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Environmental Conservation Efforts in Developing Textile Waste Incorporated Cement Blocks

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ABSTRACT. *The textile waste composition falls within the range of 0.5-1% from the total composition of municipal solid waste collection in Sri Lanka. However, the garment industry may generate textile waste accumulating from 19,000 to 38,000 tons annually, since the garment cutting waste is approximately 10 - 20% of fabric consumption. Considerable amount of textile waste is dumped in open areas and incinerated after removing small percentage for recycling and reuse. This accumulation of textile waste from all over the country causes certain serious environmental problems and health hazards. Also, finding of alternatives for river sand has arisen due to over exploitation for construction purposes resulting in various harmful consequences.*

The focus of the current study was on making solid cement blocks as building material, by partially replacing river sand with textile waste. The two forms of textile waste; cut-and-ground and cut pieces of 1cm x 2.5cm were incorporated to replace 25% sand on volume. Compressive strength, stress strain characteristics, weight and saving of sand were determined.

The results showed that the effect of compressive strength and stress-strain characteristics of the textile waste used cement blocks are within the required standards and can be used for constructing one storied buildings. Though cut-and-ground textile showed slightly high compressive strength, it is difficult to use for construction due to its additional cost of production. The small square pieces of size 1cm x 1cm were the acceptable shape for making blocks. Finally, it can be concluded that replacing of river sand by small textile waste pieces is a good alternative and environment friendly solution

INTRODUCTION

The average solid waste generation in Sri Lanka is 6400 tons per day of which about 2683 tons are collected (Anon, 2004a). The textile waste composition is 0.5-1% of the total composition of municipal waste collection in Sri Lanka, which amounts to 7344 tons per annum (Saheed *et al.*, 2007).

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The garment industry consumes 19,000 to 38,000 tons of fabric annually and it produces garment-cutting waste consisting of 10 - 20% of fabric depending on production techniques and product range in the garment textiles sector (Saheed *et al.,* 2007). Over one million tons of textiles are discarded annually, mostly from domestic sources, of which 25% are recycled (Anon, 2004b). It is likely that in Sri Lanka, 25% is reused and recycled, and 8,000 to 19,000 tons are incinerated annually. In most instances, they are combusted under adverse conditions, generating toxic gases such as dioxins, particularly from rayon and nylons.

Textile waste originates both from the household consumer sector and the industrial manufacturing sector. Consumers react to change in fashion both in clothing and household interior designs. Seasonal changes in fashion mean that clothes can become outdated very quickly. Consequently, manufacturers will increasingly develop large quantities of low durability clothing for the 'throw away' society. Economic prosperity also influences this trend.

With the expansion of the industry, the problem of waste disposal has become a major issue. At present, open dumping and incineration are the main practices of disposal. Open dumping contributes to the formation of leachate as it decomposes, which has the potential to contaminate both surface and groundwater sources. Methane gas is another product of decomposition in open dumping, which is a major greenhouse gas and a significant contributor to global warming. The decomposition of organic fibers and yarns such as wool produces large amounts of ammonia as well as methane. Ammonia is highly toxic in both terrestrial and aquatic environments, and it can be toxic in gaseous form. It has the potential to increase nitrogen in drinking water, which can adversely affect humans. Cellulose-based synthetics decay at a faster rate than chemical-based synthetics. Synthetic chemical fibers can prolong the adverse effects of both leachate and gas production due to the length of time taken for them to decay. Rather than disposing in landfills, textile wastes also incinerated in large quantities, thus emitting organic substances such as dioxins, heavy metals, acidic gases and dust particles, which are all potentially harmful to both humans and the environment (Marciano *et al*., 2009).

Textile fibers are manufactured from a unique type of fiber or from a combination of several fibers. The two main fiber types most commonly used to make textiles are natural fibers and synthetic fibers (http;//www.wasteonline.org.uk.resources/Wasteguide/mn_wastetypes_ textile.html). Natural fibers include plant fibers such as cotton, flax and hemp, animal fibers such as sheep's wool, and mineral fibers such as asbestos. Synthetic fibers are polymers based on petroleum and cellulose such as rayon and nylon.

