https://doi.org/10.36375/prepare_u.iei.a141

Feasibility of Plastic waste as Reinforcement in the Mechanical Properties of Stabilized Lateritic Soil Blocks

M.G. Sreekumar and Deepa G Nair

Department of Civil Engineering

(School of Engineering, Cochin University of Science and Technology, Kochi, Kerala, India, 682022)

{Corresponding author's email: sreekuair@cusat.ac.in}

Abstract - The popularity of earthen construction increases nowadays due to its sustainability features. Stabilized earthen blocks are much accepted as an alternative building material from earthen building products against energy-intensive conventional building blocks. The mechanical properties of stabilized earthen blocks can be further improved by the inclusion of waste materials. This study aimed to check the feasibility of using polypropylene and polythene plastic waste in stabilized masonry blocks manufacturing using locally available lateritic soil. Soil samples from two nearby locations and depths were collected and used in this study. An initial study conducted by manufacturing stabilized lateritic block specimens were made out of these samples with different mix proportions and tested. The optimized specimens based on strength were selected for further investigations using plastic wastes. Prospective results were obtained by this study. Both the plastic wastes inclusion showed enhanced strength and durability properties. The improvement can be much pronounced for polypropylene waste inclusion.

Keywords - Stabilized earthen blocks; Lateritic soil; Polypropylene waste; Polyethylene waste; Weathering test.

INTRODUCTION

Earthen construction is one of the oldest construction techniques used to fulfill the housing demands of millions of people throughout the world [1,2]. The different techniques and methods practicing in earthen construction are adobe, rammed earth, cob, wattle, and daub, etc. Compressed stabilized earthen masonry building block (CSEB) is the refined form of the adobe building blocks. The technique adopted in CSEB is the modification of properties of a selected soil sample by adding another material (stabilizer) and compressing using a manual or mechanical press [3]. The stabilized earthen blocks consume less energy and proved to be an alternative to conventional building blocks from burnt bricks and concrete blocks [4]. The engineering properties of the stabilized blocks can be further improved by the introduction of fibrous material as reinforcement in stabilized soil building blocks [5-7].

The popularity of earthen construction increases nowadays due to its sustainability features. The sustainability aspects of earthen construction rely on the use of locally available resources such as material and labor. Laterite soil is abundantly available in India but the potential of this resource is not properly explored for masonry building blocks. Accumulation of unmanaged industrial or agricultural solid waste in developing countries has resulted in an increased environmental concern. Recycling such wastes as a sustainable construction material appears to be a viable solution not only to the pollution problem but also an economical option to design green buildings [8].

This research aims to utilize the locally available lateritic soil as source material for making masonry building blocks and to check the feasibility of plastic waste as a reinforcement element for improving its mechanical properties

MATERIALS AND METHODS

Lateritic soils from two nearby locations in Cochin (Kerala, India) were collected and subjected to characterization studies. Stabilized lateritic block specimens were made out of these samples with different mix proportions and tested. The optimized specimens based on strength were selected for further investigations using plastic wastes. Details of experimental programs are illustrated in the following sections.

Materials

Lateritic soil (source material), quarry waste cement, and lime (stabilizers) were used. Properties of the materials are detailed below.

A. Lateritic Soil

Two different lateritic soil samples were collected from nearby locations in Kalamassery, Kerala, India, and designated as S2 and S4. The S2 sample was collected from an average depth of 1.50m and S4 from an average depth of 4.50m. The samples were sieved through a 4.75 mm sieve. The properties of soil samples are tabulated in Table 1.

B. Quarry waste

Quarry waste passing through a 2 mm IS sieve and retaining on a 425 micron IS sieve was used for modifying the gradation of soil samples as an initial stabilizer.

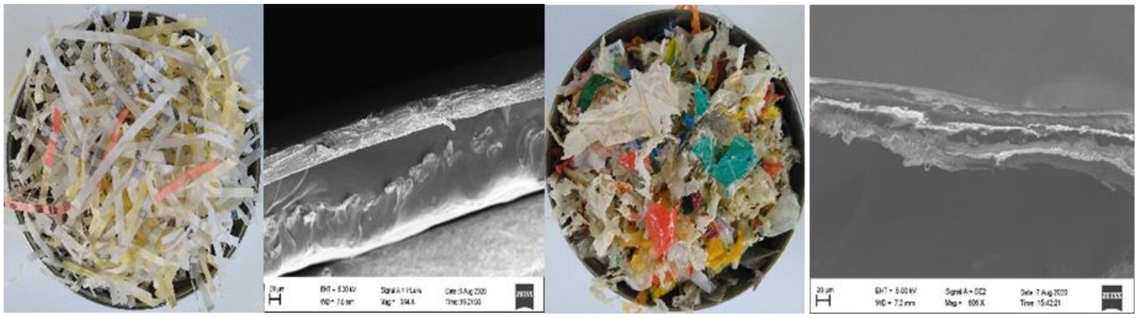
C. Cement and lime

Commercially available53 grade ordinary Portland cement and locally available shell lime were used as stabilizers.

