio of 0.1%, 0.25%, 0.5%, 0.75%,1% by weight. Blocks were made by hand pressing the earth/soil with optimum moisture content (table). Homogeneous mixture of fibre and soil is obtained by continuous repeated mixing of fibre with soil. Prepared blocks were completely sun dried for over 21 days at average temperature of 25^0c-30^0c. In case of high temperature, blocks can be covered by using plastic sheets or by banana leaf to maintain humidity. The blocks were dusted to clean before testing.

D. Physical properties test

Linear shrinkage test was undertaken by measuring the dimensions of soil building blocks before drying and after drying of the specimen.

E. Water absorption test

Water absorption test was performed by capillarity method. According to BS EN 772-11[17], the blocks were oven dried to obtain constant mass representing a normal dried block. Blocks from each mix ratio was placed on 5mm water bath facing 215 x 105 mm of block for 10 min. Mass of each block before and after absorption was determined to find the percentage of water absorption by capillarity.
Density of blocks from each ratio was determined. According to BS EN 771-1[18], the dimension of each block measured, weighted and calculated for density.

F. Mechanical properties test

According to BS EN 772-1[19], the compressive test was conducted on testing machine until the blocks of each ratio failed and the corresponding ultimate load was recorded and maximum compressive stress was calculated.
Indirect tensile stress was calculated by using formula [20] with the corresponding ultimate load of soil building blocks of each mix ratio.

G. Durability properties test

Wearing test was conducted on each mix ratio. According to ASTM D559-03[21], the blocks were soaked in water bath for 2min and allowed to oven dry for complete 24hr with an average temperature of 100°-120°c. Wearing performance was determined by calculating the dry mass reduction of the earth blocks after completing 12 cycles of stroke on each face of block. Each cycle of stroke was given using vertical wire brush and corresponding percentage of wearing was noted.

H. Erosion test

Erosion test on soil blocks was conducted according to NZS 4298[22]. The test apparatus made by plastic bath and shower head distanced by 175 mm from the shield. Depth of the eroded area (mm) per minute of each soil building block is recorded and the rate of erosion is calculated.

IV. RESULT AND DISCUSSION

The results of the experimental investigation on the physical, mechanical and durability properties of different percentages of Banana fibre and Jute fibre reinforced soil blocks, denoted as BFREB and JFREB are discussed below.
Physical Properties. Fibre reinforcement improves the physical properties of the reinforced soil blocks. The results indicate that the performance of Jute fibres is better than that of Banana fibres. Density reflects the packing of the fibre and the earth material in the block. This is an indirect indicator the carrying capacity of the block. The inclusion of fibres, though in small percentages, replaces earth material which is of higher density than the fibres. The density of fibre reinforced blocks is therefore lesser than that of unreinforced earth blocks and the density decreases with the increase in fibre replacement. The results of the study also point to the same conclusion (TABLE 3). This indicates that JFREB are lighter than BFREB, which is due to lesser specific weight of Jute fibres. At 1 % fibre replacement, there is a decrease of nearly 11 % and 16 % in the density of JFREB and BFREB respectively.

TABLE 3: Fiber density values

Fibre Inclusion (%)	Density (kg/m^3)	
	BF	JF
0	2040.6	2040.6
0.25	1985.18	1979.49
0.5	1981.39	1783.06
0.75	1955.03	1754.86
1	1810.5	1710.19

Water absorption is an important parameter that determines the choice of soil block for various construction activities. Studies show that water absorption increases with the addition of fibres, particularly in case of natural fibres. The decrease in water absorption can be attributed to higher interaction between the fibre and soil along the length of the fibre and reduction in porosity of the block. And the increase in water absorption beyond 0.75 % can be due to the balling effect of fibres, when their percentage is higher than the optimum. (FIGURE 1)

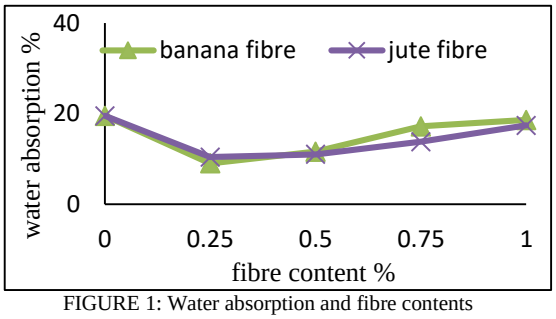

FIGURE 1: Water absorption and fibre contents

Linear shrinkage is not a desirable physical property and hence must be limited. Different standards prescribe different limits but the maximum limit is prescribed by Scottish Executive [23] as 3 %. The results of the study show that linear shrinkage is much lesser than the prescribed upper

limit of 3 % for both the unreinforced (1.69 %) and fibre reinforced earth blocks (maximum of 1.36 %). Linear shrinkage of a reinforced earth block is a function of both the type of reinforcing fibre and the quantity of the fibre used. Figure shows that linear shrinkage decreases with the increase in fibre content for all the tested percentages of fibre inclusion and the decrease is higher for JFREB than for BFREB. Presence of fibres resists the deformation/cracking in the soil matrix because of friction. Fibre controls the cracking and contains the length of the cracks by bridging them. Higher the fibre content, lesser is the quantum of linear shrinkage.

Compressive strength and tensile strength are a measure of the ability of the earth blocks to be used in the construction of load bearing structures.

JFREB and BFREB show an increase in compressive strength with the increase in fibre content for all investigated percentages of fibre inclusion. Nearly 85 % increase in the compressive strength is observed at 1 % jute fibre inclusion. The increase in strength is attributed to the frictional resistance developed between the fibre and the soil matrix. The presence of the fibres deters the formation of cracks and also helps in holding the cracks on failure, thereby increasing the load carrying capacity of the JFREB.

Fibre inclusion causes the reinforced soil matrix to behave like a more ductile material and also arrests the formation of large cracks. Tensile strength of the BFREB is lower than that of the JFREB and the behaviour is similar to that of the one observed in compressive strength, tensile strength increases with the increase in fibre content. The observations on the results of the mechanical properties of reinforced earth block shows that Jute fibres are a better option over the Banana fibres. (TABLE 4)

TABLE 4: Tensile strength in Fibre Inclusion

Fibre Inclusion (%)	Tensile Strength (MPa)	
	BF	JF
0	1.92	1.92
0.25	2.277	5.612
0.5	6.059	6.057
0.75	7.043	6.548
1	7.457	9.897

Durability of the earth blocks is a major concern in their application as a building block, particularly as they do not contain any binder like lime or cement. Durability of the reinforced earth blocks is assessed using wearing and erosion test. In both the tests, it is observed that fibre reinforcement has improved the capacity of the earth block to resist deterioration. Both fibres – Jute fibre and Banana fibre show appreciable performance in both wearing and erosion test. The fibres present in the soil matrix hold the soil together, preventing it from being washed away and thereby reduces wearing and erosion on the reinforced earth blocks. However, for practical applications it is suggested to use small amount of pozzolanic material like lime or cement, which will prove immensely useful increasing the durability of the earth blocks. Alternatively, burnt blocks can be used instead of sun-dried blocks.

V.CONCLUSION

Earth blocks can be a viable alternative to conventional bricks and reinforcing the earth blocks further improves its properties as a building material. Jute fibres and Banana fibres were used to improve the properties of the earth blocks. The results of the study show that Jute fibres improve the properties of the earth blocks in all cases of physical, mechanical and durability.

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