Textile waste takes many forms and is often complex in nature due to the range of manufacturing specifications required. Complex mixtures of fibers make separation more difficult and more costly, and this has implications for the profitability of textile recycling. Conversion of this type of textile waste into useful materials, serves a dual function: elimination of waste, and introduction of new products such as recycled fibers, recycled clothes, toys, carpets and filling material, especially from cotton fiber. The advantages of using such recycled fibers generally include lower cost of processing than virgin fibers, and the elimination of the need for waste disposal in landfills (http;//www.wasteonline.org.uk resources/Information sheet/textiles.htm).

There is an innovative trend towards the use of textile waste in the building construction field such as roofing material (Senevirathne *et al*., 2007) and brick from textile waste sludge (Balasubramanian *et al*., 2005). Use of these recycled materials is becoming more popular due to shortages of natural mineral resources and increasing waste disposal costs. For instance, sand has now become a scarce resource and price of a cube of river sand is showing an increasing trend. The situation desperately demands alternatives to river sand to overcome this crisis. During the last half a decade, there has been a rise in the demand for land mining or stream mining based sand, which resulted in flood plains, channel degradation, increased turbidity, stream bank erosion and sedimentation of riffle areas (Hemalatha *et al*., 2005). This study was aimed at exploring the possibility of replacing sand partially with textile waste for the production of cement blocks.

MATERIALS AND METHODS

Materials

The materials used in making cement blocks were sand, cement and textile waste. As the control, cement blocks were made according to the SLS standards (SLS, 1989) using sand and cement. As treatments, cement blocks were prepared with cut textile wastes and cut-and-ground textile wastes as admixture. For all treatments, cement to aggregate ratio of 1:8 by volume was maintained to ensure comparability between the treatments. Thus, the cement component in volume was kept constant while the aggregate composition was changed to include textile wastes by partially replacing sand.

Cement

Ordinary Portland cement was used which conforms to the requirement of Sri Lanka Standards (SLS) 107 (SLS, 1989).

Sand

Sand obtained locally, was cleaned to remove impurities and deleterious materials. In addition, it satisfied the SLS 882 (SLS, 1989).

Textile waste

Mixed textile wastes were used in two forms, cut and cut-and-ground. In size reduction, mixed textile wastes were cut into pieces (1cm-2.5cm length x 1cm width.) manually. Ground textiles were prepared by grinding cut textiles using a grinder (MX-T1PN, Mutsushita Electric Company Ltd, Taiwan).

Water

Clean well water, as required by SLS (522 Part 1) was used for making cement blocks. Textiles were sun dried well before making cement blocks (SLS, 1989).

Fabrication of bricks

Cement block mixtures (cement, sand, water and waste fabrics) were prepared manually according to the requirements of SLS (855 Part 1). Cement blocks were made from the mixtures using a cement block manufacturing machine (MX-T1PN, Mutsushita Electric Company Ltd, Taiwan) at a commercial cement block manufacturing company in Gelioya, Kandy, Sri Lanka. The details of the mixtures are given in Table 1.

Table 1. Composition of cement, sand and waste fabrics in the mixtures

Treatment	Cement	Sand	Cut & Ground Textile	Cut textile	Replacement of sand %
Control	1	8	0	0	0
1	1	6	2	0	25
2	1	6	0	2	25

In preparing mixtures with textile waste, first sand and cement were mixed and after which the textile waste was added according to the volume ratio. Mixing was done manually to produce six blocks from each mixture. In order to obtain homogeneous mixtures, water was sprayed onto the ingredients while mixing and turning the pile for 2 minutes. Visual observations revealed that cement and sand were uniformly scattered within the mixture. Afterwards, the fresh mixture was fed into the mold (357mm x 161mm x 100mm) of the cement block molding machine. The mold was over-filled (in excess) with the mixture according to the proportions given in Table 1 and pressure was applied to compact the material in the mold. Soon after compaction, the formed block samples were removed from the mold. No damage was observed on the bricks while it was de-molded. All block samples were cured with water in ambient shade environment for 7 days and allowed to dry for 24 h in ambient environment and weighed.

Test methods

Unit weight, cost per block, amount of blocks for a unit volume of sand and the compressive strength values of the blocks were determined for comparison purposes.

