Developing Fibre-Reinforced Cement Paving Blocks as a Method of Fibre Waste Disposal

Baines D. M
Department of Textile and Apparel Engineering
University of Moratuwa
Moratuwa, Sri Lanka
deenabaines8@gmail.com

Bogodawaththa B. P. H
Department of Textile and Apparel Engineering
University of Moratuwa
Moratuwa, Sri Lanka
pradeepabogodawaththa@gmail.com

Gunasekara U. S. W
Department of Textile and Apparel Engineering
University of Moratuwa
Moratuwa, Sri Lanka
ujithe@gmail.com

Gamage D. L
Department of Textile and Apparel Engineering
University of Moratuwa
Katubedda, Sri Lanka
gamagedeshani@gmail.com

Keywords—polyester fiber, fiber reinforcement, paver block, compressive strength, tensile splitting strength

A. Introduction

The textile industry contributes significantly to global environmental pollution, generating over 110 million tons of waste annually [1], with severe consequences for the environment. Out of Textile and apparel waste, when Textile waste fibers are considered, both pre-consumer and post-consumer wastes, present a massive challenge. Despite the potential for recycling, the rates remain low [2]. In this project, the focus is on repurposing textile waste fibers as a reinforcement material for pedestrian walkway paving blocks, addressing both waste management and paving block performance. By utilizing polyester waste fibers and recycled polyester waste fibers, the study aims to create a new market for fiber waste, benefiting multiple industries and the environment. The project's significance lies in reducing the environmental impact of the textile fiber-related industry in Sri Lanka, where textile waste is a major problem. However, challenges in recycling certain fiber types exist, and more research is needed to optimize the process and improve the performance and durability of fiber-reinforced cement paving blocks. Implementing this approach can lead to a circular economy, reduced waste management costs, and decreased greenhouse gas emissions.

This research involved an extensive experimental program, investigating the effectiveness of short random fibers (2-4 mm in length) from polyester waste and recycled polyester waste [3]–[5], at different weight volume contents (0.5%, 0.75%, and 1% by weight of the cement mixture) [3], [4], as reinforcement for cement paving blocks.

Mechanical and durability properties such as compressive strength, weight reduction, tensile splitting strength, and water absorption were evaluated to determine the optimal fiber volume content and the best fiber for reinforcement between polyester waste fiber and recycled polyester waste fiber. The findings demonstrated the feasibility of using these textile waste fibers in cement paving block production. Comparing the results with conventional cement paving blocks, both polyester waste fiber and recycled polyester waste fiber reinforced blocks showed a significant improvement in compressive strength, with the best outcome achieved at a fiber volume content of 0.75% in polyester waste fiber-reinforced cement paving blocks.

In summary, the project addresses the environmental issues caused by the textile industry's waste and aims to repurpose fiber waste as reinforcement for paving blocks. By using polyester and recycled polyester waste fibers, the study can create a new market and benefit both the textile industry and construction industry, while also reducing environmental pollution and saving natural resources in Sri Lanka [6]. The approach aligns with the demand for sustainable products and offers economic and environmental benefits for various industries.

B. Literature Review

Gannoruwa et al. [7] explore the utilization of discarded polyester spandex fabric in combination with cement to produce paving blocks for footpaths in Sri Lanka. The study reveals enhancements in various properties such as compressive strength, splitting tensile strength, water permeability, and walking comfort. A study conducted by Lv et al. [8] focuses on examining the impact of waste polyester fabric blocks on the strength and mechanical behavior of sand reinforced with cement. The findings indicate that the incorporation of fabric blocks increases both peak and residual shear strengths of cemented sand and alters its brittle nature, rendering it more ductile. A comprehensive analysis of fabric waste recycling techniques, applications, and challenges is presented in the study of Dissanayake et al. [9]. It highlights the adoption of a national fabric waste management policy and the establishment of a fabric waste recycling facility in Sri Lanka as examples.

Most of the research that is done to utilize textile waste as previously mentioned [7]–[9] is done by utilizing fabric waste but not textile fiber waste. Therefore, there’s a research gap in utilizing textile waste fibers in fiber-reinforced cement paving blocks as a remedy for textile waste disposal. The existing literature on the use of textile waste in cement paving blocks

mainly focuses on the incorporation of textile fabric waste in the form of pieces or blocks. However, the use of textile waste fibers, especially polyester and recycled polyester fibers, has not been adequately investigated. Therefore, there is a research gap to explore the feasibility and effectiveness of using textile waste fibers as reinforcements of cement-based materials. Determining the ideal amount and length of basalt fibers in concrete is crucial as it impacts the workability, strength, and toughness of the material. Excessive or excessively long fibers can lead to issues such as balling and segregation problems [10], [11].

