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STABILIZED LATERITIC BLOCKS REINFORCED WITH FIBROUS COIR WASTES

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Abstract

Tropical countries are rich in lateritic soil, a naturally available raw material for building construction. But its potential in block making is not yet satisfactorily explored. This paper focuses on an experimental investigation for improvising stabilized lateritic blocks (SLB) with coir cutting wastes from coir industry as reinforcing elements. Lateritic soil used in this study showed a higher percentage of clay content. Hence it was pre-stabilized with sand and cement. Blocks were prepared by stabilizing it further with waste fibrous additives and tested for strength and durability. Considerable improvement in strength (compressive strength @19% and tensile strength @ 9%) and durability characteristics were exhibited by the new fiber reinforced lateritic blocks (FRLB) with fiber content of 0.5%. These blocks can be successfully proposed for load bearing construction and as well as for earthquake resistant structures.

Keywords: *Fiber reinforced lateritic blocks, Strength and durability study, Fibrous coir wastes*

1.0 Introduction

Sustainable building materials are highly in demand today. Locally available soil is used for stabilized earthen block (SEB) construction. Manufacturing of these blocks are easy, economical and has got a comparable strength equivalent to that of conventional fired bricks [1]. Fibrous material addition as a reinforcing element of SEB is one of the promising outcomes of ongoing researches.

Kerala state in India produces 60% of the total world supply of white coir fiber [2].This industry produces fibrous wastes during the processing. Even though coir waste is biodegradable, the rate of degradation is very slow due to high lignin content. Accumulations of these waste materials are causing serious environmental issues. Utilization of fibrous coir wastes is explored in the production of SEBs made from copiously available lateritic soil in Kerala.

The main objective of the work is to analyze the characteristics of stabilized lateritic soil block and investigate the possibility of enhancing its strength and durability by reinforcing with degradable fibrous waste material.

2.0 Literature Review

Stabilization methods of earthen blocks mainly depend on the type of the soil. Walker suggested basic guide lines for cement stabilizations and recommended 5-10% cement stabilization for manual pressing to achieve a saturated compressive strength in the range of 1-3 N/mm^2 [3]. During the last decades, the use of fibers as admixtures either to complement or replace wood has grown exponentially due to economic, environmental and political reasons. The use of coconut fibers as admixtures in soil- cement blocks showed a reduction in the thermal conductivity and weight of soil- cement blocks with a lowered compressive strength [4].

Earlier studies on the inclusion of coconut and sisal fibers in soil blocks with a fiber content of 4% by weight showed a reduction in the occurrence of visible cracks and gave highly ductile blocks [5]. The performance of composite soil reinforced with barley straw showed a positive effect of decreasing shrinkage with straw inclusion, enhancing compressive strength and a reduction in the curing time [6]. Fiber reinforcement of mud blocks with plastic, polystyrene and barley straw in certain geometric fashion exhibited 17 to 21% compressive strength improvement [7].

A review on the existing literature shows that, only limited studies were undertaken to optimize the utilization of coir fiber wastes as reinforcing elements in soil cement blocks with respect to strength and durability characteristics. Coir industry, the largest cottage industry in the State of Kerala in India provides employment to over a million people. But waste materials from this industry add to serious public health hazards in the surrounding environment due to the slow rate of biological degradation. This research hence focused on the sustainable disposal of coir fiber wastes as reinforcing elements in earthen building blocks.

3.0 Methodology of Research

This research focuses on an experimental investigation for improvising stabilized lateritic blocks (SLB) with coir cutting wastes as reinforcing elements. Lateritic reference blocks were prepared from locally collected soil samples stabilized with sand and cement. Fiber reinforced lateritic blocks (FRLB) were prepared by stabilizing SLB further with waste coir fibers in different proportion and tested for strength and durability. A detailed explanation of this experimental program is given in the following sections.

3.1 Material Characterization

The materials used in this study for the production of FRLB and their basic properties are illustrated below:

3.1.1 Lateritic Soil

Locally collected (Aluva, Kerala) soil samples were sieved through 4.75 mm IS sieve. The properties are tabulated in Table 1.