Compressive strength

Compressive strength of the cement blocks was measured using a universal testing machine (SJ-12, New Machine Tech Private Limited, Sri Lanka). Before testing, samples were prepared by applying 5mm thick rich cement on the top and bottom surfaces of the cement blocks. After 24 hours, blocks were soaked in water for 72 hours and drained out for 24 hours prior to testing. Cement blocks were mounted on the universal test machine between thin plywood sheets. The compression load was applied onto the 357 x 100 mm face of the cement block. The ultimate crushing load and the compressive strength of the cement blocks were determined using the load extension data at a standard loading speed for cement blocks of 0.001mm/min. The stress-strain curves were plotted for all treatments including the control.

Analysis of compressive strength

The compressive strength of the cement blocks was calculated by dividing the maximum load by the original cross-sectional area of the loaded face of the cement block. The Young's Modulus of the cement blocks was calculated for the linear region of the strain versus stress relationship, which follows Hook's law.

$$\sigma = E\varepsilon \text{ --------------------------------------(1)}$$

Where, σ = stress, ε = Strain, E refers to the Young's Modulus for compression given by slope of the curve.

By its basic definition, the normal stress is given by:

$$\sigma = F/A \text{ --(2)}$$

Where, F = Load applied in N, A = Area in m^2

Strain is given by:

$$\varepsilon = \delta/L_0 \text{---------------------------------------(3)}$$

Where, δ = Deformation L_0-L in mm, L_0 = Original length in mm

Density and cost saving

Densities of cement blocks were calculated for the control and the treatments using measured densities of ingredients. Costs saving on replacing sand with textile wastes was calculated based on the volume replacement of sand by waste textile and the price of sand.

RESULTS AND DISCUSSION

Compressive strength

Compressive strengths of cement blocks of control, treatment 1 and treatment 2, were determined after 7 days of curing. The results are shown in Table 2.

The mean compressive strength values were 1.65±0.13 N/m^2, 1.85±0.48 N/m^2 and 1.97± 0.10 N/m^2 for control, treatment 1 and treatment 2 respectively. There was no significant difference in compressive strength ($p=0.12$) among treatments and the control.

In this preliminary test, the curing of blocks was made only for 7 days with constant amount of cement. Normally, compressive strength of concrete mixtures increased with age (Siddique *et al*., 2007). The recommended compressive strength of blocks for single storied buildings is 1.2 N/m^2 (SLS, 1989). Thus, it can be recommended that the blocks produced in both treatments can be used for single storied buildings, since the lowest value was above the allowable compressive strength.

Table 2. Compressive strength of cement blocks

Treatments		Crushing Load (kN)	Compressive Strength (N/m^2)	Mean Compressive Strength (N/m^2)	Young's Modulus (N/m^2)
Control	(I)	59.8	1.70		
	(II)	53.9	1.50	1.65±0.13	141.2
	(III)	61.8	1.75		
Tretment1	(I)	46.6	1.30		
	(II)	77.5	2.15	1.85±0.48	95.3
	(III)	75.0	2.10		
Treatment 2	(I)	65.2	1.85		
	(II)	74.0	2.05	1.97± 0.10	84.2
	(III)	72.1	2.00		

Stress-strain` characteristics

Stress-strain characteristics of soil-cement blocks were determined as per the procedure explained in earlier section. Relationship of the compressive stress and longitudinal strain for cement blocks are shown in Fig. 1. It represents the mean value of three specimens tested. The variations of Young's Modulus values of blocks are given in Table 2.

