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Plastic Fibre Reinforced Soil Blocks as a Sustainable Building Material

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ABSTRACT

Solid waste management, especially the huge quantity of waste plastics, is one of the major environmental concerns nowadays. Their employability in block making in the form of fibres, as one of the methods of waste management, can be investigated through a fundamental research. This paper highlights the salient observations from a systematic investigation on the effect of embedded fibre from plastic waste on the performance of stabilised mud blocks. Stabilisation of the soil was done by adding cement, lime and their combination. Plastic fibre in chopped form from carry bags and mineral water bottles were added (0.1% & 0.2% by weight of soil) as reinforcement. The blocks were tested for density, and compressive strength, and observed failure patterns were analysed. Blocks with 0.1% of plastic fibres showed an increase in strength of about 3 to 10%. From the observations of failure pattern it can be concluded that benefits of fibre reinforcement includes both improved ductility in comparison with raw blocks and inhibition of crack propogation after its initial formation.

Keywords : Sustainable building materials, plastic fibres, stabilized blocks, density, compressive strength

1 INTRODUCTION

Earth as mud bricks has been used in the construction of shelters for thousands of years. Approximately 30% of the world's population still lives in earthern structures [1]. Compressed soil masonry blocks formed using moist soil compacted mechanically to improve physical characteristics have ained popularity recently. Benefits of earth in this manner include improved strength and durability as compared to adobe while maintaining significantly low embodied energy levels than alternative materials. However problems arise from the materials low tensile strength, brittle behaviour and deterioration in the presence of water [2]. Stabilisation by a hydraulic binder such as cement or lime or a combination of the two can significantly improve water resistance and strength to some extent [3], [4], [5], [6]. Also natural fibres have been used in adobe and other traditional forms of earthen constuction for many thousands of years to reduce shrinkage cracking, to improve tensile strength, durability and ductility in tension [1], [2], [7], [8], [9], [10], [11], [12], [13]. Apart from that baking of composite bricks with natural fibres and grain leaves a porous structure which consequently enhances thermal and acoustical insulation of the finished products [10], [12]. Theoretical models were also developed on composite soil blocks reinforced with fibres subjected to shear [8]. In almost all of the above studies the fibres used are sisal fibres, coconut fibres, vegitable fibres, straw, palm fibre.

Solid waste management, especially the huge quantity of waste plastics, is one of the major environmental concerns nowadays. Their employability in block making in the form of fibres (plastic fibre- mud blocks), as one of the methods of waste management, can be investigated through a fundamental research. Also, as mentioned above, the review of the existing literature shows that most studies on natural fibres are focussed on cellulose based/ vegitable fibres obtained from renewable plant resources except in one case - animal fibre [13], and in another case - plastc fibre and polystyrene fabric [9].

In this context, for the plastic fibre-mud blocks to be more widely applicable a systematic quantification of the relavent physical and mechanical properties is crucial; to enable an objective evaluation of the composite material's response to actual field condition. This paper highlights the salient observations from the preliminary investigation of a systematic study on the effect of embedded fibre made of plastic waste on the performance of stabilised mud blocks.

2 MATERIALS AND METHODS

For the soil collected for block making, standard soil classification tests were carried out and a summary of the test results are as follows; (i) Sand = 52.0%; (ii) Silt = 43.5%; (iii) Clay = 4.5%; (iv) Specific gravity = 2.68; (v) OMC = 18%; (vi) Dry density = 1.84 g/cc. The grain size distribution of the soil sample is shown in Fig. 1. Stabilisation of the soil was done by adding cement, lime and their combination. The quantity of cement and lime added was 8% & 10%, and 2% & 4% by weight of soil respectively after many trials. Similar observations regarding the quantity of stabilisers (7.5% of cement and 2% lime) were made by Jagadeesh, 2007 [6]. It actually depends on the type of soil [14]. Combinations of these stabilisers were also tried. Plastic fibre of length 20 mm, chopped form carry bags (aspect ratio = 125) and mineral water bottles (aspect ratio = 84) were also added (0.1% & 0.2% by weight of soil) during block making (Fig. 2.). The mixture composition is shown in Table 1.
Blocks of size 305mm x 143mm x 100mm were made by pressing the prepared soil at OMC using ASTRA block making machine developed in IISc, Bangalore (Fig. 3). The blocks were cured by gently sprinkling water on straw and gunny bag which are used to cover the stack of blocks for curing. The blocks were tested for compressive strength after 3, 7, and 28

