

Utilising Polyethylene Terephthalate (Pet) as Green Materials in Concrete

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Abstract

The increasing accumulation of plastic waste, especially Polyethylene Terephthalate (PET), presents a serious environmental concern due to its non-biodegradable nature and contribution to pollution. This study investigates the effectiveness of utilising PET as a green material in concrete, aiming to reduce plastic waste and promote sustainable construction practices. The research focuses on evaluating how different PET contents affect the mechanical, physical, and thermal properties of concrete, identifying its potential as an eco-friendly additive. Concrete mixes were prepared with PET contents of 0%, 0.5%, 1%, 1.5%, and 2% by volume, with PET cut into small strips to ensure uniform distribution. Laboratory tests, conducted according to relevant British Standards (BS), assessed compressive strength, split tensile strength, water absorption, and thermal conductivity. The results revealed that the mix containing 0.5% PET achieved the most balanced performance, offering improvements in both mechanical strength and thermal insulation. The findings highlight the potential of PET waste as a sustainable additive in concrete, supporting sustainable development goals (SDGs) by reducing landfill waste and enhancing building energy efficiency. By integrating recycled PET into concrete, this study promotes the concept of a circular economy within the construction industry, demonstrating an effective approach to managing plastic waste while contributing to greener, energy-efficient, and thermally comfortable building solutions.

1. Introduction

Polyethylene Terephthalate (PET) is a widely used thermoplastic polymer in the polyester family, recognised for its transparency, semi-crystalline structure, and excellent mechanical properties. Global PET production is estimated to reach approximately 70 million tonnes annually, with significant applications in textiles, packaging, and various industrial sectors (Pudack, Stepanski, & Fässler, 2020). Its recyclability has led to increasing interest in advanced applications, such as energy storage and sensing systems. In Malaysia, plastics are categorised into seven types, but only PET, High-Density Polyethylene (HDPE), and Low-Density Polyethylene (LDPE) are commonly recycled due to their economic value and ease of recovery (Deraman, Nawi, Yasin, Ismail, & Ahmed, 2021). Despite these efforts, PET waste continues to pose environmental challenges, contributing to landfill

accumulation, greenhouse gas emissions, and persistent pollution. Developing sustainable solutions for PET management is therefore essential.

Incorporating PET into cementitious materials offers a promising approach to reducing plastic waste while enhancing concrete properties. PET-modified concrete has demonstrated satisfactory mechanical performance and potential benefits for thermal regulation, making it suitable for energy-efficient construction (Sorout, Raj, Kaur, & Lamba, 2023; Ortega-Jimenez et al., 2020). However, optimal PET content must balance structural integrity, durability, and workability without compromising environmental benefits. The objectives of this research is to determine the effects of varying PET proportions on the physical, mechanical, and thermal properties of concrete. The study also identifies the optimum PET percentage that provides the best combination of strength and thermal efficiency, with potential applications in sustainable and resilient construction.

Plastic waste mismanagement has led to serious ecological and health consequences, including microplastic bioaccumulation, contamination of water bodies, and emissions of toxic compounds from open burning. PET waste, due to its low biodegradability, exacerbates these issues and poses long-term risks to ecosystems and human health (Alaloul, John, & Musarat, 2020). As one of the largest consumers of natural resources, the construction industry is well-positioned to mitigate this problem by incorporating recycled PET into concrete mixes. This approach supports the circular economy, reduces the demand for natural aggregates, lowers construction costs, and contributes to energy-efficient building designs (Joravia & Parikh, 2015; Alaloul et al., 2020).

Concrete specimens for this study were prepared with PET contents of 0%, 0.5%, 1.0%, 1.5%, and 2.0% by volume, using Ordinary Portland Cement (OPC), fine and coarse aggregates, water, and a superplasticiser (Sika® ViscoCrete®-2192), designed to achieve a target compressive strength of 25 MPa based on the Department of Environment's standards. PET strips measuring 10 mm × 5 mm were incorporated to ensure uniform distribution. Physical and mechanical properties, including water absorption, compressive and split tensile strength, and internal homogeneity, were evaluated using British Standards, while thermal conductivity was assessed using a Guarded Hot Plate following BS EN 12667:2001. Comparative analyses determined the PET content that provides optimal performance.

This research addresses two urgent global challenges, managing PET waste and promoting sustainable construction practices. PET-modified concrete offers a dual advantage by recycling plastic waste into functional structural materials and enhancing thermal insulation, reducing operational energy consumption in buildings. Identifying the optimum PET percentage ensures a balance between environmental conservation, structural reliability, and practicality, supporting the construction industry's transition toward greener and more sustainable built environments.