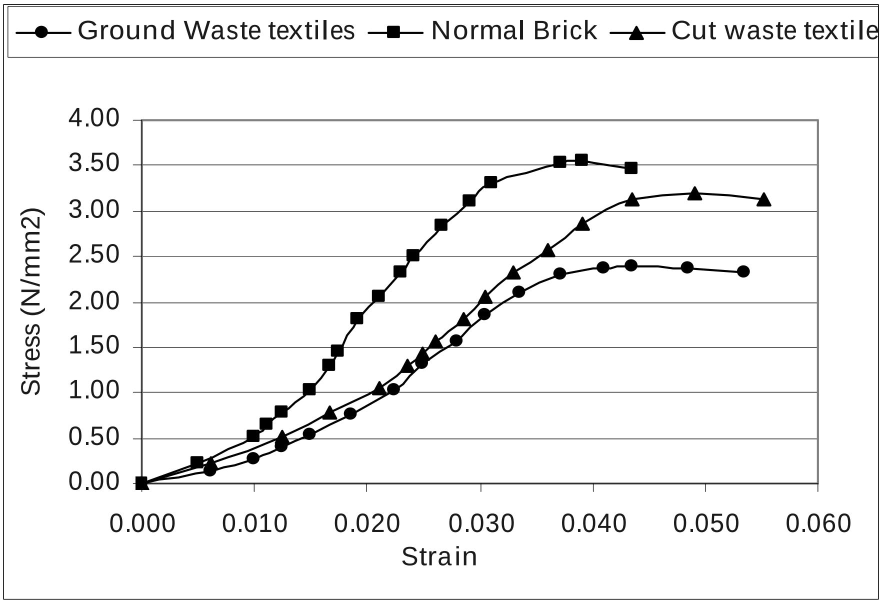

Fig. 1. Stress-strain relationships of solid cement blocks

The stress strain curves for all blocks were initially straight showing linear relationship in the elastic range. As the stresses increased further, the curves became non-linear and showed softening behavior. This behavior is clearly observable in all the three types of blocks irrespective of materials. The effect of plasticity was more in blocks made from waste textile.

The highest Young's Modulus value was shown in the control within was 141.2 N/m^2. Treatment 1 and treatment 2 had values of 84.2 N/m^2 and 95.3 N/m^2, respectively. The ultimate strain values for the blocks lie in a very close range of 0.004 to 0.005.

Density and cost saving

The weight of blocks, cost of blocks and amount of blocks produced from a sand cube (100 ft^3) were determined according to the procedures mentioned in the previous section and the results are shown in Table 3.

The weights of cement blocks were measured by a top loading balance. The average weight of the control was 12.3 kg and the others were 10.4 kg. The weight difference was 1.9 kg between control and treatments 1 and 3. On the other hand, it contributed 15% saving of sand compared to the control. The quantity of production of normal blocks and textile waste added blocks were 494 and 586 respectively from 2.83m^3 of sand. It showed that 147 more blocks can be produced by the same quantity of sand using textile waste which accounted to 33% saving for 2.83m^3 of sand.

Sand quantity was the key factor affecting the cost of a cement block. In the waste textile used samples, the cost of sand used for a block was LKR 10.00. In the control, LKR 14.00, was spent for sand per block. The difference was LKR 4.00, a 28% saving from a block. The cost of processing is met from the disposal fee paid by the Municipality or the Textile industry. However, some of the textile waste pieces (> 1 cm) were visible from the cement blocks (Fig. 2).

Table 3. Weight and Cost performance of the block

Sample No.	Type of solid cement block	Average weight of a block (kg)	Average cost for sand (LKR)	Average amount of blocks produced from a cube of sand
Control	Normal block	12.3	14	439
2	Cut, ground textile waste block	10.4	10	586
3	Cut textile waste block	10.4	10	586

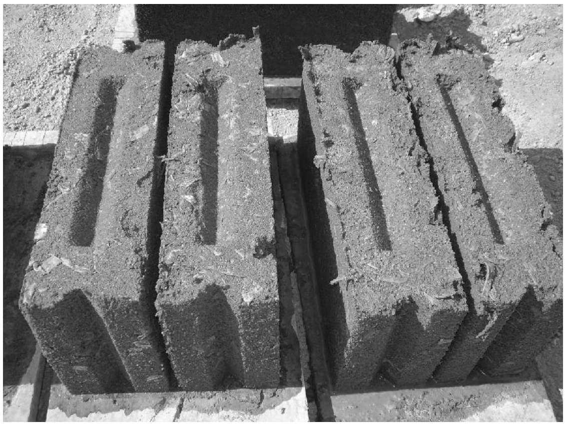

Fig. 2. Textile waste mixed solid cement blocks

CONCLUSIONS

The quantum of textile waste generated from households and textile industry is substantial and there are efforts to reuse and recycle the wastes. A better method is to replace considerable percentage of sand with textile waste. The study indicated that the compressive strength of one of the admixtures with textile waste was comparable with the normal cement blocks. In the second set of experimentation, there were considerable differences in the normal stress between the control and admixed samples. However, blocks made with ground textile waste showed acceptable values but difficulties aross in grinding of waste incurring an additional cost. All the samples showed softening, thus requiring further long-term experimentation, since replacement of sand with textile waste is economically viable and an environmental friendly alternative.

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