Table 1: Properties of lateritic soil

Properties	
Color	Often red
Specific gravity	2.55
Liquid limit (%)	58
Plastic limit (%)	35
Shrinkage limit (%)	19.79
Plasticity Index (%)	23
pH value	4.73
Clay (%)	27.6
Silt (%)	6.9
Fine sand (%)	22.5
Medium sand (%)	25
Corse sand (%)	18
Dry density (gm/cc)	1.64
Optimum moisture content	21

3.1.2 Sand

River sand passing through 2 mm IS sieve and retained on 425 micron sieve was used for this study.

3.1.3 Cement

Portland pozzolana cement under commercial name UltraTech was used.

3.1.4 Fibrous waste additives

Coir fiber wastes (CF) were collected from a coir mat industry at Alappuzha, Kerala. In this study fiber length between 20-40 mm was used. The physical and chemical properties of waste fiber are tabulated in Table 2.

Table 2: Physical and chemical properties of coir cutting waste

Physical		**Chemical**	
Diameter	0.32 mm	Lignin	39.62 %
Density	1.35 g/cc	Cellulose	22.99 %
Tenacity	14.85	Ash	2.99 %
Breaking elongation	26.53 %	Pectin	2.40 %
Swelling in water	88.35 %		

3.2 Manufacture of block specimens

Two types of block specimens were prepared. SLB as reference blocks and FRLB with coir cutting wastes as reinforcing elements.

Reference blocks (190mmx110mmx100 mm) were designated as Sx C8, where 'x' indicates the percentage of sand. Sand stabilization was selected as10%, 20 %and 25%. C8 refers to 8% cement stabilization. Cement stabilizer was fixed as 8% by weight for this study as per Reddy B.V et al [8].The soil sand mixtures were tested for compaction as per IS 2720 part 7 and Optimum moisture content (O.M.C) was found out [9]. Lateritic soil and sand were weighed and mixed according to the desired ratio in dry state to get a homogeneous mix. To this cement stabilizer was added in the required proportion and mixed well. Water (OMC) was added to this homogeneous mix and further mixed thoroughly until obtain a uniform consistency. Blocks of different designations were prepared in block making machine (ASTRAM) developed by Indian Institute of Science, Bangalore, India. Prepared blocks were stacked in a level platform and cured for 28 days under wet gunny bags. The wet compressive strength of and water absorption of these blocks were measured as per IS: 1725 – 1982 guidelines [10]. Bulk density and dry density of samples were also found out. The designation of the samples and test results are tabulated in Table 3. Block designated as S25 C8 was found to comply with relevant standards and accepted as the reference block.

Table 3: Designation and test results of reference blocks

Designation	Mix proportion by weight (%) (Soil : Sand : Cement)	Water in % as per O.M.C	Bulk density in g/cc	Dry density in g/cc	Wet Compressive strength in MPa		Water absorption in %
					7 days	28 days	
$S_{10} C_8$	90 : 10 : 8	19	2.05	1.73	2.08	2.41	14.16
$S_{20} C_8$	80 : 20 : 8	18.25	2.06	1.77	2.09	2.92	14.14
$S_{25} C_8$	75 : 25 : 8	17.75	2.06	1.75	2.12	3.60	14.13

The preparation of FRLB consists of mixing of coir waste fiber with soil-sand -cement matrix in the three different proportions (0.50, 1.00% and 1.50%) as shown in Table 4. The mixing, molding, compacting as well as curing processes were same as that of reference block preparation.

Table 4: Mix Designation of fiber reinforced blocks

Designation	Mix proportion by weight (%) soil : sand : cement: fiber
$CF_{0.5}$	$S_{25}C_8 + 0.5$ %
CF_1	$S_{25}C_8 + 1$ %
$CF_{1.5}$	$S_{25}C_8 + 1.5$ %

3.3 Laboratory Tests

Fiber stabilized lateritic blocks were subjected to different strength and durability tests. Bulk density, dry density, wet compressive strength (7 days and 28 days) and tensile splitting strength for the strength characterization were performed. Water absorption, Alternate wetting and drying test and spray test were conducted for durability characteristics.

