JOURNAL OF ADVANCED INDUSTRIAL TECHNOLOGY AND APPLICATION
e-ISSN: 2716-7097

JAITA

Vol. 5 No. 1 (2024) 83-92
https://publisher.uthm.edu.my/ojs/index.php/jaita

Compressive Strength of Paver Block Using Rubber Tyre Waste and Bamboo Fibre Under Extreme Conditions

Avelin Grace Chandra Bose[1,4], Tuan Noor Hasanah Tuan Ismail[1,2]*, Noor Khazanah A Rahman[1], Chan Chee Ming[1,2], Hazri Mokhtar[3], Nur Faezah Yahya[1], Suraya Hani Adnan[1,2]

[1] *Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Kampus Pagoh, 84600, Muar, Johor, MALAYSIA*
[2] *Sustainable Engineering Technology Research Centre (SETechRC), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Kampus Pagoh, 84600, Muar, Johor, MALAYSIA*
[3] *Civil Engineering Technology and Chemical Engineering Technology, Laboratory Management Office, Universiti Tun Hussein Onn Malaysia, Kampus Pagoh, 84600, Muar, Johor, MALAYSIA*
[4] *M&M Construction Sdn. Bhd., No. 29, Jalan Sierra 10/2, Bandar 16 Sierra, 47120 Puchong, Selangor, MALAYSIA*

*Corresponding Author: hasanah@uthm.edu.my
DOI: https://doi.org/10.30880/jaita.2024.05.01.010

Article Info

Received: 28 March 2024
Accepted: 4 June 2024
Available online: 23 June 2024

Keywords

Paver block, rubber tyre waste, bamboo fibre, compressive strength, environmental condition

Abstract

The utilisation of by-products in paver block production has gained significant attention due to its potential in environmental condition. This research investigates the effect of incorporating rubber tyre waste and bamboo fibre into the fabrication of paver block on compressive strength, water absorption, density and ultrasonic pulse velocity tests. This research comprises two batches of paver blocks fabrications following a 1:2:3 ratio (cement: fine aggregate: coarse aggregate). Batch 1 involves the fabrication of paver blocks by incorporating varying percentages of rubber tyre waste (0, 10, 20, 30, 40 and 50%), which replace a portion of the sand (referred to as rubber paver block). In Batch 2, various dosages of bamboo fibre, used as a reinforcement material were added to the paver block containing 40% rubber tyre waste, which are referred to as rubber-bamboo fibre paver blocks. Nevertheless, the compressive strength of the rubber-bamboo fibre paver blocks was further examined under two simulated environmental conditions: (1) air and dry cycle, and (2) wet and dry conditions. These conditions aim to assess the block's resistance to temperature fluctuations, moisture effects, and their overall durability. The strength of the paver blocks decreases with the additional inclusion of rubber tyre waste. While the utilisation of 0.3% bamboo fibre has shown improvement in its strength performance compared to 0.2% and 0.4%. It suitable to used for non-loading structural applications that require strength below 25 kPa. This study was able to promote sustainable and green construction materials for paving applications through the efficient recycling of waste materials. It aligns with Sustainable Development Goals (SDG) 9 (Industry, Innovation, and Infrastructure) and 11 (Sustainable Cities and Communities).

1. Introduction

Paver blocks have become more popular in the road construction industry than bitumen, particularly in urban areas. In numerous nations, including Indonesia, Malaysia and Brunei, paving blocks are utilised for a variety of purposes, including airplane hard standing, parking lots, bicycle lanes, home drives, factory floors, industrial pavements, paving for unusual loads, pedestrian areas, low-speed and medium-speed highways, and service areas [1]. Due to operational, floor, and environmental constraints, pavers are typically employed as problem-solving techniques for existing pavement in less stable regions [2]. Additionally, paver block offers a host of benefits, including quick installation, ease of handling, exceptional drainage capacity, reduced building time, and quick production. Technologies for paver blocks are reliable, adaptable, aesthetically pleasing, practical, and cost-efficient [3]. Unfortunately, traditional paver blocks cannot withstand extreme environmental conditions. Chong et al. (2020) reported that the temperature conditions can have an impact on paving block performance and can contribute to potential problems such as thermal expansion cracking and breaking. Kanawad (2018) stated that paving blocks subjected to high temperatures, such as under direct sunlight, can experience thermal expansion. Excessive thermal expansion can lead to the development of gaps or joint openings between the blocks, compromising the interlocking system and reducing overall stability. However, traditional paving blocks can be prone to cracking and breaking over time, which can lead to costly repairs and replacements. Therefore, it is important to find an alternative way to ensure that the paver blocks can perform well under extreme environmental conditions, such as air and dry cycles, and wet and dry conditions.