2. Methodology

2.1 Materials

Five primary materials were used, Ordinary Portland Cement (OPC), fine aggregates (FA), coarse aggregates (CA), clean water, and Polyethylene Terephthalate (PET) strips. OPC complied with BS 12:1996 (British Standards Institution, 1996). Aggregates were obtained locally and graded per BS EN 933-1:2012 (British Standards Institution, 2012). PET was introduced as an additive material to improve sustainability and thermal performance (Deraman, Nawati, Yasin, Ismail, & Ahmed, 2021; Halim, Taib, & Aziz, 2019). PET strips were prepared from post-consumer plastic bottles, cut manually into strips approximately 10 mm long and 5 mm wide. The strips were sieved using a 10 mm sieve to ensure consistent size, as shown in Figure 1(a). The sieved PET was stored in sealed bags before mixing (Bhogayata & Arora, 2017). A superplasticiser, Sika® ViscoCrete®-2192, shown in Figure 1(b), was used at 1% of the cement weight to improve concrete flow and prevent segregation (Shahidan, et al., 2018).



Fig. 1 (a) Sieving PET; (b) Sika® ViscoCrete®-2192

2.2 Sample Preparation

Concrete mixes were designed using the Department of Environment (DOE) method, targeting a compressive strength of 25 MPa. PET was added as an additive by volume at 0%, 0.5%, 1.0%, 1.5%, and 2.0%, while the proportions of cement, fine aggregates, coarse aggregates, and water remained unchanged across all mixes. The mix proportions for each combination are detailed in **Table 1** below.

Material (kg)	Percentage of PET (%)				
	0	0.5	1.0	1.5	2.0
Cement	8.43	8.43	8.43	8.43	8.43
Water	4.47	4.47	4.47	4.47	4.47
Fine aggregates	11.00	11.00	11.00	11.00	11.00
Coarse Aggregates	24.47	24.47	24.47	24.47	24.47
PET (strips)	0	0.231	0.462	0.693	0.924

The preparation of moulds for casting concrete specimens was carried out following BS EN 12390-1:2012, which specifies the shape, dimensions, and tolerances for test specimens and moulds (British Standards Institution, 2012). **Table 2** below shows the type and size of moulds were used. Dry materials (cement, FA, CA) were mixed manually with a shovel. Water was added gradually to the mix, and the last portion of water was included with the superplasticiser before being added to the mix. PET strips were then added gradually and mixed for 3–5 minutes for uniform distribution (Bhogayata & Arora, 2017). The concrete was poured into moulds, compacted, and left to set for 24 hours before demoulding. Following 24 hours, the specimens were taken out of their moulds and kept in a water curing tank until the day of testing (**Figure 2**) (British Standards Institution, 2019).

Testing	Type of mould	Size of Moulds
Compressive Strength Test	Cube	(100x100x100)mm
Water Absorption Test		
Thermal Conductivity Test	Panel	(300x300x20)mm
Split Tensile Strength Test	Cylinder	(Ø100x200)mm



Fig. 2 Specimens submerged in curing tank

2.3 Testing Procedures

2.3.1 Slump Test

The consistency of fresh concrete was evaluated using the slump test in accordance with BS EN 12350-2:2009. An Abrams cone with a height of 300 mm, base diameter of 200 mm, and top diameter of 100 mm was used (British Standards Institution, 2009). A 600 mm tamping rod, a non-absorbent base plate, and a ruler were employed for testing. Fresh concrete was filled into the cone in three equal layers. Each layer was compacted with 25 tamping strokes. The top surface was struck off level. The cone was then lifted vertically in 5 to 10 seconds to allow the concrete to slump. The vertical distance between the top of the cone and the highest point of the slumped concrete was measured to determine the slump height. The type of slump, whether it's true or shear slump (Figure 3), was also observed to assess workability characteristics (Shahidan, et al., 2018).

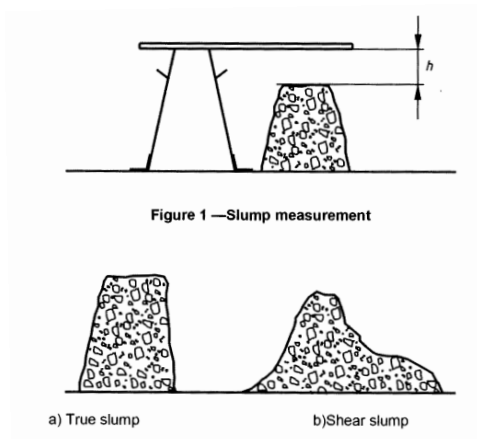


Figure 1 —Slump measurement

Fig. 3 Forms of slump

2.3.2 Compressive Strength Test

The compressive strength test was conducted to evaluate the ability of concrete specimens to resist axial compressive loads, by BS EN 12390-3:2009 (British Standards Institution, 2009). The test was carried out in the Concrete Technology Workshop using a 3000 kN compression testing machine (Figure 4).