D. Plastic Waste

Two types of plastic waste were tried in this research (polypropylene and polyethylene). Shredded polyethylene plastic with an average length of 40 mm from the municipal waste processing plant was used as one type of plastic waste. Polypropylene waste material was taken from the waste of

https://doi.org/10.36375/prepare_u.iei.a141



a) Polypropylene waste (PP)   (b) Polyethylene waste(PE)

Fig.1. Optical and SEM images of plastic waste additive material

discarded cement bags dumped in construction sites, cleaned, and used as another type of plastic waste. The woven layers of the bags were cut to an average length of 40 mm and were used. The physical and chemical properties of these waste additives are presented in Table 2 and illustrated in Figure 1.

Table.1. Physical properties of soil samples

Properties	**S2**	**S4**
Color	Often red	Blush
Specific gravity	2.42	2.58
Liquid limit (%)	60	55
Plastic limit (%)	30	34
Shrinkage limit (%)	29	32
Plasticity Index (%)	30	21
pH value	4.49	4.22
Clay (%)	23	21
Silt (%)	15	20
Fine sand (%)	14	8
Medium sand (%)	32	34
Corse sand (%)	16	17
Dry density (gm/cc)	1.64	1.67
Optimum moisture content	21	20

Table 2. Properties of plastic waste materials

Material	Melting point	Ash content	Width (mm)	Thicknes s (mm)	Polymer identified
Cement bag waste (PP)	164 - 167	9	2.57	0.04	Polypropylene
Shredded plastic (PE)	109 - 115	15	Not uniform	0.02 – 0.06	Polyethylene

Specimen preparation and testing

Studies were conducted in two phases. In the first stage masonry block specimens of size 190mmx110mmx100 mm were prepared using the ASTRAM manual press developed by the Indian Institute of Science, Bangalore, India. In this stage, specimens were prepared with varying mix proportions of lateritic soil and quarry dust (0 -25%) in combination with cement and lime. Stabilizers, by weight of soil, were mixed thoroughly in a dry state until a homogeneous mix is obtained. Required water content based on the OMC of the soil sample was added to this mix and mixed thoroughly for uniform consistency. The dosage of cement (8%, lime 4%) was fixed based on earlier studies [9-12]. The measured quantities of the mix were transferred to the manual press and compacted. Prepared blocks were stacked in a level platform for 24 hours for ambient curing and then cured under wet gunny bags for 28 days.

The specimens were tested for compressive strength and water absorption. Specimens prepared using the S2 soil sample showed maximum strength with 80% soil and 20% quarry waste. Whereas the S4 soil sample showed maximum strength without modification of its gradation among all combinations tried. The maximum strength gained specimens from each soil sample were selected for further study with the addition of plastic wastes. The designation and mix proportion of reference specimens are tabulated in Table 3.

In the second phase, 0.50% of plastic wastes (PP and PE) corresponding to the total mass of the soil was selected as the dosage based on the results of an earlier study [13]. Plastic waste reinforced masonry blocks specimens were prepared for further investigation**.** Table 3 presents the designations and mix proportions.

Table 3. Mix Designation of stabilized lateritic blocks

Soil type	Designation	Mix proportion by weight (%) (soil: quarry dust : cement: lime: plastic waste)	Type of plastic waste
S2	S_2R	80 : 20 : 8: 4	Nil
S4	S_4R	100 : 0 : 8: 4	Nil
S2	S_2PP	80 : 20 : 8: 4 : 0.50	Polypropylene
S2	S_2PE	80 : 20 : 8: 4 : 0.50	Polyethylene
S4	S_4PP	100 : 0 : 8: 4 : 0.50	Polypropylene
S4	S_4PE	100 : 0 : 8: 4 : 0.50	Polyethylene

https://doi.org/10.36375/prepare_u.iei.a141

LABORATORY TESTS

Stabilized lateritic blocks were subjected to different strength and durability tests as discussed in the succeeding sections.

A. Density

Dry density tests were carried out as per IS: 1725 -2013 [13].

B. Wet compressive strength

These tests were carried out according to the IS:3495 (Part I) [14]. Specimens were immersed in clean water for 72 hours before 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 (plywood of thickness 3mm at top and bottom). Failure load was noted and compressive strength was calculated based on the average bed face area.