Currently, there has been an increasing emphasis on utilizing by-products as alternatives construction materials, aimed at reducing dependence on natural resources, enhancing material performance, and promoting sustainable solutions replacement for traditional materials and natural resources. Industrial waste that would otherwise be disposed of as harmful environmental pollutants is frequently used as a replacement for cement or aggregate in paver blocks. Industrial by-products or solid wastes are quickly replacing other aggregates in paver blocks due to environmental and economic factors [4]. Therefore, there is a growing need to develop a way to recycle construction industry by-product materials and use them in civil engineering applications [4]. An example includes the utilisation of industry by-products such as rubber tyre waste and bamboo fibre. Recent statistics in Malaysia indicated that within these ten years, there has been an increase in the number of vehicles that have been registered that is greater than 100% [5]. There are currently thirteen million vehicles on the road, which results in a significant amount of waste tyres [6]. The disposal and management of rubber tyre wastes have emerged as a significant environmental concern. Rubber tyre wastes have the potential to release harmful chemicals, such as heavy metals, oils, and other toxic substances, which can contaminate soil, water, and air (Gammal, 2010). Since tyres do not biodegrade easily and take a long time to decompose, they occupy large volumes of space in landfills (Mohajerani et al., 2020; Elshazly et al., 2020). This inefficient use of land can lead to limited space for other waste disposal, urban development, agriculture, or conservation areas. Therefore, the inefficient use of land due to tyre disposal highlights the importance of exploring alternative methods such as recycling or repurposing to manage tyre waste more effectively. There has also been extensive research and development into the use of high-strength recycled tyres in certain mixtures to enhance certain engineering features [2]. All examined concrete mixtures produced flexural strength values greater than 6.5 MPa [7]. However, [8] stated the concrete containing rubber proved greater resistance to abrasion [8]. Meanwhile, bamboo fibres are natural fibres that are harvested from the bamboo tree and are used as a replacement for synthetic fibre due to their various benefits, including affordability, low density, environmental friendliness, sustainability, and biodegradability [9]. The use and development of bamboo fibre in civil engineering application has become a research hotspot due to sustainability.

Therefore, this study takes a holistic approach to using rubber waste tyres and bamboo fibre to fabricate paver blocks. Besides reducing these wastes in our environment, this combination provides an eco-friendly solution, improving flexibility, durability, and resistance to cracking, ultimately reducing maintenance needs and promoting sustainable construction practices. In this research, rubber tyre waste of 0, 10, 20, 30, 40 and 50% were used as a partial replacement for the fine aggregate in producing paver blocks. The study extended its scope by incorporating bamboo fibre as a reinforcement material in paver blocks containing a portion of 40 % rubber tyre waste, called rubber-bamboo fibre paver block. The performance of rubber tyre waste and bamboo fibre in the paver block were assessed based on the compressive strength, water absorption and density. The strength of the rubber-bamboo fibre paver block was further evaluated under simulated environmental conditions of air and dry circle (Simulate Environmental Condition 1) and wet and dry conditions (Simulate Environmental Condition 2).

2. Materials and Methods

2.1 Materials and Sample Preparation

The fabrication of alternative paver blocks involved key materials such as rubber tyre waste, bamboo fiber, ordinary portland cement, sand, and coarse aggregate, with a mixing ratio of 1:2:3 for cement, fine aggregate, and coarse aggregate. Rubber tyre waste was used as a partial substitute for sand in varying percentages of 10, 20, 30, 40, and 50%. Bamboo fiber was incorporated as a reinforcement material. Paver blocks, with dimensions of 100 mm length, 100 mm width, and 60 mm thickness, were fabricated in two batches. Batch 1 was focused on developed rubber paver blocks with different mixes of rubber tyre waste ranging from 0 to 50% with 10% intervals. In Batch 2, the fabrication of rubber-bamboo fiber paver blocks involved incorporating various ratios of bamboo fiber (0.2%, 0.3%, and 0.4% by weight of the paver block) into the mixture containing 40% rubber tyre waste, determined based on compressive strength. The performance of paver blocks from both Batch 1 and Batch 2 was assessed through compression strength, water absorption, density, and UPV tests. Additionally, the compressive strength of the rubber-bamboo fiber paver block was further evaluated under simulated aggressive environments, including air and dry cycle conditions (thermal and temperature effects) and wet and dry conditions (moisture effects). Table 1 describes the mix design of paver block.

Table 1 *Paver block mix design*

Sample Code	Cement (g)	Fine Aggregate		Coarse Aggregate (g)	Bamboo Fibre (g)	Water Cement Ratio
		Rubber Tyre Waste (g)	Sand (g)			
Batch 1						
M_{R0}	250	-	500	750	-	0.5
M_{R10}	250	50	450	750	-	0.5
M_{R20}	250	100	400	750	-	0.5
M_{R30}	250	150	350	750	-	0.5
M_{R40}	250	200	300	750	-	0.5
M_{R50}	250	250	250	750	-	0.5
Batch 2						
M_{RB0}	250	40 % of Dosage From Batch 1		750	-	0.5
$M_{RB0.2}$	250			750	3	0.5
$M_{RB0.3}$	250			750	4.5	0.5
$M_{RB0.4}$	250			750	6	0.5

Notes:
The total weight of Each Paver Block is 1.5kg
Mix of Rubber Tyre Waste: $MR0$, $MR10$, $MR20$, $MR30$, $MR40$, $MR50$
10%, 20%, 30% ,40% and 50%
Mix of Bamboo: $MRB0$, $MRB0.2$, $MRB0.3$, $MRB0.4$
0.2%. 0.3% and 0.4% (by weight of mixture)

2.2 Simulated Environment Conditions

This study simulated two environmental conditions which are air and dry condition and wet and dry condition. Air and dry conditions are paver blocks exposed to dry air which affect paver blocks under Temperature, UV light, and air. Wet and dry conditions happen when block is wet and dried by rainfall or water exposure. Paver blocks can be damaged by moisture absorption and drying cycles under such conditions. Air and dry condition were stimulation in temperature condition. Subsequently, the specimens were placed in a controlled room at room temperature, typically around 20-25°C, for 18 hours. This initial step aimed to acclimate the specimens to ambient conditions. Then, the specimens were transferred to an oven set at 75°C, where they were kept for 6 hours to simulate a dry condition. This cycle of 18 hours at room temperature followed by 6 hours in the oven was repeated for five days a week. The entire process continued for a total of 4 weeks, during which the specimens underwent a daily fluctuation between room temperature and the high-temperature drying environment, effectively simulating air and dry conditions.