Fig. 4 3000kN Compression Testing Machine

A total of 30 cube specimens were tested, including control samples and those with PET added at different percentages. All specimens were water-cured until testing on day 7 and day 28. Before testing, bearing surfaces were cleaned to remove dust or debris. Each cube was placed centrally on the lower platen of the testing machine. A continuous load was applied at a constant rate until specimen failure. The maximum load was recorded for strength calculation by using Equation 1 below.

$$f_c = \frac{F}{A_c} \quad (1)$$

This test was crucial in assessing the impact of PET content on the load-bearing capacity of the concrete, with strength trends helping to identify the optimum PET dosage for structural performance (Wattanavichien & Iwanami, 2024).

2.3.3 Splitting Tensile Strength Test

The splitting tensile strength test was used to determine the tensile capacity of concrete, which is inherently weak in tension. This property is essential for understanding crack resistance in structural applications. The test was performed using a 3000 kN compression testing machine in the concrete laboratory (**Figure 5**).



Fig. 5 3000kN Compression Testing Machine

The procedure followed BS EN 12390-6:2009 (British Standards Institution, 2009). A total of 15 cylindrical specimens were tested. After 28 days of water curing, specimens were removed and allowed to reach room temperature. Each cylinder was placed horizontally between the platens of the testing machine. A wooden strip was inserted along the length of the cylinder to ensure uniform load distribution and proper alignment. The load was applied gradually along the vertical diameter until failure occurred. The splitting tensile strength was calculated using Equation 2 below.

$$f_{ct} = \frac{2F}{\pi \times L \times d} \quad (2)$$

This test provided insight into the effect of PET content on concrete's ability to resist tensile-induced cracking, an important consideration for structural durability (Bhogayata & Arora, 2017)(Shahidan, et al., 2018).

2.3.4 Thermal Conductivity Test

The thermal conductivity of the concrete specimens was measured using the Guarded Hot Plate (GHP) method, by BS EN 12667:2001. This standard applies to building materials with medium to high thermal resistance and is known for providing precise, steady-state thermal property measurements (British Standards Institution, 2001). Specimens were cast in slab form, incorporating different PET contents.



Fig. 6 Guarded Hot Plate Test Machine

Before testing, all specimens were thoroughly dried to eliminate moisture, which could otherwise affect thermal performance. Each specimen was placed between two plates, a centrally heated guarded hot plate and a cooler plate (**Figure 6**). The system was allowed to reach a steady-state thermal condition. A constant heat flux was applied, and the temperature difference across the specimen was measured. Thermal conductivity, k was calculated using Equation 3 below.

$$k = \frac{Q \times d}{A \times \Delta T} \quad (3)$$

This test was crucial in assessing how PET modification influences the insulating performance of concrete for sustainable building applications (Deraman, Nawi, Yasin, Ismail, & Ahmed, 2021) (Wattanavichien & Iwanami, 2024).

2.3.5 Water Absorption Test

Water absorption test was conducted by BS 1881-122:2011, which outlines the procedure for determining the water absorption of hardened concrete (British Standards Institution, 2011). This test served as an indicator of concrete porosity and long-term durability. A total of 15 cube specimens were prepared with varying PET content. All specimens were oven-dried at $105 \pm 5^\circ\text{C}$ for at least 72 hours, or until a constant mass was achieved. After drying, specimens were cooled in an enclosed room for 24 hours to prevent atmospheric moisture absorption.

The dry weight of each specimen was recorded as W_1 . Then, the specimens were immersed in water at $20 \pm 2^\circ\text{C}$ for 30 minutes. After immersion, surface moisture was gently wiped off, and the saturated weight was recorded as W_2 . The water absorption of the samples were calculated using Equation 4 below.

$$\text{Water Absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100\% \quad (4)$$

This test helps assess how PET content affects the concrete's ability to resist moisture ingress—critical for durability in aggressive environments (Demeke Worku & Ejigu, 2024).

2.4 Data Analysis

All experimental tests were conducted in triplicate for each mix design to ensure the reliability of results. Mean values for each test were calculated and used for analysis. Data were processed, and graphs were plotted to visualise trends and performance patterns. Relationships between PET content and key performance indicators, including compressive strength, splitting tensile strength, water absorption, and thermal conductivity, were

evaluated. The optimum PET content was determined by assessing the overall mechanical and thermal performance across all test results.

3. Results and Discussion

3.1 Workability

The slump test was performed to assess the workability of concrete mixtures incorporating varying percentages of PET. As presented in **Table 3**, all mixtures exhibited a true slump, indicating cohesive and stable mixes with no signs of shear or collapse. The measured slump values fell within the medium workability range (60–180 mm), which is suitable for normal reinforced concrete construction and allows for adequate compaction without segregation (Bhogayata & Arora, 2017).

