Analysis of Compressive Strength and Water Absorbency Behavior in Textile waste Fiber-Reinforced Cement Paving Blocks

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I. Introduction

As the global population expands and living standards rise, fiber consumption has increased significantly over the past few decades. It results in significant amounts of pre-consumer and post-consumer fiber waste. From them, a considerable amount of textile waste ended up in landfills or incinerated. According to literature, in 2015, the textile and apparel industry consumed approximately 53 million tons of textile fiber, of which 73% was landfilled or incinerated [1]. Less than 1% of the material is recycled for new clothing. Closed-loop recycling is essential for sustainability but has limitations such as high cost and processing challenges. Upcycling offers a practical alternative by converting waste into high-value products [2]. Therefore, upcycling should be considered as an alternative rather than only relying on closed-loop recycling. In this research, the aim is to manufacture textile fiber-reinforced cement paving block which manages textile waste and adds value to the product.

Nowadays paving blocks are widely used in pavements, sidewalks, and other areas due to their easy installation, low maintenance, aesthetic appeal, and durability. However, they also have disadvantages such as high cost, low strength, and the possibility of damage due to heavy loads. By using fiber waste for reinforcement, the project aims to improve the strength of pavement blocks while addressing the challenges of fiber waste disposal. That means they produce pre-consumer and post-consumer waste. This research integrates recycled polyester and polyester fiber waste into the production of cement paving blocks.

The research focuses on an extensive experimental program to investigate the effectiveness of incorporating short random fibers (10-30 mm in length) of polyester waste fibers and recycled polyester waste fibers. The fibers are used at volume contents of 0.25%, 0.50%, and 0.75% by weight of the cement mixture, into cement paving block reinforcement. According to the study [3], it is recommended to investigate the setting for imparting vibration to the mold and compaction through compression. Then, the researchers applied the solid compaction technique combined with vibration and pressure, which is now called Vibropressing. It increases their density and strength by distributing the cement mixture evenly and removing air pockets. The research incorporates the vibropressing method to manufacture fiber-reinforced cement paving blocks.

To determine the optimal fiber volume content as the key parameter, the Compressive strength and water absorbency tests are evaluated. Additionally, the evaluation aims to identify the best fiber type for the reinforcement of polyester waste fiber and recycled polyester waste fiber. The findings will contribute to optimizing the performance of cement paving blocks while promoting sustainable practices.

II. Literature Review

A. *Fiber Parameters*

The length of a fiber is not a precise measurement. It is distribution including varying length. It has been discovered that combinations of various fiber lengths are more efficient than mono-length fibers [4]. Moreover, the [5], investigated the effect of mechanical properties of cement composition, including its modulus of elasticity, flexural strength, and compressive strength. In the case of 20 mm PET fibers, after 28 days there is a significant increase in flexural strength.

According to the study [6],1 cm, 2 cm, and 3 cm fiber lengths are the frequently used lengths, and they are considered as the most suitable fiber lengths for various applications. Since it is complicated to keep the length of the fiber constant, the length is maintained at an average of 1 cm – 3 cm during fabrication of this project.

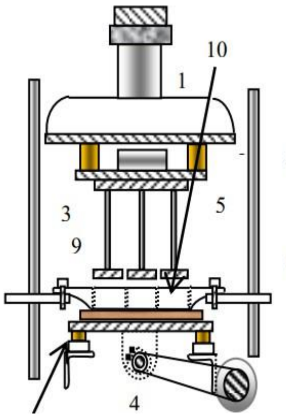
B. *Fiber Mixing Ratio*

It is important to maintain optimum mixing ratios since they have an impact on the properties of the composite. According to the [7], impact strength was shown to be significantly improved by using polypropylene fibers with fiber volume fractions of 0.1%, 0.3%, and 0.5%. Based on the study [8], efficiently polypropylene fiber was added in the following ratios to concrete paver blocks, 0%, 0.05%, 0.15%, 0.25%, and 0.35%.