The experimental procedure for wet and dry conditions commenced with the preparation of specimens. In the wetting phase, the specimens were submerged in tap water for a period of 5 days to simulate exposure to moisture or rain. Following the 5-day wet period, the specimens were transferred to an oven set at 75°C for 6 hours, representing the dry condition. Similar to the air and dry condition, this cycle of 5 days of wetting followed by 6 hours of drying in the oven was repeated. The wet and dry cycle continued for a total of 4 weeks, effectively simulating the environmental effects of exposure to rain or humidity followed by a drying period. After subjecting the paver block to extreme conditions, several physical characteristics were observed and measured.

2.3 Testing

To investigate the physical and mechanical characteristics of the Paver Block, 4 laboratory tests were conducted which compression strength, water absorption, ultra pulse velocity and density tests. A water absorption test was conducted to assess the impact of Paver Block exposure to water or humid conditions, following the guidelines of the British Standard (BS EN 1338:2003). The specimens were immersed in potable water at a temperature of (20 ± 5) °C using a vessel until a constant mass M1 was reached. The specimens were separated by at least 15 mm, ensuring a minimum of 20 mm of water above them. The minimum period of immersion was three days, and constant mass was considered reached when two weighing performed at an interval of 24 hours showed a difference in the mass of the specimen of less than 0.1%. Before each weighing, the specimen was wiped with a cloth moistened and squeezed to remove any excess water. Drying was deemed correct when the surface of the concrete became dull. Each specimen was placed inside the oven, ensuring a distance of at least 15 mm between each specimen, and dried at a temperature of (105 ± 5) °C until it reached a constant mass M2. The minimum drying period was three days, and constant mass was considered achieved when two weighing performed at an interval of 24 hours showed a difference in the mass of the specimen of less than 0.1%. The specimens were allowed to cool to room temperature before being weighed. The water absorption expression, calculating the percentage of water absorption (WA) using the difference between the considerably saturated weight and dry weight, was employed. According to Kasim and Rohim, the quality of the paver blocks increased with a decrease in the amount of water they absorbed, suggesting an improvement in their quality when the water absorption decreased.

The density measurement for paver blocks was performed to ascertain the mass per unit volume, indicating their compactness and quality. The testing procedure comprised several stages. Initially, representative samples of paver blocks were selected from the production batch, cleaned, and dried. The length, breadth, and height of each sample were precisely measured using a caliper or another measuring device. These measurements were then multiplied to determine the volume of each paver block. Subsequently, the mass of each paver block sample was measured using a scale or balance to ensure instrument accuracy and precision. The density was calculated by dividing the mass by the volume. Typically, the density value was expressed in kilograms per cubic meter (kg/m^3) or grams per cubic centimeter (g/cm^3). Multiple samples were examined to ensure representativeness, and the obtained density values were compared to desired specifications or standards to assess the quality of the paver blocks. The greatest measured resistance under axial loading was referred to as the compressive strength of the samples. Due to its simplicity, the uni-axial compression test was the most frequently employed method to evaluate the performance of paver blocks. The weight of each sample was measured after the completion of this test, typically done on the 28-day. All specimens were tested using a Semi Auto 3000kN Compression Machine. Compression testing equipment ranges were designed to consistently and reliably test various specimens. The tests were conducted in accordance with BS 8110-1:1997 compression strength test. The speed rate used ranged from 0.6 to 0.8 kN/s.

The quality of both Rubber Paver Block and Rubber-Bamboo Fibre Paver Block were investigated using ultrasonic pulse velocity (UPV) testing in accordance with BS EN 12504-4:2004. The measurement of ultrasonic pulse velocity required the use of a sending transducer and a receiving transducer. The UPV test in this research was conducted by sending an ultrasonic pulse (direct transmission method) through the Rubber Paver Block and Rubber-Bamboo Fibre Paver Block and measuring the time taken by the pulse to pass through the structure. Higher speeds suggested good product performance and consistency, as per the instruction manual for UPV test conditions, while slower speeds might indicate concrete with numerous cracks or voids. This test was performed using the direct transmission method. The distance between the transducers represented the path length, and, where appropriate, the path length measurement accuracy was ± 1%, with the accuracy reported.

3. Result and Discussion

3.1 Density of Paver Block

Figures 1 shows the density of Rubber Paver Block at 28 Days, depicting various dosages of rubber tyre waste (ranged from 10 to 50%) as a partial substitute for fine aggregate. The findings show that the density of the paver block decreased from 2417 kg/m^2 (control sample) to MR50 with an increase in rubber tyre waste dosage up to 50%. The higher rubber tyre waste component in the paver blocks is the reason for the drop in density.

J. of Advanced Industrial Technology and Application Vol. 5 No. 1 (2024) p. 83-92

Because rubber tyre waste has a lower density around 1.1 g/cm^3 than the other materials used to make paver blocks and adding rubber to the mixture may cause its density to decrease [10].