Table 3 Slump Test Results

PET (%)	Slump value (mm)	Types of Collapse	Workability	(Bhogayata & Arora, 2017)
0	78	True	Medium workability	99
0.5	71	True	Medium workability	94
1.0	64	True	Medium workability	85
1.5	66	True	Medium workability	82
2.0	63	True	Medium workability	77

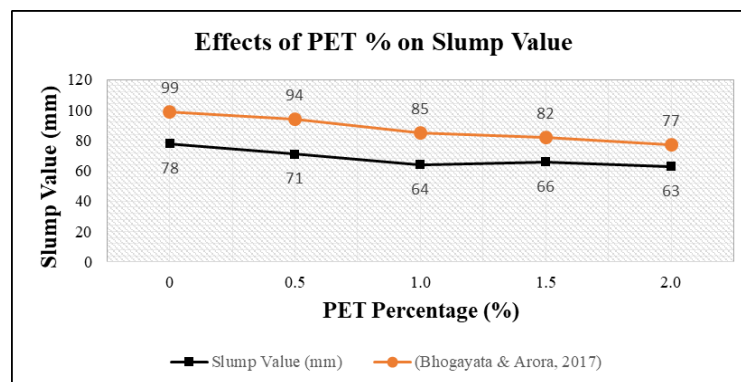


Fig. 7 Effect of PET Content on Slump Value

A consistent decrease in slump values was observed as PET content increased, ranging from 78 mm for the control mix to 63 mm for the 2.0% PET mixture. The relationship, illustrated in **Figure 7**, shows that as PET content increased to 0.5%, 1.0%, 1.5%, and 2.0%, slump values declined to 71 mm, 64 mm, 66 mm, and 63 mm, respectively. The slight recovery in the slump at 1.5% PET is likely due to experimental variation, improved PET dispersion, or temporary water retention effects. This effect was not sustained at 2.0% PET, where the slump resumed its downward trend.

When compared with the findings of Bhogayata and Arora (2017), this study recorded lower slump values despite using the same PET percentages. In Bhogayata and Arora's research, the control mix achieved a slump value of 99 mm, while the slump values decreased to 94 mm, 85 mm, 82 mm, and 77 mm for 0.5%, 1.0%, 1.5%, and 2.0% PET, respectively. The observed differences can be attributed primarily to PET dimensions. This study utilised PET strips measuring 10 mm × 5 mm, whereas Bhogayata and Arora utilised PET fibres of 10 mm × 1 mm. The larger width of the PET strips increased surface area and caused greater physical obstruction in the mix, absorbing more cement paste and restricting material flow (Bhogayata & Arora, 2017). This mesh-like configuration resulted in stiffer, less workable concrete compared with mixes using thinner PET fibres.

These findings confirm that the larger the PET size, the greater the reduction in workability, even at identical PET content, underscoring the importance of fibre dimensions when incorporating PET into concrete mixtures.

3.2 Compressive Strength Test

The compressive strength of concrete specimens was evaluated at 7 and 28 days for varying PET contents. **Table 4** presents the compressive strength results. A decreasing trend in strength was observed with increasing PET content at both curing ages.

Table 4 Compressive Strength Test Results

PET (%)	Compressive Strength, (N/mm ²)		(Bhogayata & Arora, 2017)
	7th Day	28th Day	
0%	17.66	29.09	38
0.5%	16.56	26.74	35
1.0%	16.26	22.64	32
1.5%	15.47	19.42	30.5
2.0%	14.19	15.37	29

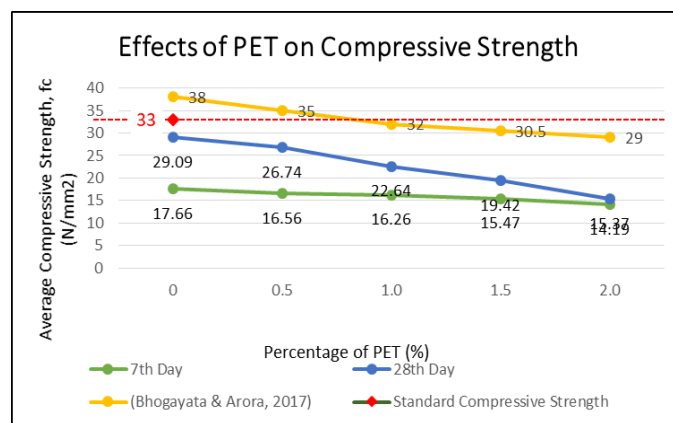


Fig. 8 Effect of PET Content on Compressive Strength

The compressive strength of PET-modified concrete was tested at 7 and 28 days to determine how PET content affects structural performance. As shown in **Table 4**, the control mix (0% PET) reached 17.66 MPa at 7 days and 29.09 MPa at 28 days. Strength consistently dropped as PET content increased. At 2.0% PET, strengths decreased to 14.19 MPa (7 days) and 15.37 MPa (28 days), representing a nearly 47% decrease compared to the target mean strength of 38 MPa. Eurocode 2 (EN 1992-1-1:2004) requires at least 33 MPa for normal structural concrete, indicating that higher PET contents are not suitable for load-bearing applications (British Standards Institution, 2004).