C. Tensile splitting strength

The test was carried out as per IS 15658: 2006 [15]. Three samples at the age of 28 days were tested and an average is reported. Completely cured specimens were immersed in water for 24 hours, taken out, wiped dry, and placed on the universal testing machine with packing pieces on the upper face and bed face. The load was smoothly and progressively applied at a rate 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.

D. Water Absorption test

This test was carried out according to the IS:3495 (Part II) [16]. 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 their 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.

E. Weathering

This test was carried out according to IS 1725:2013 [13]. The test consists of dry the specimens in the oven at 60 ± 5˚ C till they attain constant weight immersing the blocks in water for a period of 5hours and then oven drying at 70± 5˚C for 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. After completion of 12 cycles dry the specimen at 60 ± 5˚ C till they attain constant weight. For every sample, the variation in weight was computed after 12 cycles and the average percentage weight loss of specimens was reported.

RESULTS AND DISCUSSION

The results of different experiments conducted are presented in **Table 4**. The significance of plastic waste on the strength and durability characteristics of stabilized lateritic masonry blocks are discussed based on their results.

Strength Characteristics

The density of the blocks was verified before and after reinforcing with plastic waste. are tabulated in **Table 4**. A slight improvement was observed corresponding to the reference block of each soil type.

The compressive strength of the reference blocks made from the S4 soil sample showed much higher strength than the S2 soil sample. This may be due to the chemical and mineralogical variation in lateritic soil along with the depth of extraction however this may be verified with more samples with varying depth. The compressive strength of both the samples further improved after adding the plastic waste as reinforcement. The details are illustrated in Figure 2. The improvement in strength over the reference blocks of each soil sample is illustrated in Figure 3. PP waste added specimens showed much higher compressive strength than PE waste. The improvement is more significant for the S4 soil sample with the PP waste.

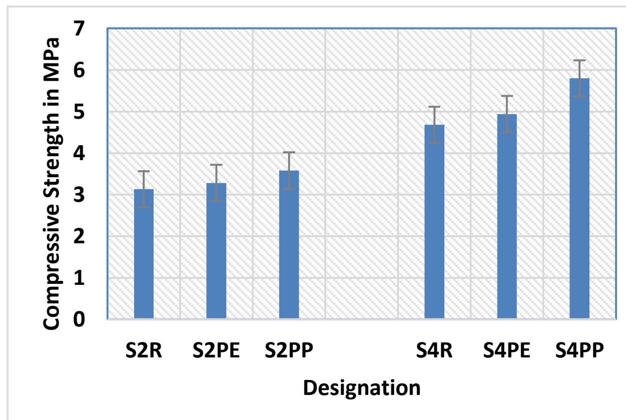


Fig. 2. Compressive strength comparison of Stabilized earthen blocks

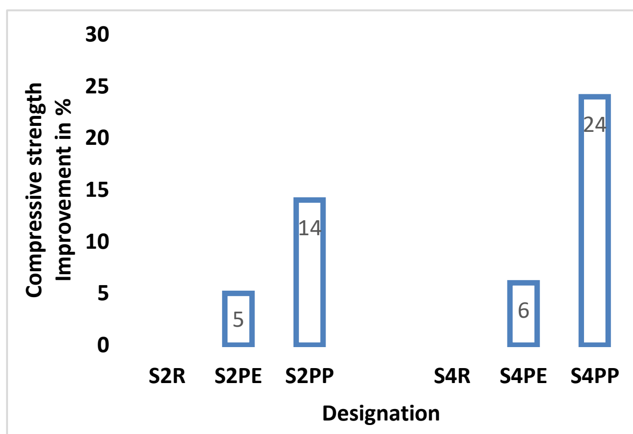


Fig.3. Compressive strength of improvement over reference block

Tensile strength showed a similar trend as seen in the compressive strength study. The tensile strength improvement over the reference block is illustrated in Figure 4. Plastic waste inclusion showed an enhanced tensile strength for both soil samples. The PP waste added specimens showed more tensile strength improvement than the PE waste added specimens.

https://doi.org/10.36375/prepare_u.iei.a141

.