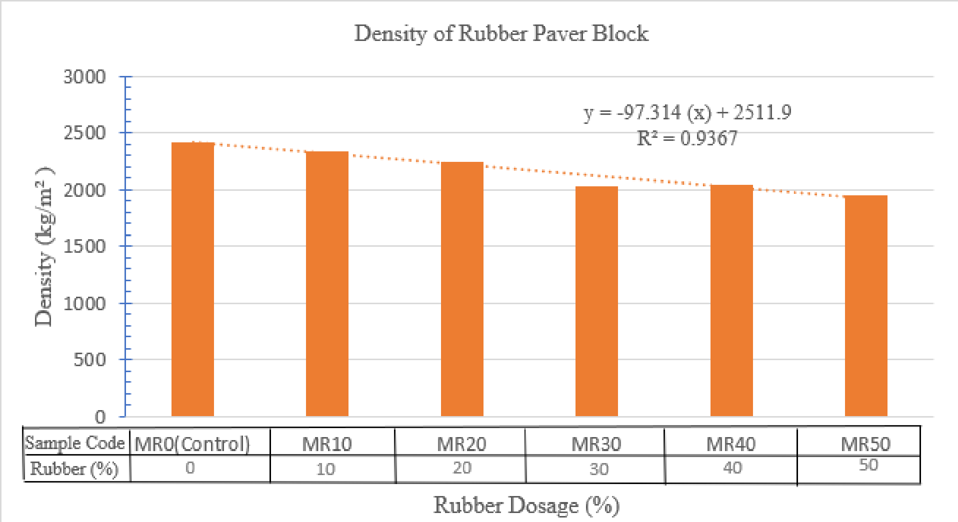

Fig. 1 *Density of rubber paver block at 28 days*

In this study, a modification was made by replacing 40% of the rubber dosage in all rubber bamboo fibre paver blocks, aiming to enhance strength by integrating bamboo fibre as a reinforcement material. Figure 2 illustrates the density of rubber-bamboo fibre paver blocks tested at 28 days and under two environmental conditions (air and dry, wet and dry). The results show a slight decrease in density with the addition of rubber MR40 and bamboo fibre dosage ranging from 0.2 to 0.4%. However, the density remains nearly identical across the range of bamboo fibre additions from 0 to 0.4% under both environmental conditions. In mixtures reinforced with bamboo fibres, it has been observed that the density decreases by 0.7% to 2.5% upon the inclusion of bamboo fibres [11].

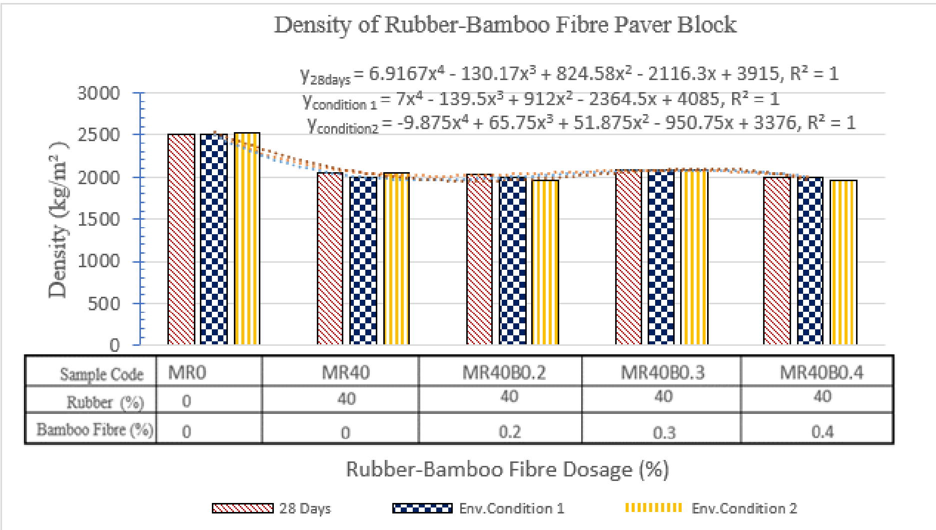

Fig. 2 *The density of rubber bamboo fibre paver blocks at 28 days of curing, under environmental condition 1 and environmental condition 2*

3.2 Water Absorption of Paver Block

Figure 3 shows the sample codes representing the water absorption findings for rubber paver blocks. MR0 (control) exhibits a water absorption rate of 3.571%. Notably, with the introduction of rubber dosage, the water absorption increases progressively. The relationship between rubber dosage and water absorption has been observed, with an increase in rubber dosage leading to a gradual rise in water absorption [12].