The reduction in strength occurs because PET is hydrophobic and chemically inert, leading to poor bonding with the cement matrix. PET particles also create more voids, weaken the interfacial transition zone (ITZ), and promote micro-cracking, reducing the concrete’s load-bearing capacity (Shahidan et al., 2018). **Figure 8** shows a clear negative correlation between PET content and compressive strength. The decline is sharper beyond 1.0% PET. These findings are similar to Bhogayata and Arora (2017), who reported a 28-day strength drop from 38 MPa (0% PET) to 29 MPa (2.0% PET). The lower strengths in this study are likely due to larger PET strips (10 × 5 mm) compared to Bhogayata’s smaller fibres (10 × 1 mm), which caused more disruption in the cement matrix (Bhogayata & Arora, 2017).

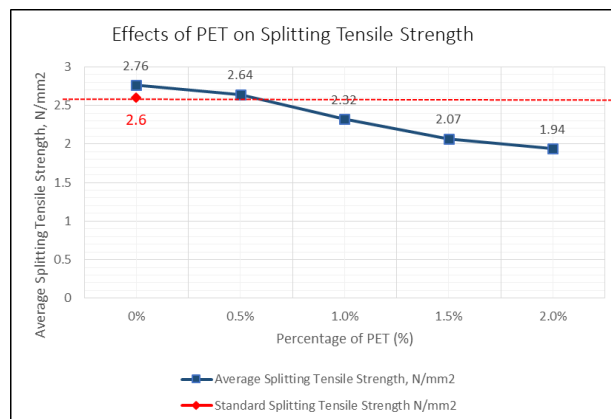
Despite the strength reduction, PET contents up to 1.0% maintained compressive strengths above 22 MPa, making them suitable for light structural and non-structural uses. PET levels of 0.5–1.0% offer a good balance between sustainability and mechanical performance (Shahidan et al., 2018).

3.3 Splitting Tensile Strength Test

The splitting tensile strength of PET-modified concrete decreased significantly with increasing PET content. The control mix achieved an average of 2.76 MPa, slightly higher than the Eurocode 2 (EN 1992-1-1:2004) requirement of 2.6 MPa (British Standards Institution, 2004). With PET inclusion, tensile strength dropped progressively to 2.64 MPa at 0.5%, 2.32 MPa at 1.0%, 2.07 MPa at 1.5%, and 1.94 MPa at 2.0% PET (**Table 5**).

Table 5 Splitting Tensile Strength Test Results

PET (%)	Splitting Tensile Strength, (N/mm ²)	(Bhogayata & Arora, 2017)
0%	2.76	2.80
0.5%	2.64	3.10
1.0%	2.32	3.30
1.5%	2.07	3.40
2.0%	1.94	3.05

**Fig. 9** Effect of PET Content on Splitting Tensile Strength

This decline occurs because PET's hydrophobic surface weakens bonding with the cement paste, creating a poor interfacial transition zone (ITZ) and increasing porosity. These factors introduce micro-voids that act as weak points under tensile stress (Shahidan et al., 2018). **Figure 9** shows this clear downward trend, with tensile strength falling below the Eurocode 2 minimum for PET contents of 1.0% and above, indicating unsuitability for structural applications without further optimisation.

These results differ from Bhogayata and Arora (2017), who reported improved tensile strength with PET fibres, peaking at 3.40 MPa at 1.5% PET before a slight decrease to 3.05 MPa at 2.0% PET. The discrepancy is mainly due to PET geometry, while this study used 10 × 5 mm strips that disrupted the matrix and increased voids, while Bhogayata's finer fibres provided better bonding and crack-bridging effects. Differences in mix design, water-to-cement ratio, and curing conditions may also contribute. These findings emphasise the importance of optimising PET type, size, and dosage to balance sustainability and mechanical performance.