The interaction between various types of fibers and their combinations in concrete can significantly affect the rheological, mechanical, and durability properties of the material. Certain fibers may have negative effects on one another or on the cement matrix itself [12]–[15]. Therefore, according to Saha [10] Bheel [11] Anas et al. [12] Pichardo et al. [13] Bagher Shemirani [14], and Hadeed et al. [15] it is clear that it is important to find the optimum mixing ratios of fibers when it is adding to the cement mixture and also find the compatibility of different fibers with the cement mixture.

Therefore, there's a research gap in finding the optimum fiber mixing ratios when reinforcing textile fibers in cement paving blocks. Further research in these areas could help improve the performance and durability of fiber-reinforced cement paving blocks and make them more attractive for a broader range of applications.

C. Materials and Methods

The study utilized fibers collected from textile fiber-related industries in Sri Lanka, which funded the project. The utilized fiber waste types are polyester fiber waste: 7D 64mm long hollow fibers and 150D/75f 70mm long recycled polyester waste fibers. Though it was given as 2 - 40mm in literature, due to the cutting limitations and enhancement of bridging activity, the fibers were manually cut using scissors to an average length of 40mm. Different fiber packets were created to achieve 0.5%, 0.75%, and 1% fiber content in the cement mixture. Plastic fiber molds with the dimensions of 100*200*80mm were used for fabricating paving blocks.

The cement mixture was prepared by mixing cement, finer aggregates, coarser aggregates, and sand in a ratio of 1:0.6:6:5 using a cement mixer. Fibers of both types were separately mixed in 0.5%, 0.75%, and 1% of the mixture. The mixture was filled to the mold in three layers and was compacted in layers using a vibrating table to remove air bubbles and ensure strong particle cohesion. Due to the higher volume occupied by the fibers due to the crimp nature, the excess amount of the mixture is removed such that the weight fraction of each component is kept constant. After 24 hours, the blocks were removed from the molds, labeled, and immersed in water for 28 days for curing.

D. Results and Discussion

Table 1 Important performance measures specified in codes of practice.

Requirement	BS EN 1338:2003	ASTM C936	Sri Lanka 1425 (2011)
Compressive Strength (MPa)	-	≥ 55.2	Class A – 50N/mm^2 Class B – 40N/mm^2 Class C – 30N/mm^2 Footpath – 15N/mm^2
Tensile Splitting Strength (MPa)	≥ 3.6	-	-
Water Absorption Test (%)	-	≤ 5	≤ 6

The tests have done according to the standards mentioned in Table 1. According to the test results, the weight of the fiber-reinforced cement paving blocks was significantly less than the conventional cement paving block. The higher the volume of fibers added, the lighter the paving blocks became. Lighter blocks offer advantages like easy transportation, handling, installation, and improved durability due to reduced dead load. The compressive strength test showed that all samples met the required strength according to the Sri Lankan standards for footpath paving blocks. Fiber-reinforced cement paving blocks have increased the compressive strength immensely and the best performance was observed in blocks reinforced with 0.75% polyester fiber waste.

The strength-to-weight ratio of fiber-reinforced cement paving blocks was very high and significant so higher strength could be achieved with a lower volume of materials used and the highest strength-to-weight ratio was showed by 0.75% polyester fiber-reinforced cement paving blocks. However, the split tensile strength of fiber-reinforced cement paving blocks was lower than that of conventional blocks due to the presence of voids in between components. Nevertheless, when considering fiber-reinforced cement paving blocks, the higher the fiber content, the higher the splitting tensile strength achieved. Water absorption of the fiber-reinforced cement paving blocks failed due to the trapping of water molecules inside the voids present because of the bulky nature of fibers. However, it was clear it has not affected the most significant property of compressive strength of fiber-reinforced cement paving blocks. The summary of the test results have included in the Table 2.

Table 2 Summary of the test results

Type of the Paving Block		Avg Weight of the Paving Block	Avg Compressive Strength (MPa)	Avg Tensile Splitting Strength (MPa)	Water Absorption Percentage (%)
Polyester	P 1%	1.871	36.2	1.6	8%
	P 0.75%	2.151	41.9	1.5	11%
	P 0.5%	2.436	29.3	1.1	21%
Recycled polyester	RP 1%	2.119	37.6	1.7	13%
	RP 0.75%	2.299	36.5	1	16%
	RP 0.5%	2.476	28.1	0.8	18%
Normal	N	3.005	33	3.7	4%

E. CONCLUSION

Though the intention was to embed waste textile fibers in cement paving blocks as a practical method of waste disposal, it also improved the prominent properties of the cement paving blocks by reinforcing them. Therefore, we have achieved the aims and objectives of the project successfully. Overall, polyester waste fiber-reinforced cement paving blocks with an optimal fiber weight of 0.75% showed the best performance in terms of strength-to-weight ratio and compressive strength. The fiber-reinforced cement paving blocks show immense results in the most significant property of compressive strength.