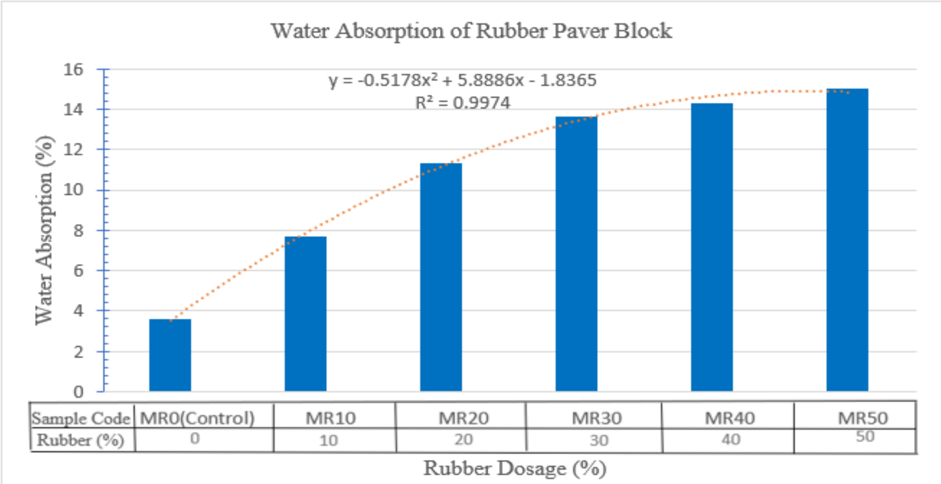

Fig. 3 *Water absorption of rubber paver block*

Rubber-Bamboo Fibre Paver Blocks were incorporated with 40% rubber tyre waste and various dosage of bamboo fibre (0, 0.2, 0.3 and 0.4%) as reinforcing materials, respectively. Figure 4 depicts the relationship between normal paver block, rubber paver block, and rubber-bamboo fiber paver block concerning water absorption. With an escalating proportion of bamboo fibre in conjunction with rubber tyre waste, there is a consistent and notable increase in water absorption. A study has reported that the addition of fibres in paver blocks can lead to higher water absorption [13].

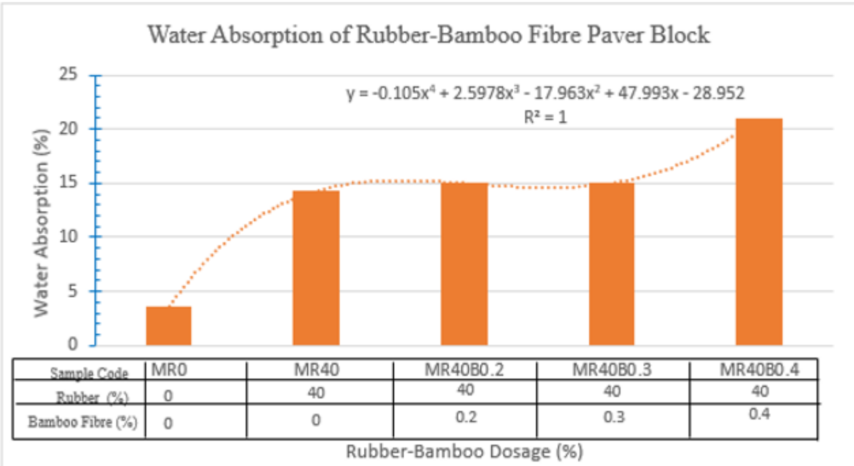

Fig. 4 *Water absorption of rubber bamboo fibre paver block*

3.3 Ultrasonic Pulse Velocity Test (UPV Test)

Table 2 shows the pulse velocity of rubber paver blocks at different rubber dosages, including MR0 (control sample, without rubber), MR10, MR20, MR30, MR40, and MR50. MR0 has pulse velocity values for three samples 3.419, 3.472, and 3.441 km/s which represent the medium concrete quality grading while MR10, MR20, MR30, MR40, and MR50 has pulse velocity values below 3.0 km/s which represent doubtful and not achieve the concrete quality grading. In concrete quality grading, a higher pulse velocity is generally associated with higher quality and strength, while slower pulse velocities generally indicate the presence of issues such as cracks or voids within the paver block [14].

Table 3 displays the pulse velocity of rubber-bamboo fiber paver blocks at different rubber-bamboo fiber dosages, including MR0 (control sample), MR40, MR40B0.2, MR40B0.3, and MR40B0.4 at 28 days of curing, under Environmental Condition 1 (air & dry) and Environmental Condition 2 (wet & dry). MR0 exhibits pulse velocity values representing medium concrete quality grading, while MR40, MR40B0.2, MR40B0.3, and MR40B0.4 have pulse velocity values below 3.0 km/s, indicating doubtful and inadequate concrete quality grading to 28 days of curing, under Environmental Condition 1 and Environmental Condition 2. The decrease in

J. of Advanced Industrial Technology and Application Vol. 5 No. 1 (2024) p. 83-92

pulse velocity with the increase in bamboo fibre percentage is attributed to factors such as fibre length, diameter, alignment, and overall mix design composition [15].

Table 2 *Pulse velocity of rubber paver block*

Rubber dosage (%)	Pulse Velocity (km/s)		
	Sample 1	Sample 2	Sample 3
M_{R0}	3.419	3.472	3.441
M_{R10}	2.395	2.438	2.396
M_{R20}	2.394	2.384	2.407
M_{R30}	2.091	2.052	2.113
M_{R40}	1.631	1.633	1.663
M_{R50}	1.625	1.635	1.649

Table 3 *Pulse velocity of rubber-bamboo fiber paver block*

Conditions	Rubber-Bamboo fiber dosage (%)	Pulse Velocity (km/s)		
		Sample 1	Sample 2	Sample 3
28 days curing	M_{R0}	3.419	3.472	3.441
	M_{R40}	1.631	1.633	1.663
	$M_{R40B0.2}$	1.834	1.814	1.795
	$M_{R40B0.3}$	1.867	1.894	1.894
	$M_{R40B0.4}$	1.750	1.712	1.771
Air and dry circle (Simulate Environmental Condition 1)	M_{R0}	3.222	3.222	3.162
	M_{R40}	1.637	1.655	1.676
	$M_{R40B0.2}$	1.908	1.882	1.911
	$M_{R40B0.3}$	1.869	1.872	1.893
	$M_{R40B0.4}$	1.780	1.772	1.818
Wet and dry circle (Simulate Environmental Condition 2).	M_{R0}	3.164	3.077	3.096
	M_{R40}	2.002	2.008	1.988
	$M_{R40B0.2}$	2.013	1.993	1.991
	$M_{R40B0.3}$	1.857	1.829	1.812
	$M_{R40B0.4}$	1.800	1.763	1.761