Table 4. Average measured strength and durability properties of Stabilized Earthen blocks

Designation	Dry density (g/cc)	Wet compressive strength (MPa)	Tensile splitting strength		Water Absorption (%)	Weathering Mass loss (%)
		28days	Tensile strength (MPa)	Failure load per Length (N/mm)		
S_2R	1.72	3.13	0.28	44.21	14.14	2.88
S_4R	1.73	4.68	0.42	66.32	14.17	2.86
S_2PP	1.74	3.58	0.31	48.42	13.82	2.81
S_4PP	1.75	5.80	0.51	80.00	13.85	2.80
S_2PE	1.74	3.28	0.29	45.26	13.82	2.83
S_4PE	1.74	4.94	0.44	68.42	13.84	2.81

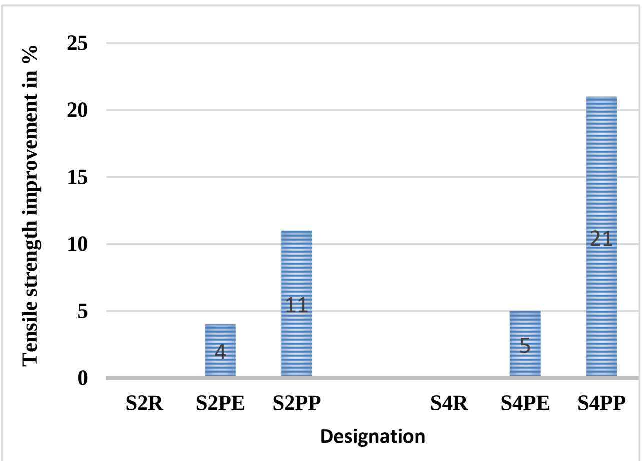


Fig. 4. Tensile strength of improvement over reference block

The plastic reinforced specimen showed enhanced compressive and tensile strength characteristics. The S_4 soil sample with plastic waste reinforcement exhibited much more strength than specimens made from the S_2 soil sample with plastic waste. The improvement of the strength after the inclusion of plastic waste can be explained that, when fibers of relatively high tensile strength are embedded in a soil matrix, the shear stresses generated between the soil particles are transferred to the fibers in the form of tensile strength resulting in a transition from brittle to ductile behavior and contributing to significant improvement in compressive strength [17]. It can be seen that the strength gain is more significant for polypropylene waste (PP) than polyethylene waste (PE). This is due to the uniform size of PP waste from the cement bag strip (fig. 1) have a better aspect ratio than the PE shredded waste collected from the waste treatment plant. Moreover, polypropylene polymer is stiffer than polyethylene and exerting more tensile strength in the soil fiber matrix

Fig.5. Stabilized lateritic soil blocks before and after weathering test

Durability characteristics

Durability characteristics are verified by Water Absorption and weathering test. Test results are tabulated in Table 5. Improved water absorption characteristics can be observed in all cases after the inclusion of plastic waste in the masonry block specimens. Both types of the PP and PE waste reinforced specimens showed little affinity towards water absorption and less water absorbent than the reference block of each soil type. The water absorption observed for all types of specimens is well within the 18% limit insisted in the Indian standard.

Figure 5. illustrates the specimens before and after 12 cycles of the weathering test. The accepted value of mass loss after 12 cycles of alternate wetting and drying tests is 3% as per the Indian code practice. The test result of specimens is well within the accepted value. It can be observed from the results that, the plastic waste reinforced specimens showed better performance against weathering action than unreinforced specimens of both soil samples.

CONCLUSIONS

This research could establish utilization of locally available lateritic soil as source material for making masonry building blocks and viability of plastic waste as a reinforcement element in enhancing its properties. Based on the experimental study following conclusions are drawn.

1. Plastic waste inclusion in soil samples showed enhanced compressive and tensile strength for both the soil samples and justifies its usage in the production of the stabilized lateritic soil masonry blocks.

3. Among the plastic waste tried the polypropylene waste showed significant improvement than the polyethylene waste inclusion in the soil samples.

4. Plastic waste reinforced specimens showed better durability properties (water absorption and weathering resistance) than unreinforced specimens.

5. S4 soil samples taken from the higher depth showed much higher strength than S2 soil samples from shallow depth. This may be due to the chemical and mineralogical variation in lateritic soil along with the depth of extraction however this may be verified with more samples with varying depth.