3.4 Thermal Conductivity Test

The thermal conductivity of PET-modified concrete decreased significantly with increasing PET content (**Table 6**). The control mix recorded an average of 1.611 W/m·K, slightly below the BS EN 12524:2000 reference value of 1.65 W/m·K (British Standards Institution, 2000). As PET content increased from 0.5% to 2.0%, thermal conductivity dropped progressively to 1.309 W/m·K, 1.139 W/m·K, 0.829 W/m·K, and 0.507 W/m·K, respectively.

Table 6 Thermal Conductivity Test Results

PET Content (%)	Thermal Conductivity, λ (W/mK)
0	1.611
0.5	1.309
1.0	1.139
1.5	0.829
2.0	0.507

This reduction is due to PET's low thermal conductivity, weak bonding with cement paste, and the creation of micro-voids that interrupt heat flow, resulting in improved insulation. **Figure 10** illustrates a steep downward trend, with a marked decline beyond 1.0% PET. At 2.0% PET, thermal conductivity fell by 69.3% compared to the standard, demonstrating PET's strong insulating potential.

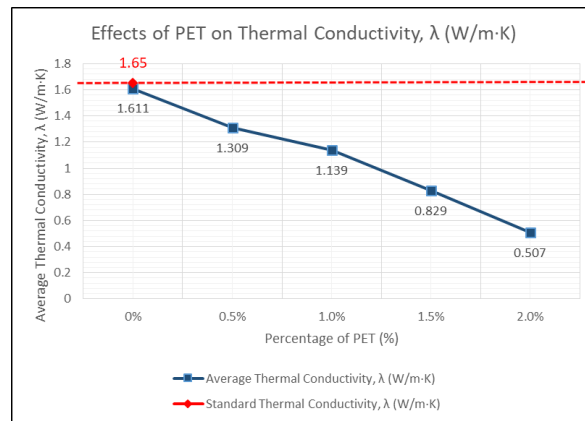


Fig. 10 Effect of PET Content on Thermal Conductivity Test

These findings confirm that PET-modified concrete can enhance thermal efficiency by reducing heat transfer through building elements, lowering heating and cooling demands, and improving indoor comfort. This makes PET-based concrete a viable option for energy-efficient and sustainable building designs (Ortega-Jimenez et al., 2020). In conclusion, while PET may reduce mechanical properties, it greatly enhances the thermal insulating performance of concrete. Its incorporation, especially at contents of 1.5% and above, can be recommended for non-structural elements where thermal efficiency is prioritised over compressive strength.

3.5 Water Absorption Test

The water absorption results in **Table 7** show a clear increase with rising PET content. The control mix recorded 2.34%, which falls within the acceptable limit for dense and durable concrete (BS 1881-122:2011). At 0.5% PET, absorption rose slightly to 2.36%, indicating minimal change at low PET levels. However, at 1.0%, 1.5%, and 2.0% PET, absorption increased sharply to 3.95%, 6.41%, and 7.99%, respectively. This corresponds to a transition from acceptable to high porosity, as values above 5% indicate poor resistance to water penetration and a greater risk of long-term environmental degradation (Demeke Worku & Ejigu, 2024).

Table 7 Water Absorption Test Results

PET (%)	Water Absorption (%)
0	2.34
0.5	2.36
1.0	3.95
1.5	6.41
2.0	7.99

This upward trend is primarily due to PET’s hydrophobic nature and poor bonding with cement paste, which increase void content and create micro-gaps within the concrete matrix. **Figure 11** illustrates the non-linear rise in absorption, with significant jumps occurring beyond 1.0% PET.

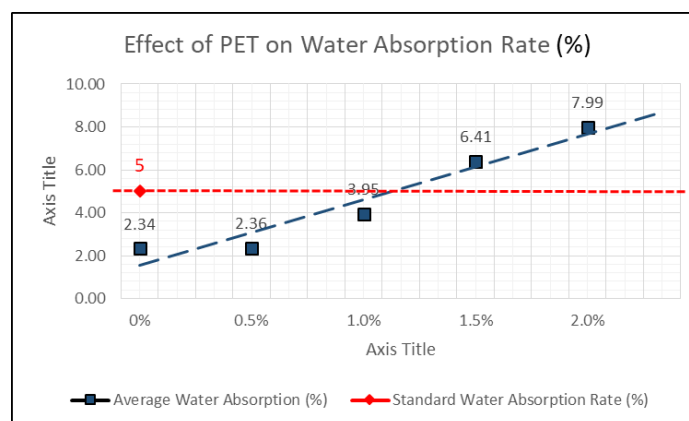


Fig. 11 Effect of PET Content on Water Absorption Test

According to standard durability classifications, water absorption values exceeding 5% indicate high porosity and reduced resistance to water ingress. Therefore, mixes with 1.5% and 2.0% PET are likely to be less durable when exposed to environmental conditions such as freeze-thaw cycles, chloride penetration, or sulphate attack. Despite these issues, PET-modified concrete containing up to 1.0% PET can still be used in non-structural indoor applications or dry environments, especially when thermal insulation or material sustainability is more important than long-term durability. However, for external or exposed structural applications, additional measures like surface sealers or supplementary cementitious materials would be required to improve resistance to moisture-related effects deterioration.

