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Research paper

Physical, Mechanical and Durability Properties of Soil Building Blocks Reinforced with Synthetic Fibre

S. Selsiadevi[1], Evangelin Ramani Sujatha[2]

[1]School of Civil Engineering, SASTRA Deemed University, Thanjavur, Tamilnadu, India.
**Corresponding Author Email: [2]r.evangelin@gmail.com*

Abstract

Earth construction is the most economic way to solve housing problems, particularly in case of low cost building, with the limitation of resources. The simplicity in production of earth blocks justifies by the availability of soil as raw material and by the less energy in production. Generally, fibre inclusion increases the strength and performance of the earth blocks. Synthetic fibre such as AR glass fibre, polypropylene fibre were used and investigated experimentally with different percentages of fibre 0.25 %, 0.50 %, 0.75 % and 1 % by weight of earth. A sequence of test was conducted with and without addition of fibre to soil building blocks. Physical properties, mechanical properties and durability properties specifically density test, water absorption by capillarity test, linear shrinkage, compressive test, indirect tensile stress, 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.

1. Introduction

The oldest building material in the world is earth/soil, but its use as a building material was suppressed with the discovery of recent building materials like concrete, steel and reinforced bricks. Earth as a building material has numerous advantages, such as cost, less impact on environment and easy availability. Construction using earth is still common practice especially in regions with suitable climatic conditions. 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 cost effective building materials. Soil building blocks reinforced with agricultural waste are the most common alternate building material that have resulted in environmentally and economically sustainable options. Fibres such as coconut coir, bagasse, and oil palm fibre [4] of different aspect ratio were used for reinforcing the earth blocks. Several other agricultural waste fibres such as jute, 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] have also been studied to improve the performance of 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. But still there is a large lacuna in the application of the reinforced earth blocks from theory to practice. Similarly the study on the choice of synthetic fibres as reinforcement in soil building blocks is also limited. An attempt has therefore been made to study the physical, mechanical and durability properties of earth blocks reinforced with two synthetic fibres, namely alkali resistant (AR) glass fibres and polypropylene fibres. Various percentages of the selected fibres were used to assess the effect of fibre reinforcement in soil blocks.

2. Materials

The soil to make reinforced earth blocks was obtained from Kallaperambur, Thanjavur district. The soil is low plastic in nature with negligible organic content. The properties of the soil used to make the soil blocks are listed in (Table 1).

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

AR glass fibre and polypropylene fibres are used as reinforcement. The properties of AR glass fibres and polypropylene fibres [16] are such that, AR glass fibre has a high zirconia content, which makes it alkali resistant and also has a modulus of elasticity adequate to absorb shrinkage stresses before cracks are formed. They have high tensile strength with no health hazards. Polypropylene fibres increase ductility, promote low water absorption, provide high impact resistance and toughness and are inert to chemical reaction. The fibre specification indicating length, diameter is shown in (Table 2).

3. Methods

Physical, mechanical and durability properties of soil building blocks were tested by a compressive experimental programmed that includes the following tests - density, water absorption by capillarity, linear shrinkage, compressive strength, indirect tensile stress, wearing and erosion. Different fibre percentages were used in the study to arrive at the optimum percentage of fibre inclusion.

Preparation of Blocks

Soil building blocks of size 215 mm x 105 mm x 65 mm were prepared by using AR glass fibre and polypropylene fibre as reinforcement with the different mix ratio of 0.1 %, 0.25 %, 0.5 %, 0.75 % and 1 % by weight. Blocks were made by hand pressing the earth/soil with optimum moisture content (Table 1). Homogeneous mixture of fibre and soil was obtained by continuous repeated mixing of fibre with soil. Prepared blocks were sun dried for over 21 days at average temperature of 25^0 C-30^0 C. In case of high temperature, blocks can be covered by using plastic sheets or by banana leaf to maintain the humidity. The blocks were dusted before testing.

Physical Properties

Physical properties such as linear shrinkage, water absorption and density were compared. The dimension of each block was measured and weighed as prescribed by BS EN 771-1 [17]. The weight and volume measure was used to calculate the density. Water absorption test was performed by capillarity method. In accordance with BS EN 772-11 [18], the blocks were oven dried to obtain constant mass representing a normal dried block. Blocks from each mix ratio were placed on a 5 mm water bath facing the 215 mm x 105 mm side of the block for 10 minutes. Mass of each block before and after absorption was determined to find the percentage of water absorption by capillarity. Linear shrinkage measured the change in dimensions of reinforced soil building blocks before and after drying of the specimen.