REFERENCES

1) Parisi, Fulvio, Domenico Asprone, Luigi Fenu, and Andrea Prota. “Experimental Characterization of Italian Composite Adobe Bricks Reinforced with Straw Fibers.” *Composite Structures* 122 (2015): 300–307. https://doi.org/10.1016/j.compstruct.2014.11.060.
2) Nagaraj, H. B., A. Rajesh, and M. V. Sravan. “Influence of Soil Gradation, Proportion and Combination of Admixtures on the Properties and Durability of CSEBs.” *Construction and Building Materials* 110 (2016). https://doi.org/10.1016/j.conbuildmat.2016.02.023.
3) Adam, E.a., and P.J. Jones. “Thermophysical Properties of Stabilised Soil Building Blocks.” *Building and Environment* 30, no. 2 (1995): 245–53. https://doi.org/10.1016/0360-1323(94)00041-P.
4) Reddy, B. V., &Jagadish, K. S. “Embodied energy of common and alternative building materials and technologies.” *Energy and buildings*, *35*(2) (2003): 129-137.
5) Binici, Hanifi, Orhan Aksogan, and Tahir Shah. “Investigation of Fibre Reinforced Mud Brick as a Building Material.” *Construction and Building Materials* 19, no. 4 (2005): 313–18. https://doi.org/10.1016/j.conbuildmat.2004.07.013.
6) Danso, Humphrey, D. Brett Martinson, Muhammad Ali, and John B. Williams. “Physical, Mechanical and Durability Properties of Soil Building Blocks Reinforced with Natural Fibres.” *Construction and Building Materials* 101 (2015): 797–809. https://doi.org/10.1016/j.conbuildmat.2015.10.069.
7) Hejazi, Sayyed Mahdi, Mohammad Sheikhzadeh, Sayyed Mahdi Abtahi, and Ali Zadhoush. “A Simple Review of Soil Reinforcement by Using Natural and Synthetic Fibers.” *Construction and Building Materials* 30 (2012): 100–116. https://doi.org/10.1016/j.conbuildmat.2011.11.045.
8) Raut, S.P., R.V. Ralegaonkar, and S.A. Mandavgane. “Development of Sustainable Construction Material Using Industrial and Agricultural Solid Waste: A Review of Waste-Create Bricks.” *Construction and Building Materials*, 2011. https://doi.org/10.1016/j.conbuildmat.2011.04.038.
9) Eades, James L, and Ralph E Grim. “A Quick Test to Determine Lime Requirements For Lime Stabilization.” *The 45th Annual Meeting of the Committee on Lime and Lime-Fly Ash Stabilization*, 1960.
10) Reddy, B. V.Venkatarama, and Ajay Gupta. “Strength and Elastic Properties of Stabilized Mud Block Masonry Using Cement-Soil Mortars.” *Journal of Materials in Civil Engineering*, 2006. https://doi.org/10.1061/(ASCE)0899-1561(2006)18:3(472).
11) Venkatarama Reddy, B. V., and P. Prasanna Kumar. “Embodied Energy in Cement Stabilised Rammed Earth Walls.” *Energy and Buildings* 42 (2010): 380–85. https://doi.org/10.1016/j.enbuild.2009.10.005.
12) Sreekumar, M G, and Deepa G Nair. “STABILIZED LATERITIC BLOCKS REINFORCED WITH FIBROUS COIR WASTES Methodology of Research.” *International Journal of Sustainable Construction Engineering & Technology* 4, no. 2 (2013): 23–32.
13) Sreekumar, M G, Deepa G Nair. “Mechanical Properties of Stabilized Lateritic Soil Blocks with Fibrous Waste Additives.” *International Journal of Sciences: Basic and Applied Research (IJSBAR* 8, no. 12 (2018): 336–350.
14) Bureau of Indian standards. *IS 1725 : 2013 (Reaffirmed Year : 2019) Stabilized Soil Blocks Used in General Building Construction - Specification*. New Delhi: Bureau of Indian standards, 2013.
15) Bureau of Indian standards. *IS 1725 : 2013 (Reaffirmed Year : 2019) Stabilized Soil Blocks Used in General Building Construction - Specification*. New Delhi: Bureau of Indian standards, 2013.
16) Bureau of Indian standards. *IS 15658:2006. Indian Standard Precast Concrete Blocks for Paving – Specification*. New Delhi: Bureau of Indian standards, 2006.
17) Bureau of Indian standards. “Burnt Clay Building Bricks — Methods of Tests Part 2 Determination of Water Absorption (Fourth Revision).” In *IS 3495 : Part 2 : 2019*. New Delhi: Bureau of Indian standards, 2019.
18) Tan, Teingteing, Bujang B K Huat, Vivi Anggraini, Sanjay Kumar Shukla, Teingteing Tan, Bujang B K Huat, Vivi Anggraini, and Sanjay Kumar. “Strength Behavior of Fly Ash-Stabilized Soil Reinforced with Coir Fibers in Alkaline Environment Strength Behavior of Fly Ash-Stabilized Soil Reinforced with Coir Fibers in Alkaline Environment.” *Journal of Natural Fibers* 00, no. 00 (2019): 1–14. https://doi.org/10.1080/15440478.2019.1691701.