3.4 Compressive Strength of Paver Block

Figure 5 shows the compressive strength values for rubber of paver blocks with various rubber dosage at 28 days. A dramatic decrease in compressive strength was observed as the rubber dosage increased in the paver block mixture, particularly noticeable when the rubber dosage exceeded 40% (sample MR40). These findings show that the Rubber Paver Blocks do not meet the standard requirement even for the lower grade (grade 20). The weakening of Rubber Paver Block is attributed to the presence of rubber tyre waste. This is primarily caused by inadequate adhesion between the rubber particles and the cement [17], resulting in insufficient bond within the rubber-to-cement mix.

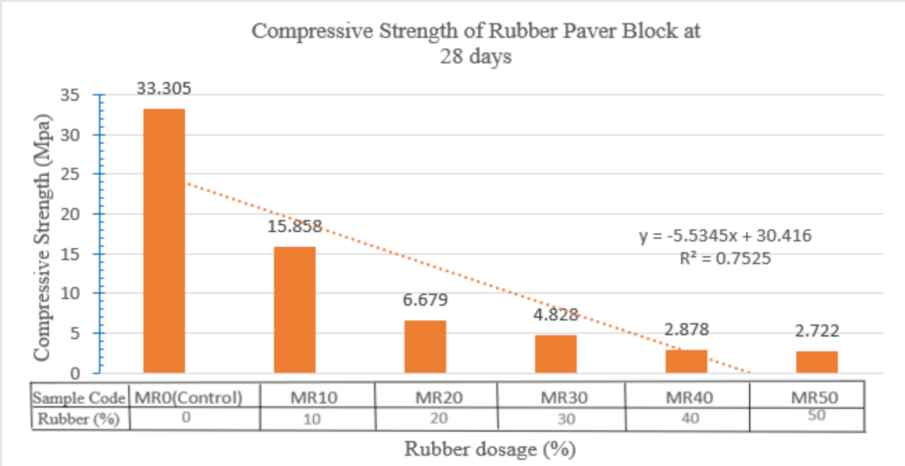

Fig. 5 *Compressive strength of rubber paver block at 28 days*

Figure 6 shows the compressive strength of rubber-bamboo fibre paver block at 28 days. MR0 (control sample) displays a compressive strength of 33.305 MPa. The compressive strength significantly decreased with the addition of 40% rubber dosage. A substantial decrease of 91% in compressive strength is observed compared to the control sample. Further modifications involve the addition of bamboo fibre alongside the 40% rubber dosage, which showed a slight improvement in compressive strength when bamboo fibre was added to the paver block, up to 0.3% (3.628 MPa), but it did not yield a significant effect on compressive strength. The fibres act as a reinforcement network, distributing stress and preventing the development of cracks [15].

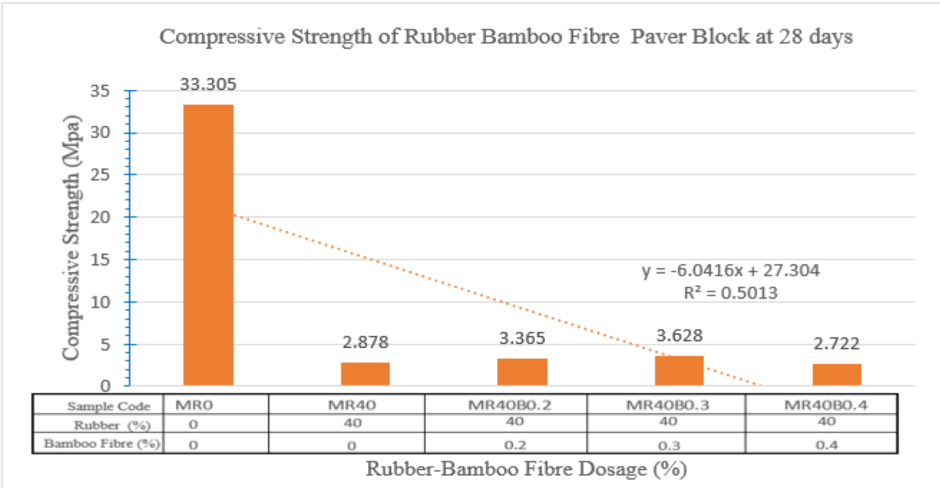

Fig. 6 *Compressive strength of rubber bamboo fibre paver block at 28 days*

Figure 7 illustrates the impact of environmental condition 1 (Air & Dry) on the compressive strength of rubber-bamboo fibre paver. The addition of 40% rubber dosage results in a significant 90% decrease in compressive strength compared to the control sample. However, incorporating a bamboo fibre dosage of 0.3% as a reinforcing material in MR40B0.3 shows a positive effect on compressive strength, indicating improvement. However, there is a positive change in strength observed in environmental condition 1 compared to the strength after 28 days of curing, the Rubber-Bamboo Fibre Paver Block does not achieve the prescribed minimum strength (grade 20) of paver block. Environmental Condition 1 (Air & Dry) shows a slight enhancement compared to Rubber Bamboo Fibre Paver Block M40, potentially due to the expedited strength development caused by higher curing temperatures during the drying process in the oven [16].