Table 2: Properties of Reinforcing Fibres

Fibre	AR glass fibre	Polypropylene fibre
Length (mm)	12	12
Diameter (mm)	0.05	0.15
Tensile strength (Mpa)	330 – 414	316 – 328

Mechanical Properties

Compressive strength and tensile strength of the reinforced soil blocks were studied. The compressive strength of the samples was tested according to BS EN 772-1 [19]. The blocks were loaded till they failed and the corresponding ultimate load was recorded. The maximum compressive stress was calculated at the failure load. Indirect tensile stress [20] was calculated using the relation.

Tensile Stress = $0.648\ P/dl$ (1)

Where P=force (N), d= equivalent diameter (mm), l=length of the specimen (mm).

Durability Properties

Durability of the reinforced earth blocks were assessed using their rate of wearing and erosion. Wearing test was performed in accordance with the procedure outlined in ASTM D559-03 [21]. The blocks were soaked in a water bath for 2 minutes and then allowed to oven dry for a period of 24 hours at an average temperature of 100^0 C -120^0 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 a vertical wire brush and the corresponding percentage of wearing was calculated. Erosion test on the soil blocks was conducted according to NZS 4298 [22]. The test apparatus consisted of a plastic bath and shower head at a distance of 175 mm from the shield. Depth of the eroded area (mm) per minute of each soil building block was recorded and the rate of erosion was calculated.

4. Results and Discussion

The results of the experimental investigation on the physical, mechanical and durability properties of different percentages of AR glass fibre and polypropylene fibre reinforced soil blocks, denoted as ARGREB and PPREB are discussed below.

Physical Properties

Fibre reinforcement improves the physical properties of the reinforced soil blocks. The results indicate that the performance of polypropylene fibres is better than that of AR glass fibres.

Density

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 PPREB are lighter than ARGREB, which is due to lesser specific weight of polypropylene fibres. At 1 % fibre replacement, there is a decrease of nearly 11 % and 16 % in the density of ARGREB and PPREB respectively.

Table 3: Density of Fibre Reinforced Earth Blocks

Fibre Addition (%)	0	0.25	0.5	0.75	1
Density – ARGREB (kg/m^3)	2040.60	1865.29	1864.89	1854.97	1810.50
Density – PPREB (kg/m^3)	2040.60	1812.12	1805.38	1715.72	1710.19

Water Absorption

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. But, with the addition of AR glass fibre and polypropylene fibre water absorption decreases with increase in fibre content upto 0.75 % fibre inclusion and beyond that there is a slight increase in water absorption at 1 % (Fig.1). 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.

Linear Shrinkage

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. (Fig.1) 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 PPREB than for ARGREB. 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.

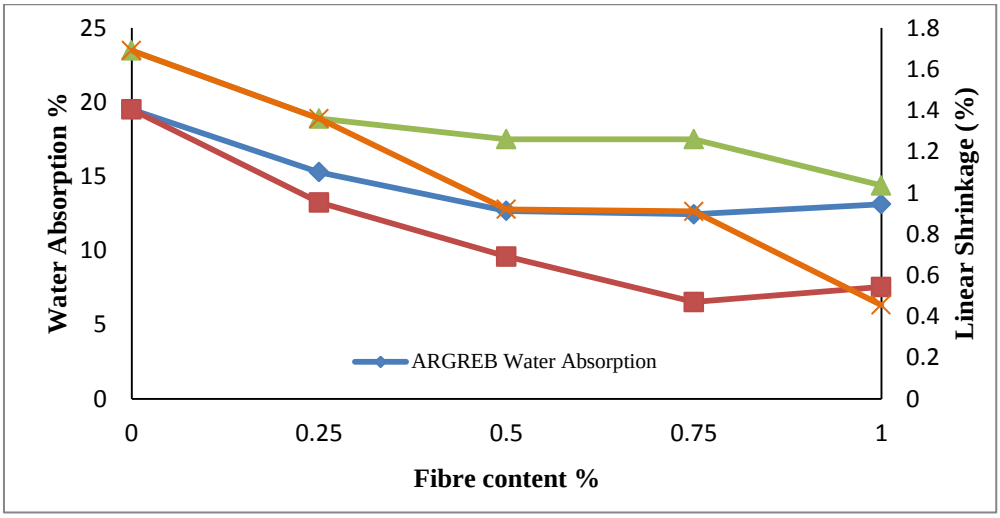

Fig. 1: Linear Shrinkage and Water Absorption of Fibre Reinforced Earth Blocks

Mechanical Properties

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.