3.3.1 Bulk and dry density

Bulk and dry density tests were carried out as per IS: 2720 (Part VII) -1980. The bulk density, γ_m in g/cc is calculated using following equation.

$$\gamma_m = m/Vm$$

Where m = mass in gm of block and

Vm=Volume of the block in cc

3.3.2 Wet compressive strength

These tests were carried out according to the IS: 1725 – 1982 (Reaffirmed 1997). Specimens were immersed in clean water for 72 hours prior testing, taken out, wiped dry and tested in a universal testing machine. Axial load was applied centrally on each specimen at a uniform rate (14 N/mm^2) up to failure after placing it in the machine between packing sheets (ply woods of thickness 3mm at top and bottom). Failure load was noted and compressive strength was calculated based on average bed face area.

3.3.3 Tensile splitting strength

The test was carried out in accordance with IS 15658: 2006 [11]. Three samples at the age of 28 days were tested and average is reported. Completely cured specimen were immersed in water for 24 hours, taken out, wiped dry and placed on the universal testing machine with packing pieces on upper face and bed face. The load was smoothly and progressively applied at a rate which corresponding to an increase in stresses of 0.05 ± 0.01 MPa. The failure load was recorded in N, to the nearest 0.01 N.

3.3.4 Water Absorption test

This test was carried out according to the IS: 1725 – 1982 (Reaffirmed 1997). In this test five specimens of each combination were dried in a ventilated oven at a temperature of 105 to 115˚C till attain constant mass and noted it's mass. Completely dried blocks were then immersed in clean water for 24 hours and noted the new mass. The average difference of masses was expressed in percentage.

3.3.5 Alternate wetting and drying

This test was carried out according to ASTM D 559-03 standards [12]. Test consists of immersing the blocks in water for a period of 5hours and then oven drying (at 71˚C) for a period of 42 hours. The procedure is repeated for 12 cycles; samples were brushed after every cycle to remove the fragment of the material affected by the wetting and drying cycles. For every sample, the variation in weight was computed after 12 cycles.

3.3.6 Weathering test – Spray test

This test was carried according to the specifications of IS: 1725 – 1982. The block to be tested was mounted on a test ring in such a way as to expose any one of the faces to a shower (10 cm diameter with 36 holes of 2 mm diameter each) having a pressure of 1.50 ± 0.2 kgf/cm^2 for a period of 2 hours. The shower should be placed at a distance of 18 cm from the block. The exposed surface was examined for possible pitting.

4.0 Results and discussion

Results of different experiments conducted are presented in table 5.

Table 5: Average measured Strength properties of the fiber reinforced blocks

Designation	Bulk density (g/cc)	Dry density (g/cc)	Wet compressive strength (MPa)		Tensile splitting strength	
			7 days	28days	Spilt tensile strength (MPa)	Failure load per Length (N/mm)
$S_{25}C_{8\,(SLB)}$	2.06	1.75	2.12	3.6	0.34	52.28
$CF_{0.5}$	2.11	1.79	2.43	4.28	0.37	57.89
CF_1	2.01	1.71	2.23	3.31	0.26	40.53
$CF_{1.5}$	1.86	1.58	2.14	3.01	0.21	33.16

4.1 Bulk density

The effect of coir fiber wastes on bulk density of blocks is shown in Fig. 1. An increase in bulk density was observed for the blocks stabilized with 0.5% coir cutting wastes. The bulk density was found decreasing on increasing the percentage of CF beyond 0.5%. The replacement of soil-cement (dense material) matrix by coir fiber wastes (light material) resulted in the increase in the total volume of mix. This increases in volume of compacted mix resulted in a decrease in weight and density of the specimens [4].

4.2 Compressive strength

This study showed an improvement in the compressive strength of fiber stabilized blocks in the range of 3.01-4.28 N/mm^2. Stabilization of blocks reinforced with coir cutting wastes @ 0.50 % showed an improvement of 19% over reference block. But the compressive strength was found decreasing with the further additions of fibrous material as shown in figure 2. This is in concordance with previous research by Yetgin et al. [13], which observed that for normal adobe mixture, the fiber content should be restricted at about 0.5% by weight.