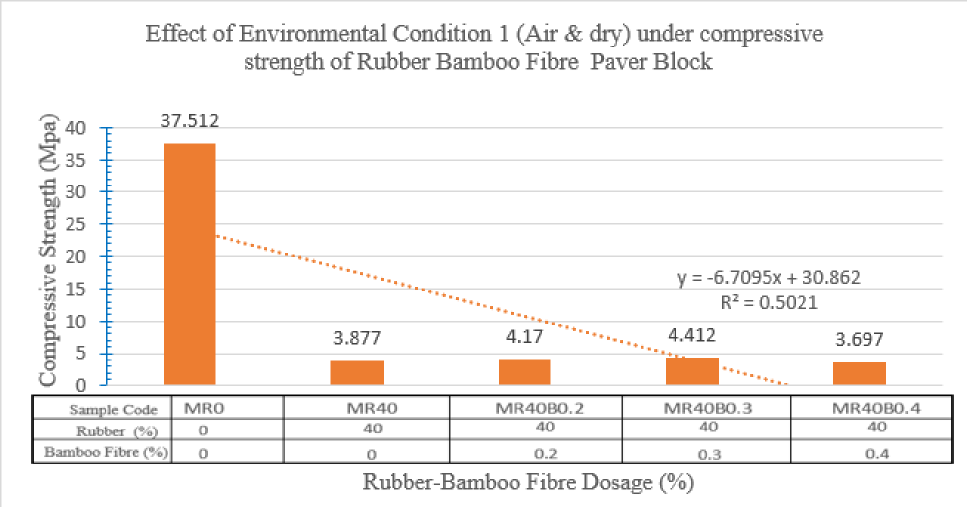

Fig. 7 *Effect of environmental condition 1 (air & dry) under compressive strength of rubber bamboo fiber paver block*

Figure 8 shows the effect of environmental condition 2 (wet & dry) under compressive strength of rubber bamboo fibre paver block. MR0 (control) demonstrates a compressive strength of 33.485 MPa. With the addition of 40% rubber dosage, a substantial 90% decrease in compressive strength is observed compared to the control sample. Environmental Condition 2 (Wet & Dry) demonstrates a slight improvement compared to the rubber bamboo fibre paver block M40, despite the inherent decrease in strength contributed by rubber dosage. However, there is not much improvement compared to the strength after 28 days of curing. The improvement in compressive strength under wet and dry conditions may be explained by the possibility that the oven drying process accelerated the strength development. This is because higher curing temperatures generally speed up the material's strength gain [16].

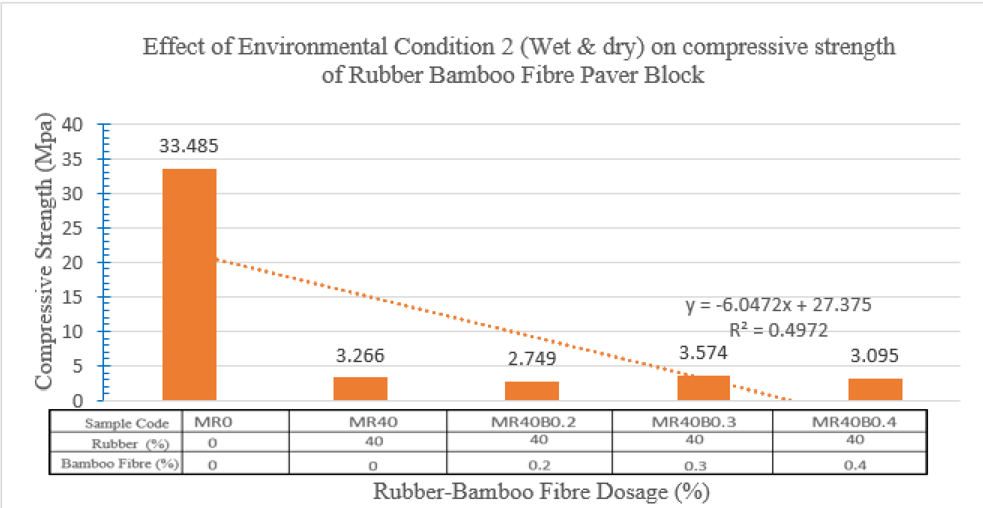

Fig. 8 *Effect of environmental condition 2 (wet & dry) under compressive strength of rubber bamboo fibre paver block*

4. Conclusion and Recommendation

The study revealed that increasing rubber and bamboo fibre dosage led to decreased density, potentially resulting in more porous blocks. Water absorption tests indicated that both rubber and rubber-bamboo blocks exceeded the acceptable limit, attributing it to the characteristics of rubber tyre waste and bamboo fibres. Pulse velocity values for both types of blocks showed a decrease below 3.0 km/s, indicating doubtful quality. Moreover, the results show that the compressive strength decreases with increasing rubber-tyre waste up to 50%, while their strength increases with inclusion of the bamboo fibre in the paver block mixture. However, this can still be used for non-loading structural applications that require strength below 25 kPa. The performance of the rubber-bamboo fiber paver blocks did not show significant change under various environmental conditions.

