PRODUCING A CEMENT BLOCK WITH SUSTAINABLE USE OF POLYESTER YARN WASTE AND DETERMINING OPTIMUM MIX PROPORTIONS

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INTRODUCTION

Cement blocks are one of the main precast building materials used in constructing walls in single and multi-storied buildings and factories etc. Cement, fine aggregate and water are the main ingredients required to produce cement blocks. With rapid urbanization and industrialization, the demand for raw materials required to produce cement blocks is rising exponentially.

Safe disposal of waste materials, which are by-products of various processes, has become one of the rising global challenges in recent decades. Recycling waste is one of the best solutions to reduce the cost involved in disposal and the environmental problems created by unsafe disposal. According to statistics, the Sri Lankan garment industry generates approximately 30000-40000 tons of textile waste (Institute for Manufacturing, 2016) annually which includes high amounts of synthetic and non-biodegradable polyester which causes serious environmental issues. Only a little amount of this waste is recycled and reused in the industry. This research study was conducted to explore the feasibility of using polyester yarn obtained from textile waste to produce cement blocks beneficial in many ways for both the construction and textile industries.

Sri Lanka Standards Institution has published standards comprising requirements and test methods for cement blocks (SLS 855: Parts 1 & 2, 1989). This research study explores the effects of using different percentages of polyester yarn waste in cement blocks to achieve optimal mix proportions in cement blocks. Comparing physical and mechanical properties of the proposed block with the conventional block after identifying optium mix proportion and its cost effectiveness are the outcomes from this research.

METHODOLOGY

Initially, it was decided to determine the best cement and sand mix proportions for producing conventional cement blocks satisfying requirements specified in SLS 855. This is achieved through a series of preliminary tests performed on varying mix proportions. Ordinary Portland Cement conforming to SLS 107 was used as the binder and quarry dust free of harmful substances conforming to SLS 882 was used as the aggregate. Cement blocks were produced at a casting yard using a typical industrial type block-making machine. Based on the outcome of the preliminary tests conducted on conventional cement blocks, a cement: sand mix proportion of 1:10 and a water/cement ratio of 0.60 were selected as the optimum solution satisfying SLS 855 requirements.

Based on the previous research conducted by G. Navya & J. Venkateswara Rao (2014) on producing concrete paver blocks it was decided to vary polyester yarn content from 0.1% to 0.5% replacing the fine aggregate. V. Vinitha (2017) also came to the same conclusion using polypropylene fibre. During the experimental phase it was noted that increasing the yarn percentage further makes mixing mortar very difficult due to tangling of wet yarn. Polyester

yarn obtained from the Horana factory of Eco-spindles (Pvt.) Limited was used in the study. Selected yarn cut pieces ranged from 3mm to 6mm in length and 1.15 g/cm^3 in density.

Following the recommendations of SLS 855, compressive strength test, density test, moisture content test, and water absorption test were performed on blocks cast varying the polyester yarn percentage from zero (control sample) to 0.50% in steps of 0.1% to determine the optimum mix proportions satisfying all the SLS 855 requirements. Split temsile tests were also carried out to determine the tensile capacity of blocks.

RESULTS AND DISCUSSION

Compressive Strength Test

The compressive strength of the blocks was determined according to SLS 855: Part 2: 1989. As per SLS 855 Part 1:1989, the minimum specified compressive strength value is 1.2 N/mm^2 for single-storey buildings. However, the age at which this strength needs to be achieved is not specified. All six different types of blocks tested after 7 days of curing achieved compressive strengths much higher than the SLS requirement as shown in Figure 1. Blocks having 0.4% yarn produced the highest compressive strength value of 4.5 N/mm^2. Since the lead time is very important, further tests were done on blocks having 0.4% yarn replacement after 2 days of curing. Tested blocks achieved strengths ranging from 1.7 to 2.1 N/mm^2.