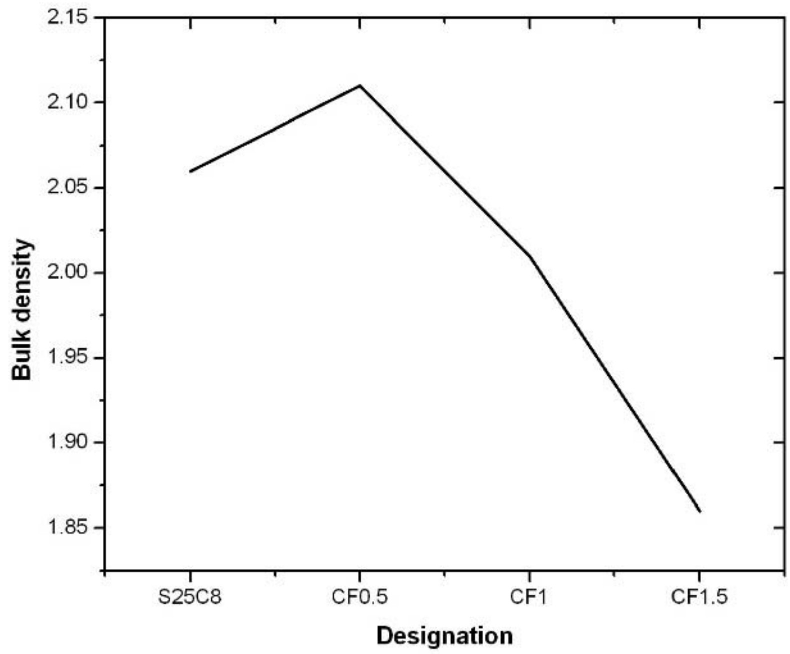

Figure 1: Variation in Bulk density with respect to percentage of CF

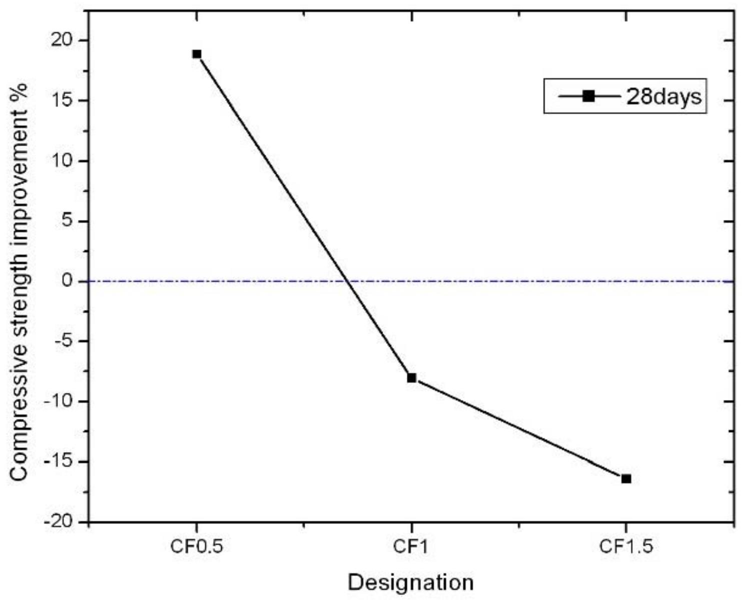

Figure 2: Compressive strength improvement of FRLB over reference blocks

4.2.1 Compressive strength Failure pattern

Fig. 3 shows the failure pattern of SLB & FRLB. Reference block without fiber showed a sudden and brittle failure pattern where as blocks stabilized with coir fiber wastes exhibited a ductile pattern. The ductility was found increasing with increase in fiber content. Fibers increase the cohesion among soil particle as well as the interaction of the fibers among themselves. The improved fiber flexibility makes them behave as a structural mesh and hold the soil together [14]. Hence, fiber reinforced mud bricks can store more elastic energy compared to other mud brick types, making it more suitable to earthquake resistant structures.

(a) SLB (b) FRLB

Figure 3: Compressive strength failure pattern.

4.3 Tensile strength

Tensile strength improvement of 9% over reference block has been observed for blocks stabilized with coir fibers @ 0.50%. The details are illustrated in figure 4. The tensile strength was also found decreasing with further increase in fiber content.