Based on this study, some recommendations for future studies and experimental work have been provided to enhance the knowledge and findings in these studies, which are:

1. Further research should focus on identifying the optimum percentage of bamboo fibres to achieve the highest compressive strength. This can involve fine-tuning the mix composition and assessing the material's response under different conditions and conduct trials with higher bamboo fibre percentages to assess any positive effects on performance.
2. The optimal dosage of rubber in the paver block mix may vary depending on the specific study and conditions. It is recommended to conduct further research to determine the optimal rubber dosage that provides the best balance between strength and crack resistance.
3. Ensure that the materials used in the paver block production process are of high quality and properly prepared. This may include using appropriate curing techniques, ensuring proper mixing of materials, and controlling the moisture content in the mix.
4. The study on crack formation in the paver blocks presents an opportunity for targeted improvement. Exploring potential reinforcement methods or materials may enhance the block's resistance to cracking. A continuous monitoring and documentation process over time will provide valuable insights into the effectiveness of implemented solutions and further guide refinements in addressing the identified problems.

Acknowledgment

The authors thank the Department of Civil Engineering Technology and the Sustainable Engineering Technology Research Centre (SETechRC) at Universiti Tun Hussein Onn Malaysia (UTHM) for their support. Special thanks to M&M Construction Sdn. Bhd. for their collaboration.

Conflict of Interest

The authors declare no conflict of interest.

Author Contribution

Avelin Grace Chandra Bose: conceptualization, methodology, writing. Tuan Noor Hasanah Tuan Ismail: ***supervision, review****. Noor Khazanah A Rahman:* ***data curation, analysis****. Chan Chee Ming:* ***project administration, funding****. Hazri Mokhtar:* ***resources, validation****. Nur Faezah Yahya:* ***investigation, visualization****. Suraya Hani Adnan:* ***software, data analysis****.*

References

[1] Ismail, T. N. H. T, Wahab, M. F. A., Adnan, S. H., Kusbiantor, A., Hassan, N. N. M., ... & Jusoh, W. A. W. (2023). Development Of Sustainable Interlocking Pavement Block (SIPB) Using High-Density Polyethylene (HDPE) And Recycled Asphalt Pavement (RAP). Malaysian Construction Research Journal, 39(1), 107-116.

[2] Jusli, E., Nor, H. M., Jaya, R. P., Haron, Z., & Mohamed, A. (2016). A Review of Double Layer Rubberized Concrete Paving Blocks. Journal of Engineering Research and Technology.

[3] Mudjanarko, S. W., Limantara, A. D., Mayestino, M., Sutrisno, A. E. A., Ibrahim, M. H. W., & Wiwoho, F. P. (2020, July). The Utilization of Bamboo Innovation as Aggregate Substitute for Paving Block. In Journal of Physics: Conference Series IOP Publishing.

[4] Ling, T. C., Nor, H. M., & Lim, S. K. (2010, February). Using recycled waste tyres in concrete paving blocks. In Proceedings of the Institution of Civil Engineers-Waste and Resource Management, 163(1), pp. 37-45. Thomas Telford Ltd.

[5] Chan, D. (2022). Vehicles outnumber people in Malaysia. New Straits Times.

[6] Chai, L. T. (2008). Engineering Properties and Structural Performance of Rubberized Concrete Paving Blocks (Doctoral dissertation, Universiti Teknologi Malaysia).

[7] Binici, H., Shah, T., Aksogan, O., & Kaplan, H. (2008). Durability of concrete made with granite and marble as recycle aggregates. Journal of materials processing technology.

[8] da Silva, F. M., Barbosa, L. A. G., Lintz, R. C. C., & Jacintho, A. E. P. (2015). Investigation on the properties of concrete tactile paving blocks made with recycled tyre rubber. Construction and Building Materials.

[9] Hengl, H. L., Kluger-Eigl, W., Blab, R., & Füssl, J. (2018). The performance of paving block structures with mortar filled joints under temperature loading, accessed by means of numerical simulations. Road Materials and Pavement Design.

[10] Faizah, R., Priyosulistyo, H., & Aminullah, A. (2019, October). The Properties of Waste Rubber Tyres in Increasing the Damping of Masonry Wall Structure. In IOP Conference Series: Materials Science and Engineering, Vol. 650 (1), pp. 012041. IOP Publishing.

[11] Maier, M., Javadian, A., Saeidi, N., Unluer, C., Taylor, H. K., & Ostertag, C. P. (2020). Mechanical properties and flexural behavior of sustainable bamboo fiber-reinforced mortar. Applied Sciences, 10(18), 6587.
[12] Gamage, S., Palitha, S., Meddage, D. P. P., Mendis, S., Azamathulla, H. M., & Rathnayake, U. (2022). Influence of crumb rubber and coconut coir on strength and durability characteristics of interlocking paving blocks. Buildings.
[13] Rao, K. M. M., & Rao, K. M. (2007). Extraction and tensile properties of natural fibers: Vakka, date and bamboo. Composite structures, 77(3), pp. 288-295.
[14] Ling, T. C., & Nor, H. M. (2006, September). Granulated waste tyres in concrete paving block. In Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference, Kuala Lumpur, Malaysia, pp. 5-6.
[15] Gao, X., Zhu, D., Fan, S., Rahman, M. Z., Guo, S., & Chen, F. (2022). Structural and mechanical properties of bamboo fibre bundle and fibre/bundle reinforced composites: A review. Journal of Materials Research and Technology, 19, pp. 1162-1190.
[16] El Nouhy, H. A., & Zeedan, S. (2012). Performance evaluation of interlocking paving units in aggressive environments. HBRC Journal.
[17] Bharathi Murugan, R., Rama Sai, E., & Natarajan, C. (2019). Impact Response of Paver Blocks with Waste Tyre Crumb Rubber. In Recent Advances in Structural Engineering, Volume 1: Springer Singapore.