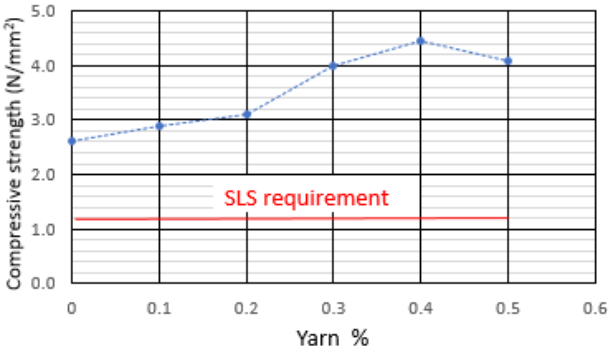

Figure 1: 7 day compressive strength against fiber %

Water Absorption and Moisture Content Test

Water absorption and moisture content tests were carried out conforming to the SLS 855: Part 2: 1989. The upper limit recommended in SLS 855 for moisture content of cement blocks is 40%. Test results obtained for moisture content with variable yarn % are shown in Figure 2 and it is obvious that the moisture content increases gradually with increasing yarn % but lies well below 40% which is the upper limit.

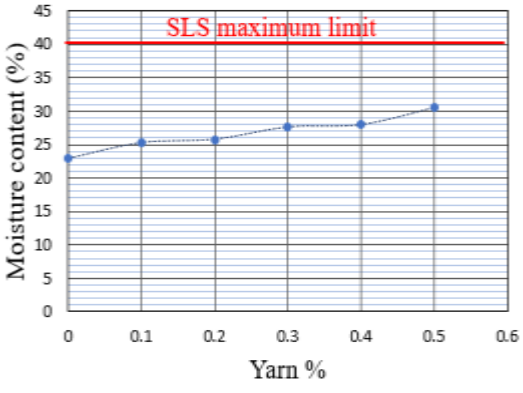

Figure 2: Variation of Moisture content against yarn percentage

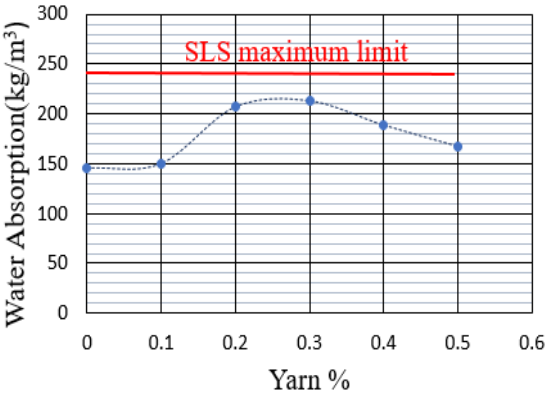

Figure 3: Variation of Water absorption against yarn percentage

Water absorption test results are plotted in Figure 3. The peak value of water absorption, 213 kg/m^3, was observed for 0.3% yarn percentage and lies below the SLS 855 recommended maximum acceptable limit of 240 kg/m^3.

Density of the Blocks

According to SLS 855 PART 1:1989, the maximum and minimum acceptable values for block density are 2800 kg/m^3 and 1000 kg/m^3 respectively. Mass and the volume of the blocks in each mix proportion were measured to determine the density of the blocks and the variation is plotted in Figure 4. It can be seen that there are no significant fluctuations in density with the variation of yarn percentage and all the block density values lie within the acceptable range.