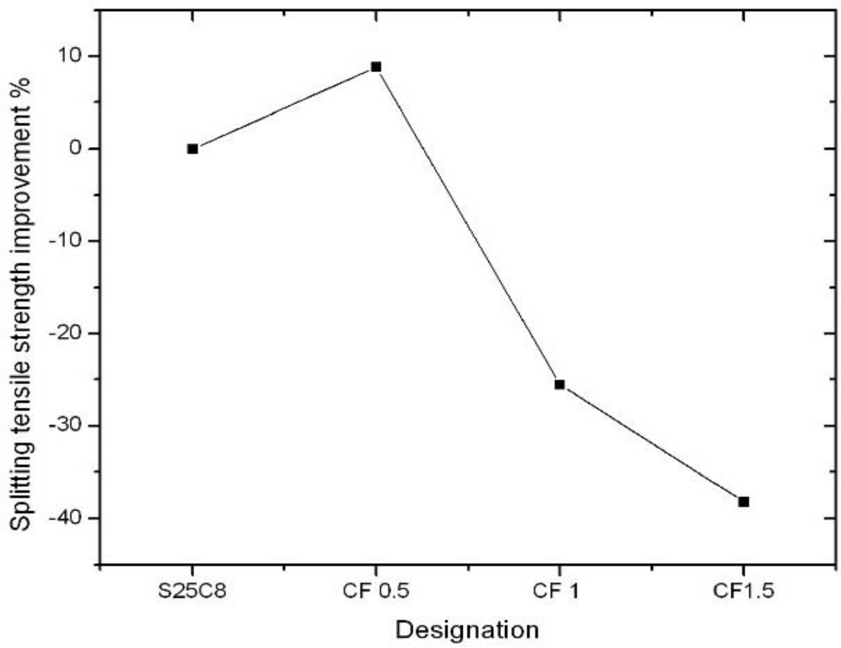

Figure 4: Tensile strength improvement of FRLB over reference block.

The compressive and tensile strength of FRLB depends on the formation and bonding of fiber-soil matrix. The bonding can be affected by dimensions, surface conditions and number of fiber present in the given volume of material. Therefore, the increase in coconut fiber content resulted in a decrease in bond strength of the specimens, leading to lower strength [4].

4.4 Durability studies

Table 6 presents the results of different durability studies conducted on the samples.

Table 6: Durability Test Results

Designation	Water absorption %	Spray test	Alternate wetting and drying
		Diameter of pit (mm)	Mass loss (%)
$S_{25}C_8$	14.13	Nil	2.57
$CF_{0.5}$	14.17	Nil	2.52
CF_1	20.46	Nil	6.02
$CF_{1.5}$	24.32	Nil	7.27

4.4.1 Effect of fiber on Water Absorption

Blocks stabilized with coir fiber waste @ 0.5% showed comparatively lower water absorption with respect to other combinations as illustrated in fig 5 and was found within the limit (15%) specified by Indian standard (IS: 1725 – 1982). The higher water absorption rates of blocks stabilized with coir fibers beyond 0.5 percentage can be explained by the hydrophilic nature of fibers. On increasing the percentage of fibers in mix might lead to the disruption of homogeneous matrix resulting in void spaces and lower block densities. Whereas blocks with lower fiber content resulted in higher density blocks due to homogeneity of the matrix.