3.6 Summary of Findings

The test results in **Table 8** demonstrate that incorporating Polyethylene Terephthalate (PET) into concrete significantly affects both its fresh and hardened properties. As PET content increased from 0% to 2.0%, workability decreased, with slump values dropping from 78 mm for the control mix to 63 mm at 2.0% PET. This reduction is attributed to the hydrophobic and irregular surface characteristics of PET, which stiffen the mix and limit the ease of compaction (Bhogayata & Arora, 2017). Concurrently, the density of concrete gradually decreased from 2266.67 kg/m³ to 2133.33 kg/m³ as lighter PET replaced denser conventional aggregates, leading to a reduction in overall unit weight.

Mechanical properties showed a clear downward trend. The 28-day compressive strength declined from 29.09 N/mm² for the control mix to 15.37 N/mm² at 2.0% PET, while the splitting tensile strength decreased from 2.76 N/mm² to 1.94 N/mm². This reduction is linked to PET's inert and hydrophobic nature, which weakens bonding with the cement matrix and increases micro-void formation in the interfacial transition zone (ITZ), adversely affecting load-bearing capacity (Shahidan et al., 2018; British Standards Institution, 2004).

On the other hand, PET addition positively impacted thermal insulation properties. Thermal conductivity decreased substantially, from 1.085 W/mK in the control mix to 0.524 W/mK at 2.0% PET, indicating enhanced insulating performance. However, this benefit was accompanied by a significant rise in water absorption, from 2.34% to 7.99%, signifying higher porosity and lower resistance to moisture penetration (Demeke Worku & Ejigu, 2024).

Overall, PET enhances thermal insulation but compromises mechanical strength, durability, and internal homogeneity when used in excessive amounts. A PET content of 0.5% is considered optimal, striking a balance between sustainability, acceptable strength, and durability performance for light structural and non-structural applications.

Table 8 Summary of Findings

Test / PET Ratio (%)	0 (control)	0.5	1.0	1.5	2.0
Slump Test (mm)	78	71	64	66	63
Density (kg/m ³)	2266.67	2233.33	2183.33	2166.67	2133.33
Compressive Strength Test-28 days (N/mm ²)	29.09	26.74	22.64	19.42	15.37
Splitting Tensile Strength (N/mm ²)	2.76	2.63	2.32	2.07	1.94
Thermal Conductivity (W/mK)	1.085	0.649	0.626	0.563	0.524
Water Absorption (%)	2.34	2.36	3.95	6.41	7.99
Ultrasonic Pulse Velocity (km/s)	4.36	4.09	3.21	2.29	2.22

4. Conclusion

This study examined the effectiveness of using Polyethylene Terephthalate (PET) as a green additive in concrete, meeting all research objectives. PET, being lightweight and hydrophobic, reduced the density of concrete and lowered its thermal conductivity, improving its insulating properties. However, higher PET contents weakened compressive and tensile strength due to poor bonding and increased porosity. A PET content of 0.5% was identified as optimal, with a 28-day compressive strength of 26.74 MPa, exceeding the Eurocode 2 requirement of 25 MPa (British Standards Institution, 2004), making it suitable for structural and non-structural use. The improvement in thermal insulation supports energy-efficient building design, reducing heat transfer and enhancing indoor comfort while promoting recycling of plastic waste.

For broader application, future research should explore methods to improve the bond between PET and cement, such as surface treatments or blending PET with supplementary cementitious materials like fly ash or silica fume to enhance strength, durability, and workability. PET-modified concrete at 0.5% can be used in structural elements, including beams, slabs, and walls, and in non-structural components like internal partitions, precast panels, roof screeds, and insulation layers, where thermal performance and sustainability are priorities.

Additionally, comprehensive life-cycle assessments (LCA) and life-cycle cost analyses (LCCA) are needed to evaluate the environmental and economic benefits of PET-modified concrete. Such assessments would quantify its carbon footprint, resource efficiency, and long-term cost-effectiveness, supporting evidence-based decisions for large-scale adoption. Overall, PET-modified concrete at low contents offers a promising solution for sustainable construction by reducing plastic waste, improving thermal efficiency, and meeting structural requirements while contributing to global climate action and responsible consumption goals (SDGs 12 and 13).