C. *Manufacturing Methods*

The conventional method of manufacturing cement paving blocks is the manual method. It uses manpower to punch on top of the block [9]. It will compact the mixture to some extent. The pressing method uses a hydraulic press machine to pressurize the cement mixture. Since the pressure is applied by a steel die, it gives an even pressure along the length of the paving block.

The most common method used in manufacturing cement paving blocks is the vibration table method. In this method, a vibrating table is used which can pass the materials from one end to the other end while vibrating the material that is kept on it. The table is electrically operated, and the vibration time can vary appropriately [10]. Vibro-pressing is a new technology that combines vibration and pressing simultaneously. The vibro-pressing machine is capable of changing vibration frequency, vibration time duration, and the pressure applied.



A detailed description:
1. Hydraulic pressure cylinder
2. CPB head pressure plate
3. Accessories
4. Unbalancing the vibrator
5. Die
6. Vibrating dynamo
7. Rubber vibration dampers
8. Mold back cylinder
9. CPB pressure bars
10. CPB mold

Fig. 1. Vibro-pressing machine

III. Material and Methods

The major materials used for manufacturing fiber-reinforced cement paving blocks are fibers, cement, fine aggregate, and chip powder. The cement type was Ordinary Portland Cement by Tokyo Super which has a strength class of 42.5 N. In this study, cement and stone powder (chip powder) were used in a ratio of 1:5 as determined by an industrial survey. There are different types of stone powder sizes in the industry. The project incorporated 0.15 mm size of stone powder as the fine aggregates of cement paving blocks. Polyester fiber waste and recycled polyester fiber waste were used as reinforcement materials. Polyester fibers were sourced from a pillow company which offer 7D hollow conjugated fibers. Recycled polyester fibers were sourced from a yarn spinning mill, which offers fiber waste from the yarn spinning process, with no more than 75D fiber/yarn waste. The properties of these fibers are described in Table 1.

TABLE I. Fiber Properties

Fiber Type	Description	Cross Section	Length
Polyester	Hollow Conjugated Siliconized	7D	64 mm
Recycled Polyester	False Twisted Textured	< 75D	Continuous Filament

In this project, the optimum waste fiber mixing ratio was utilized as 0.25%, 0.5%, and 0.75% by weight of cement paving block. And the dimensions of the fiber-reinforced cement pavement were 200mm x 100mm x 80mm.

Initially, fiber waster was cut into an average length of 10mm – 30mm by using the crusher machine. Fiber mass was measured, and six fiber bags were prepared, each containing fiber for 12 blocks. The vibropressing machine is set to size 200×100×80 mm. The frequency used is 40 Hz, and the pressure is 75 kg/cm². Tokyo Super Ordinary Portland Cement (OPC) mixed with chip powder at a ratio of 1:5 was used. Water was added to maintain a water/cement ratio of 0.35. Fibers are pre-soaked in water to improve bonding with cement, then squeezed to remove excess water. Then the pre-soaked fibers were added to cement mixer and fiber mixed with cement mixture for 4 minutes. The fiber-cement mixture was poured into the molds in the vibrator, which was vibrated for 3 seconds, followed by 2 seconds of vibration after lowering the die. Cast blocks were removed, labeled, and kept at room temperature for 24 hr. The paving blocks were labeled with 'E' to denote blocks containing recycled polyester fiber, and 'C' for those containing polyester fiber. The numbers following the letters, such as E-1, E-2, E-3, and C-1, C-2, C-3, indicate fiber percentages with higher numbers representing higher fiber percentages.

IV. Results and Discussion

After the curing period, the fiber-reinforced cement paving blocks were tested to determine their properties.

A. *Compressive Strength Test*

The compressive strength test was conducted following British and Sri Lankan standards. Before testing, the fiber-reinforced cement pavement blocks underwent a 28-day curing period to achieve that optimum compressive strength.