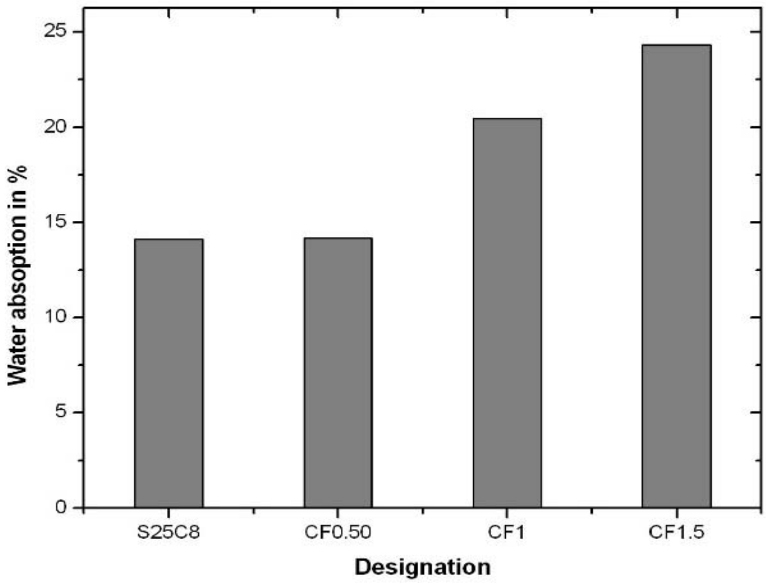

Figure 5: Water absorption of FRLB

4.4.2 Alternate wetting and drying

Fig. 6 shows the variation in mass loss of blocks with different percentage of coir cutting waste reinforcement after alternate wetting and drying test.

Fitzmaurice (1958) set out guidelines for maximum weight loss and suggested that the weight loss should be less than 5 % for permanent buildings and can have a higher values of 10 % for rural buildings in any climate [15]. According to Fitzmaurice's guidelines, CF 0.5 combination can withstands all types of climate. Other combination with higher percentage of fiber reinforcement showed a mass loss between 5% and 10 %.

According to Guettala et al. the weight loss was restricted as 10% for blocks in the regions with annual rain fall less than 500 mm [16].

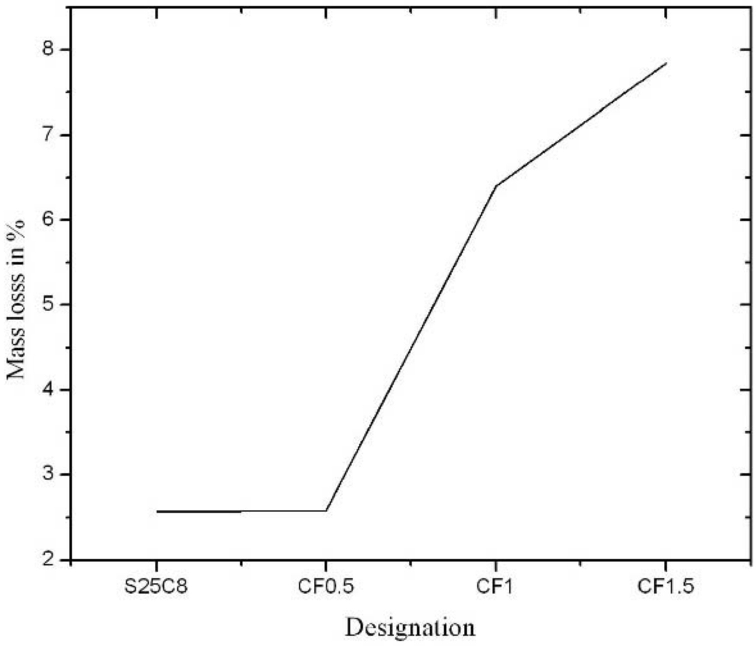

Figure 6: Mass loss of FRLB

4.4.3 Weathering test – Spray test

No pit formation and mass loss was found for blocks stabilized with coir fiber waste. As per Indian standard: IS: 1725 – 1982 the maximum permissible diameter of the pit formed after this test should be within 10 mm for satisfactory performance. FRLB has thus showed an improved performance against weathering.

5.0 Conclusions

Considerable improvement in the strength and durability characteristics were exhibited by fiber reinforced lateritic blocks on comparing with stabilized lateritic blocks without fibers. Following conclusions were arrived from the research:

5.1 Strength characteristics

- **Compressive strength:** 19% improvement was observed for the compressive strength of blocks stabilized with fibrous coir wastes @0.5%.
- **Tensile strength:** An improvement of 9% was reported on tensile strength.
- The compressive strength and tensile strength was found decreasing with the increases of the fiber content beyond 0.5%.
- **Ductility:** Fibrous material addition improves ductility of the blocks making it suitable for earth quake resistant construction

5.2 Durability characteristics

Results showed improved durability characteristics of FRLB with 0.5% fiber content compared with reference blocks. Other combinations showed higher percentage of water absorption and mass loss. But they can be proposed for internal wall construction considering its elastic property and strength characteristics.

This research has proved that fiber reinforced lateritic blocks from coir cutting wastes can be successfully proposed for load bearing structures and earthquake resistant constructions with the improved strength and durability characteristics.

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