days using a digital 1000 kN compression testing machine with least count of 20 N. The dry density, compressive strength results and observed failure pattern were analysed.

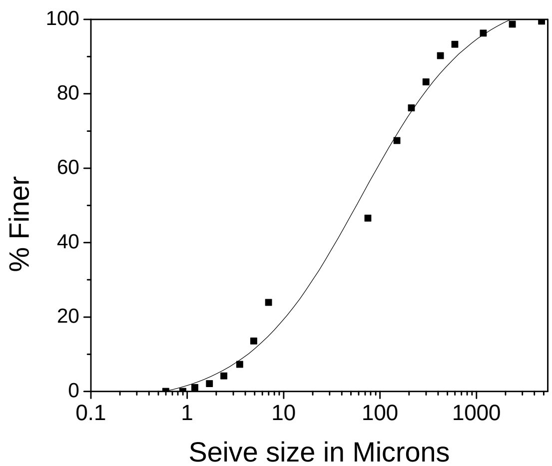

Fig.1 Grain Size Distribution of Soil Sample

Fig. 2. Typical plastic fibre from pet bottles

3 RESULTS AND DISCUSSIONS

The density of the blocks varied from 1805 kg/m³ to 1894 kg/m³. A typical test result is given in Table 2 for mud block with and without fibre made from carry bags. It coincides with the desirable limit for producing a stabilised mud block which is specified as 1800 kg/m³ to 1850 kg/m³ [6]. Effect of the fibre content was less pronounced on the density of the specimen, where there is only a small change in the density over the range of fibre added. Note that the specific gravity of the fibres varied between 1.07 to 1.1. The wet compressive strength of the blocks at 28 days curing varied from 1.96 to 4.16 MPa for the range of stabilizers and fibres added. Based on wet compressive strength the stabilized blocks may be classified in to three grades - (i) Grade 4 with strength range 4-5 MPa; (ii) Grade 3 with strength range 3-4 MPa; (iii) Grade 2.5 with range 2.5-3 MPa [6]. Compared to virgin blocks there was an increase of 8.2% and 29.1% in strength when the soil was stabilised by 8% and 10% of cement respectively. Compared to block with 10% cement there was an increase of 5.2% and 17.8% in strength when this soil was stabilised by 2% and 4% of lime respectively. The stabilised blocks showed strength values of 3.5 – 4.1 MPa; a value which is highly satisfactory compared to that of minimum compressive strength of 3.5 MPa for a well burnt brick as per BIS 1077 [15].

In all combinations blocks with 0.2% of plastic fibre made from carry bags showed reduced strength and it contradicts the results observed by Maranti et al. [11]. This reduction may be due to non uniform distribution of the large quantity of fibres present in the block creating weaker planes. Blocks with 0.1% of above plastic fibres showed only marginal increase in strength (3 to 10%). The marginal increase in strength shows that, prior to cracking, the fibre would appear to have some effect on material behaviour. The percentage increase in strength with fibre was for cement stabilised blocks as opposed to raw blocks (without stabilisation). Also, in all experimental tests it was observed that the fibres were pulled out during failure of the samples and no rupture of the fibres were observed, especially in raw soil blocks. On observation, a loss of bond was observed in stabilised blocks with fibres still holding the soil matrix without fibre failure. Similar observations were made in few investigations elsewhere using palm fibre and wool fibre [11], [13]. These results and observation together show that cement stabilised soil blocks offer some resistance to fibre sliding, and this causes a marginal increase in compressive strength.