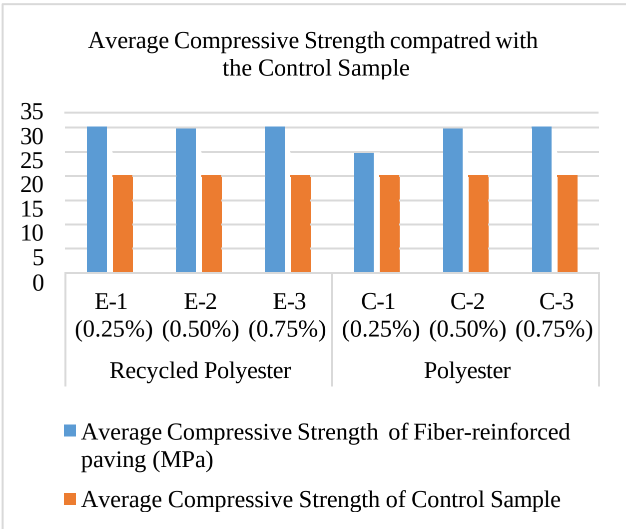


Fig. 2. Results of Compressive Strength Test

According to the result of the table, recycled polyester fibers show higher compressive strength compared to the control sample. The polyester fibers added to paving blocks show higher compressive strength than the control sample. Compared with the control sample, it can be observed that fiber-added paving blocks have higher compressive strength. Also, the best performance was observed in E-3 and C-3 paving blocks with 0.75% fiber content.

B. Water Absorbency Test

The water absorbency test was conducted by first drying the specimens in a ventilated oven at a temperature range of 105 °C to 115 °C until they reached a substantially constant mass. Once dried, the specimens were cooled to room temperature, and their weights were measured. Subsequently, the dried specimens were fully immersed in clean water maintained at a temperature of 27 ± 2 °C for 24 hours. After the immersion period, the specimens were removed from the water, and a damp cloth. The specimens were then weighed water, and any excess water on their surfaces was wiped off using a damp cloth. The specimens were then weighted again to obtain their new mass. Finally, the cold-water absorption, expressed as a percentage by mass after 24 hours of immersion, was calculated using the formula.

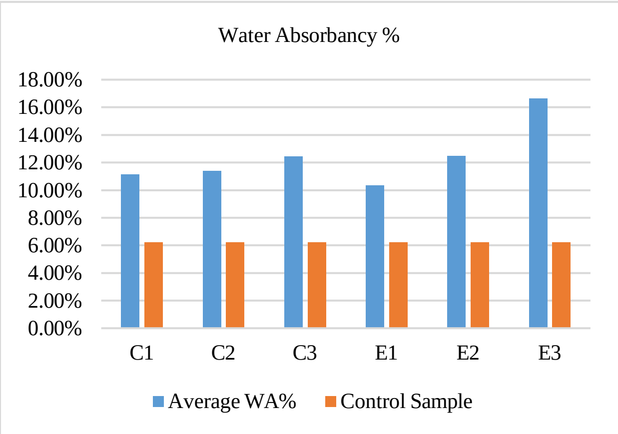


Fig. 3. Results of Water Absorbency Test

The results show the water absorbency has changed drastically when adding fibers to the cement paving block. The control sample shows less water absorbency. This occurs because the cement forms stronger bonds between the particles, reducing the pores through which water can be absorbed into the cement paving block [11]. When incorporating fibers, it creates voids allowing water to get into the cement paving block. According to the graph, the paving blocks with polyester fibers have higher water absorption at lower fiber percentages, while blocks with recycled polyester fibers exhibit higher absorption at higher percentages. This pattern is influenced by the fiber's crimped structure, which creates voids that retain water, and the presence of a silicon coating on the fibers, which affects their hydrophobic properties.