To address the reduction of tensile splitting strength of fiber-reinforced cement paving blocks, the use of the compression method during fabrication instead of a vibration table and adding a binding agent was suggested. Moreover, to reduce water absorption, adding a waterproof coating and using the compression method for fabrication can be used. The study faced challenges in cutting fibers to precise lengths, but this can be overcome through the development of mechanical equipment for fiber cutting. Moreover, further tests can be followed to investigate the durability and the finishing of the fiber-reinforced cement paving blocks.

REFERENCES

[1] B. Ütebay, P. Çelik, and A. Çay, "Textile Wastes: Status and Perspectives," in Waste in Textile and Leather Sectors, IntechOpen, 2020. doi: 10.5772/intechopen.92234.

[2] A. Villanueva, L. Delgado, Z. Luo, P. Eder, A. Sofia Catarino, and D. Litten, "Study on the selection of waste streams for end-of-waste assessment. Final Report", doi: 10.2791/41968.

[3] Y. M. Ghugal, "Performance of extruded Polyester Fibre Reinforced Concrete." [Online]. Available: https://www.researchgate.net/publication/30600029 8

[4] H. Toutanji, "Chloride permeability and impact resistance of polypropylene-fiber-reinforced silica fume concrete," Elsevier, vol. 28, no. 7, pp. 961–968, 1998.

[5] E. Lglm and D. Alwis AAP, "Waste flow analysis in textile and apparel sector, A case study of textile and apparel wet processing industries in Sri Lanka," 2021.

[6] A. Chandel, T. Shah, T. Shah, and D. Varde, "A Comparative Strength Study of Coir Fibre Reinforced Concrete (CFRC) Over Plain Cement Concrete (PCC)," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN, vol. 13, no. 2, pp. 101–103, doi: 10.9790/1684-130201101103.

[7] G. K. B. M. Gannoruwa, S. M. A. Nanayakkara, and S. S. K. Muthurathna, "Utilization of Textile Waste in Development of Interlocking Paving Blocks for Foot Paths," 2021, pp. 543–554. doi: 10.1007/978- 981-15-7222-7_44.

[8] X. Lv and H. Zhou, "Shear Characteristics of Cement-Stabilized Sand Reinforced with Waste Polyester Fiber Fabric Blocks," Advances in Materials Science and Engineering, vol. 2019, pp. 1–12, Jul. 2019, doi: 10.1155/2019/3758413.

[9] D. G. K. Dissanayake and D. U. Weerasinghe, "Fabric Waste Recycling: a Systematic Review of Methods, Applications, and Challenges," Materials Circular Economy, vol. 3, no. 1, p. 24, Dec. 2021, doi: 10.1007/s42824-021-00042-2.

[10] S. Saha, "A Short Review on the Utilization of Basalt Fibres in Concrete," 2022, pp. 590–597. doi: 10.1007/978-3-030-83719-8_51.

[11] N. Bheel, "Basalt fiber-reinforced concrete: review of fresh and mechanical properties," Journal of Building Pathology and Rehabilitation, vol. 6, no. 1, p. 12, Dec. 2021, doi: 10.1007/s41024-021-00107-4.

[12] M. Anas, M. Khan, H. Bilal, S. Jadoon, and M. N. Khan, "Fiber Reinforced Concrete: A Review," in ICEC 2022, Basel Switzerland: MDPI, Sep. 2022, p. 3. doi: 10.3390/engproc2022022003.

[13] P. P. Pichardo, G. Martínez-Barrera, M. Martínez- López, F. Ureña-Núñez, and L. I. Ávila-Córdoba, "Waste and Recycled Textiles as Reinforcements of Building Materials," in Natural and Artificial Fiber- Reinforced Composites as Renewable Sources, InTech, 2018. doi: 10.5772/intechopen.70620.

[14] A. Bagher Shemirani, "Effects of Fiber Combination on the Fracture Resistance of Hybrid Reinforced Concrete," Iranian Journal of Science and Technology, Transactions of Civil Engineering, vol. 46, no. 3, pp. 2161–2172, Jun. 2022, doi: 10.1007/s40996-021-00703-x.

[15] M. Hadeed, A. M. Humad, and M. Al-Gburi, "Utilization of hybrid fibers in different types of concrete and their activity," J Mech Behav Mater, vol. 32, no. 1, Feb. 2023, doi: 10.1515/jmbm-2022-0262.