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design were carried out by Shivanesswary Sathasivam, Syed Mohd Fareed Bin Syed Zin and Wan Amizah Binti Wan Jusoh. Data collection was performed by Shivanesswary Sathasivam. Analysis and interpretation of results were conducted by both Shivanesswary Sathasivam, Syed Mohd Fareed Bin Syed Zin and Wan Amizah Binti Wan Jusoh. The draft manuscript was prepared by Shivanesswary Sathasivam. All authors reviewed the results and approved the final version of the manuscript.

References

Journal

- Alaloul, W. S., John, V. O., & Musarat, M. A. (2020). Mechanical and Thermal Properties of Interlocking Bricks Utilizing Wasted Polyethylene Terephthalate. *International Journal of Concrete Structures and Materials*, 14(1). doi:10.1186/s40069-020-00399-9
- Bhogayata, A. C., & Arora, N. K. (2017). Fresh and Strength Properties of Concrete Reinforced with Metalized Plastic Waste Fibers. *Construction and Building Materials*, 455-463.
- Demeke Worku, G., & Ejigu, A. A. (2024). Production of Paver Blocks from Polyethylene Terephthalate Solid Waste as Partial Replacement of Sand. *Engineering Research Express*, 6(3), 035005. doi:10.1088/2631-8695/ad6392
- Deraman, R., Nawati, M. N., Yasin, M. N., Ismail, M. H., & Ahmed, R. S. (2021, November 13). Polyethylene Terephthalate Waste Utilisation for Production of Low Thermal Conductivity Cement Sand Bricks. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 88(3), 117-136. doi:10.37934/arfmts.88.3.117136
- Joravia, D. H., & Parikh, K. B. (2015, 3 31). Study on Performance of Infill Wall Masonry RCC Frame Using Alternative Types of Bricks: A Review. *Journal of Advance Research in Mechanical and Civil Engineering*, 2(3), 72-75.
- Ortega-Jimenez, C. H., Eduardo, A., Pineda, J., Ventura, C., Núñez, C., Núñez, D., & Romero, C. (2020). Recycled Polymer Concrete Composite: A Retrospective Review of the Literature and Framework for Thermal Comfort in Homes. *Materials Science Forum*, 15-21.
- Pudack, C., Stepanski, M., & Fässler, P. (2020). PET Recycling – Contributions of Crystallization to Sustainability. *Chemie Ingenieur Technik*, 92(4), 452 - 458.

Shahidan, S., Ranle, N. A., Zuki, S. S., Khalid, F. S., A.R.M.Ridzuan, & Nazri, F. M. (2018, January 9). Concrete Incorporated with Optimum Percentages of Recycled Polyethylene Terephthalate (PET) Bottle Fiber. *International Journal of Integrated Engineering*, 10(1), 1-8.

Sorout, J., Raj, S., Kaur, D. P., & Lamba, P. (2023). Waste-Based Bricks: Evaluation of Strength Behaviour of Bricks Containing Different Waste Materials as an Additive. *Water, Air, & Soil Pollution*, 234(7). doi:10.1007/s11270-023-06438-x

Wattanavichien, P., & Iwanami, M. (2024, September). Investigation of the mechanical, microstructure, and durability properties of concrete with fine uniform and non-uniform polyethylene terephthalate (PET) aggregates. *Cleaner Materials*, 13, 100267. doi:10.1016/j.clema.2024.100267

Report by a Group Author

British Standard Institution. (1986). Testing Concrete. In Part 203: Recommendations for Measurement of Velocity of Ultrasonic Pulse in Concrete. British Standard Institution.

British Standards Institution. (1996). BS 12:1996. In Portland Cement. Standards Policy and Strategy Committee.

British Standards Institution. (2000). BS EN 12524. In Building Materials and Products. British Standards Institution.

British Standards Institution. (2001). BS EN 12667:2001. In Thermal Performance of Building Materials and Products. Standards Policy and Strategy Committee.

British Standards Institution. (2004). Eurocode 2 - Design of Concrete Structures. British Standards Institution.

British Standards Institution. (2009). BS EN 12350 - 2 : Testing Fresh Concrete. In Part 2: Slump Test. British Standards Institution.

British Standards Institution. (2019). BS EN 12390 Testing hardened concrete. In Part 2: Making and curing specimens for strength tests. British Standards Institution.

Conference Session

Halim, N. F., Taib, N., & Aziz, Z. A. (2019). The Performance of Thermal Property in Concrete Containing Waste PET (Polyethylene Terephthalate) as an Alternative Sustainable Building Material. IOP Conference Series: Earth and Environmental Science. Sumatera Utara.

Musa, M. F., Mohammad, M. F., Mahbub, R., & Yusof, M. R. (2014). Enhancing the Quality of Life by Adopting Sustainable Modular Industrialised Building System (IBS) in the Malaysian Construction Industry. AMER International Conference on Quality of Life. Kota Kinabalu.