The failure mode of blocks made of raw soil was very quick without warning. In contrast, in the case of blocks with fibres, after the ultimate load was reached, the specimen still deformed and fine crack could be seen on the specimen. Also, unlike raw soil blocks, blocks with fibres showed fine irreregular but distingushable cracks on its surface. Similar observations were made by Maranti et al. [11] in a study on strength and ductility of randomly distributed palm fibres reinforced with silty-sand soils, and by Galan-Marin et al.[13] in a study on clay based composite stabilised with natural polymer and fibre. After final failure, the soil fibre composite was not disintegrated completely in contrast to blocks with raw soil. From the observations of failure pattern it can be concluded that benefits of fibre reinforcement includes both improved ductility in comparison with virgin / raw blocks, and inhibition of large crack propogation after initial formation. Following these initial tests, further tests are ongoing to study in detail pre and post cracking characteristics of blocks and masonry.

The plastic fibre chopped from mineral water bottle is found to be inconsistent with soil in enhancing the compressive strength. In certain cases they reduce the strength and alter the failure pattern. This may be due to the surface finish which results in lack of bond with soil. Also due to the thickness and stiffness of the fibres, during mechanical compression, the soil particles may go apart laterally leaving air space between the chips and that of soil creating already weaker planes. This relaxation of fibre can be reduced by moulding the blocks at higher moulding pressure. Its influence on strength parameter is to be further evaluated.

Fig. 3 Soil Block Samples

TABLE 1
BLOCK COMPOSITION

Mix Composition	Sample Label
Raw Soil	RS
Raw Soil + 8% Cement	RS-8C
Raw Soil + 8% Cement + 2% Lime	RS-8C/2L
Raw Soil + 8% Cement+ 4% Lime	RS-8C/4L
Raw Soil +10% Cement	RS-10C
Raw Soil + 10% Cement+ 2% Lime	RS-10C/2L
Raw Soil + 10% Cement+ 4% Lime	RS-10C/4L

TABLE 2
DENSITY IN kg/ m^3 AND STRENGTH IN MPa

Sample No	0% Fibre		0.1% Fibre-(0.1P)		0.2% Fibre-(0.2P)	
	Kg/m^3	MPa	Kg/m^3	MPa	Kg/m^3	MPa
RS	1885	2.69	1818	2.78	1805	1.96
RS-8C	1888	2.91	1884	3.22	1836	2.96
RS-8C/2L	1879	3.46	1849	3.81	1824	3.09
RS-8C/4L	1849	2.92	1842	3.46	1835	2.97
RS-10C	1894	3.48	1877	3.85	1830	3.21
RS-10C/2L	1881	3.66	1860	3.84	1820	2.81
RS-10C/4L	1861	4.1	1855	4.16	1819	3.74

4 Conclusions

Following are the salient conclusions of the study:

- Compared to raw blocks, there was an increase of 8.2% and 29.1% in strength when the soil was stabilised by 8% and 10% of cement respectively.
- The stabilised blocks showed strength values of 3.5 – 4.1 MPa; a value which is highly satisfactory compared to that of minimum compressive strength of 3.5 MPa for a well burnt brick as per BIS 1077.
- Blocks with 0.1% of plastic fibres made from carry bags showed a small increase in strength of 3 to 10% and in the case of raw blocks it was marginal. This shows that cement, acting as the binder of the composite material, was found to govern the strength of the fibre-blocks.
- The plastic fibres chopped from mineral water bottle are found to be inconsistent with soil in enhancing the compressive strength.
- From the observations of failure pattern it can be concluded that benefits of fibre reinforcement includes both improved ductility in comparison with raw blocks and inhibition of large crack propogation after initial formation.
- Further investigations are ongoing for studying the effects of varied moulding pressure, cement-sand mixture addition in clayey soil containing plastic fibres, and to study in detail pre and post cracking characteristics of blocks and masonry.

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