Compressive Strength

Inclusion of AR glass fibre causes a decrease in the compressive strength of the earth blocks. There is a considerable decrease, of nearly 32 % at 0.25 % AR glass fibre inclusion in the compressive strength of ARGREB. The decrease can be attributed to the lack of frictional contact between the glass fibres and the soil due to the smoothened surface of the fibres. The fibres may also show a tendency to ball or clump reducing the compressive strength of the soil block. PPREB shows an increase in compressive strength with the increase in fibre content for all investigated percentages of fibre inclusion. Nearly 65 % increase in the compressive strength is observed at 1 % polypropylene 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 PPREB.

Tensile Strength

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 ARGREB is lower than that of the unreinforced earth block and the behaviour is similar to that of the one observed in compressive strength. But in case of polypropylene fibre reinforced earth blocks, tensile strength increases with the increase in fibre content. The observations on the results of the mechanical properties of reinforced earth block shows that polypropylene fibres are a better option over the AR glass fibres

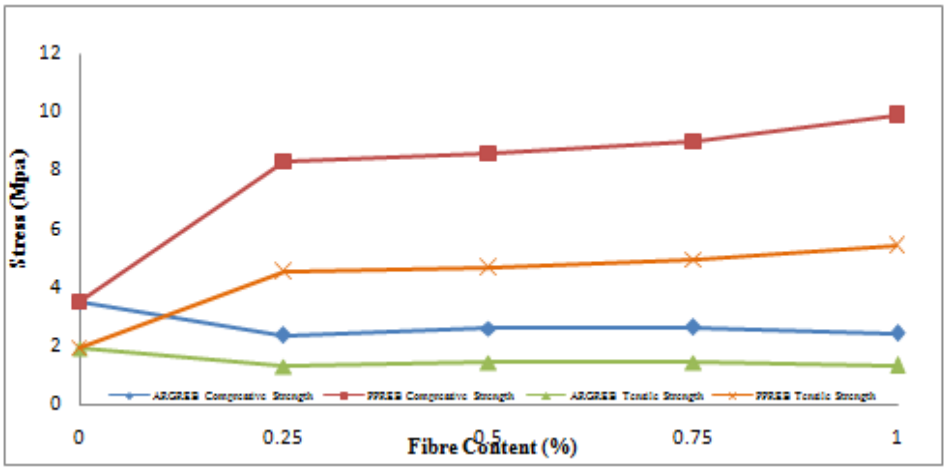

Fig. 2: Compressive and Tensile Strength of Reinforced Earth Blocks

Durability

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 – AR glass fibre and polypropylene 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.

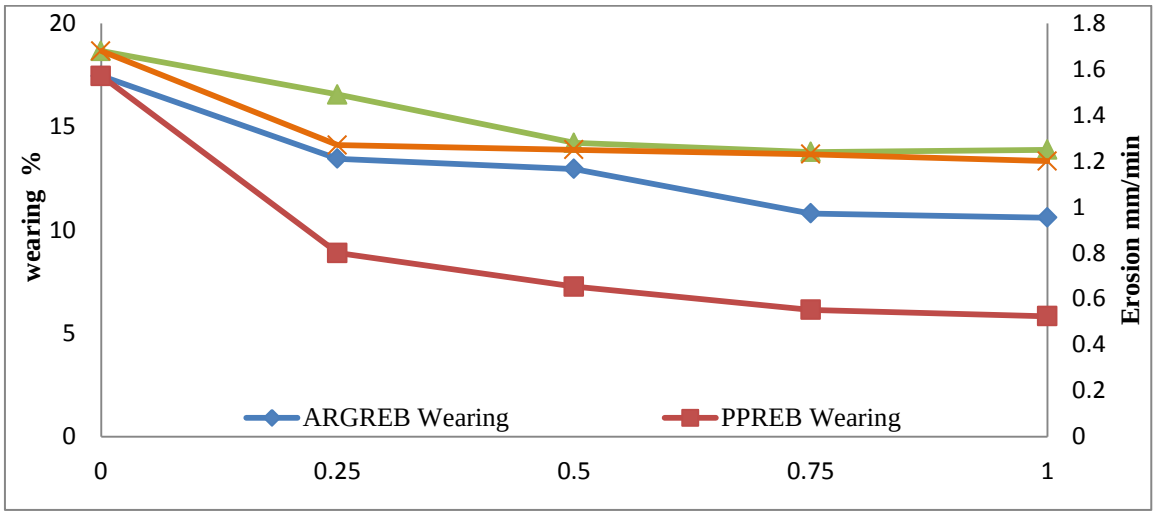

Fig. 3: Durability Properties of Reinforced Earth Blocks

5. Conclusion

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

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