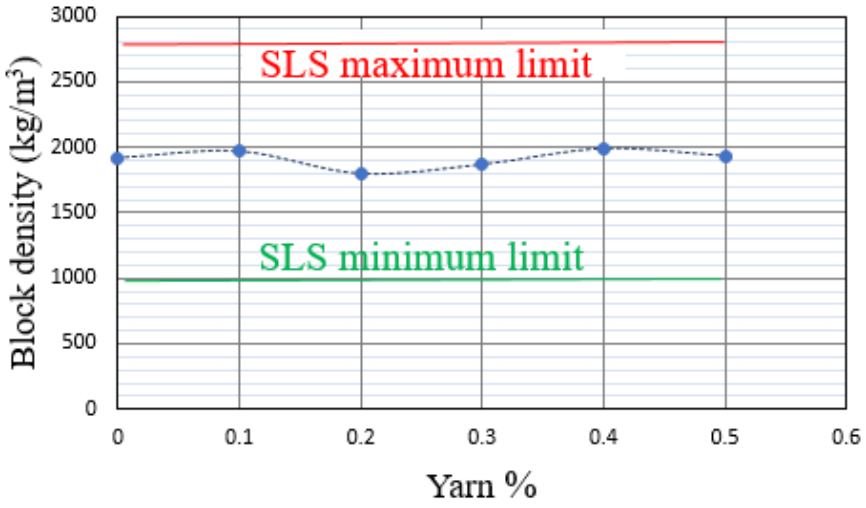

Figure 4: Variation of block density against yarn percentage

Split Tensile Test

SLS 855 does not recommend any tensile test on cement blocks since masonry walls are not expected to carry any tension. However, in order to observe the improvement made by the addition of yarn, split tensile test was carried out and the results are plotted in Figure 5.

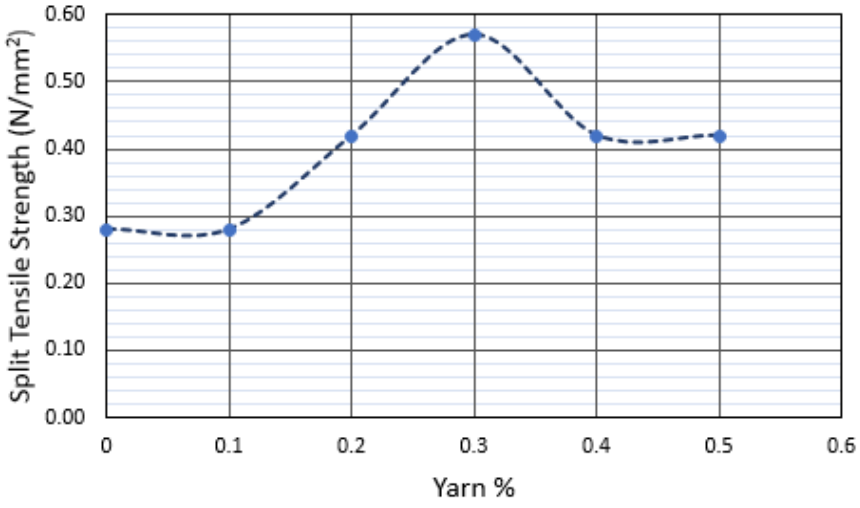

Figure 5: Variation of Split tensile strength against yarn percentage

According to the test results, there is a substantial improvement in tensile strength due to the addition of yarn. The peak value, which is a 100% increase compared to the control sample, is observed with 0.3% yarn addition.

CONCLUSIONS/RECOMMENDATIONS

The primary aim of this research was to recycle polyester yarn, which currently ends up as waste material in garment factories, partially replacing construction materials that are in high demand. Experimental results indicate that the replacement of fine aggregate used for making conventional cement blocks with polyester yarn is not only a sustainable practice but also improves the engineering properties of cement blocks.

Results of the compressive strength, moisture content, water absorption, and block density tests, recommended in SLS 855 for cement blocks, indicated that the addition of yarn improves the tested engineering properties. At a mix proportion of 0.4 % fiber, it was possible to increase the compressive strength by 73%, or to 4.5 N/mm^2, when compared to conventional block strength of 2.6 N/mm^2. This makes it possible to use the block with 0.4% yarn even for load-bearing walls.

This strength gain is due to the tensile capacity enhancement by the polyester yarn compared to purely compressive blocks made with cement sand mortar. This is further evidenced by the results of the split tensile strength test. A 100% increase in tensile strength was observed when 0.4% yarn is added compared to ordinary cement blocks.

Since yarn is a waste material, garment manufacturers need to invest in the safe disposal of yarn as well. Giving away waste yarn freely to cement block manufacturers results in cost reductions for both garment and cement block manufacturers. Based on the results of this study future researchers are encouraged to find alternative ways to use yarn in products like precast wall panels, ceiling boards, etc.

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