V. Conclusion

This study shows the use of polyester and recycled polyester fiber waste as reinforcement in cement paving blocks. They provide an effective solution to textile waste management in Sri Lanka. Based on the test results, both recycled polyester and polyester fibers are suitable as raw materials for fiber-reinforced cement paving blocks, and both types can be sourced from industrial waste. It is important to carefully consider the fiber content in the paving blocks when incorporating these fibers. Research highlights that fiber-reinforced cement pavement blocks exhibit superior compressive strength compared to conventional blocks, especially with an optimum fiber content of 0.75%.

However, the increased water absorption of these blocks, which exceeds Sri Lanka and ASTM standards, poses a durability challenge, especially in flooded areas. This can be minimized by waterproofing measures. The study recognizes the need for careful water control during production to avoid machine problems and suggests adding a top layer of cement to improve surface appearance. Overall, the improved mechanical strength and durability of these blocks contribute to their long service life, reduced maintenance costs, and positive environmental impact.

References

[1] Y. Wang, "Fiber and textile waste Utilization," Waste Biomass Valorization, vol. 1, no. 1, pp. 135–143, Mar. 2010, doi: 10.1007/s12649-009-9005-y.

[2] H. S. Lee, S. Jung, K. Y. A. Lin, E. E. Kwon, and J. Lee, "Upcycling textile waste using pyrolysis process," Feb. 10, 2023, Elsevier B.V. doi: 10.1016/j.scitotenv.2022.160393.

[3] R. Hameed, M. Tahir, Zaib-un-Nisa, S. Shahzad, S. M. S. Kazmi, and M. J. Munir, "Impact of Compression Casting Technique on the Mechanical Properties of 100% Recycled Aggregate Concrete," Sustainability (Switzerland), vol. 15, no. 10, May 2023, doi: 10.3390/su15108153.

[4] G. Charan Behera, S. Panda, and P. Kanda, "Effect of Length of Fibers on Mechanical Properties of Normal Strength Concrete," in IOP Conference Series: Materials Science and Engineering, IOP Publishing Ltd, Nov. 2020. doi: 10.1088/1757-899X/970/1/012020.

[5] F. Pelisser, O. R. K. Montedo, P. J. P. Gleize, and H. R. Roman, "Mechanical properties of recycled PET fibers in concrete," Materials Research, vol. 15, no. 4, pp. 679–686, Jul. 2012, doi: 10.1590/S1516-14392012005000088.

[6] H. Taherkhani, "An Investigation on the Properties of the Concrete Containing Waste PET Fibers," International Journal of Science and Engineering Investigations, vol. 3, p. 27, 2014, [Online]. Available: https://www.researchgate.net/publication/312039151

[7] P. Zhang and Q. F. Li, "Effect of polypropylene fiber on durability of concrete composite containing fly ash and silica fume," Compos B Eng, vol. 45, no. 1, pp. 1587–1594, Feb. 2013, doi: 10.1016/j.compositesb.2012.10.006.

[8] A. Ananthi, "Study on the Effects of Polypropylene Fiber in Concrete Paver Blocks," 2017. [Online]. Available: www.journalspub.com

[9] E. Widayanto, A. Soehardjono, W. Wisnumurti, and A. Zacoeb, "The effect of vibropressing compaction process on the compressive strength based concrete paving blocks," AIMS Mater Sci, vol. 7, no. 3, pp. 203–216, 2020, doi: 10.3934/MATERSCI.2020.3.203.

[10] C. Udawattha, H. Galabada, and R. Halwatura, "Mud concrete paving block for pedestrian pavements," Case Studies in Construction Materials, vol. 7, pp. 249–262, Dec. 2017, doi: 10.1016/j.cscm.2017.08.005.

[11] T. TA, "The Use of Plastic Waste as Transition Materials in the Production of Pavement Blocks," Civil Engineering Research Journal, vol. 9, no. 1, Sep. 2019, doi: 10.19080/cerj.2019.09.555753.