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Assessing The Efficacy of Polyethylene Terephthalate (PET) In Concrete Brick for Sustainable Construction

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Abstract

This paper presents the results of an experimental study investigating the effects of incorporating Polyethylene Terephthalate (PET) into concrete bricks on their compressive strength and water absorption. A total of 120 samples were produced and subjected to water curing for periods of 7, 14 and 28 days to monitor the development of compressive strength. Each parameter was tested on three brick samples to ensure accuracy and obtain average values. PET was added as a plastic aggregate at four different percentages which are 2.5%, 5%, 7.5% and 10% with a corresponding reduction in fine aggregate. The results showed that the inclusion of 5% PET yielded the highest compressive strength. Meanwhile, bricks containing 10% PET demonstrated the lowest water absorption. The 28 days curing period was found to be the most effective for enhancing compressive strength as it allows for more complete cement hydration.

Keywords: Polyethylene Terephthalate (PET), Compressive Strength, Water Absorption, Curing Period.

1. Introduction

In construction projects, brick comes as the second most utilized material following concrete. Clay and sand bricks are prominently employed in residential construction. Increasing number of constructions, its lead to the increasing number of brick production. The growing demand for construction has led to a corresponding increase in brick production. According to Rihan Maaze and Shrivastava (2023), India is currently the second-largest brick producer globally. Concurrently, plastic waste continues to rise at an alarming rate worldwide. Naderi Kalali et al. (2023) projected that global plastic production could reach approximately 1.1 billion tons by 2050, while only around 7% of plastic waste is recycled annually.

Recent data by the OECD (2024) also confirm that global plastic output has surpassed 400 million metric tons per year, with projections indicating a potential tripling by 2060. In Hong Kong, waste plastic was the third largest component of municipal solid waste (MSW), contributing approximately 945.9 thousand tons, or 21% of total MSW, in 2020 (Zou et al., 2024). Among the most prevalent types of plastic waste is

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Polyethylene Terephthalate (PET), widely used in beverage containers and packaging. Recent research has focused on innovative strategies for recycling PET, including enzyme-based degradation and conversion into high-value materials (Muringayil J. T. et al., 2024). PET also repurposed in recycling stream because of its favorable properties and widespread availability (Sam et al., 2025; Sakr et al., 2025; Agrawal et al., 2023)

In response to the increasing accumulation of plastic waste, this study explores the incorporation of waste PET into concrete bricks. Several studies have explored the incorporation of PET in concrete and mortar as a partial replacement for fine aggregates which most focus primarily on conventional concrete applications rather than molded brick units (Shaker et al., 2023; Naderi et al., 2023; Rahmani et al., 2013). Moreover, existing studies also often lacks consistency in identifying an optimal PET percentage that balances mechanical performance with durability. Additionally, they rarely consider the fineness of PET**,** particularly when it is used as a fine aggregate, which could significantly influence the overall mix properties and performance. The gaps hinder the widespread adoption of PET-enhanced bricks in sustainable construction. Therefore, this study aims to fill these research gaps by systematically evaluating the mechanical and durability properties of PET-incorporated concrete bricks across various replacement levels and curing periods, with the goal of identifying the most effective and environmentally beneficial formulation.

This approach also supports the construction industry's alignment with the United Nations Sustainable Development Goals (SDGs), particularly by applying the 3R principles which are Reduce, Reuse and Recycle. The study specifically contributes to SDG 9: Industry, Innovation and Infrastructure. In recent times, industrial waste has emerged as a serious environmental concern, posing significant threats to both soil and groundwater. To mitigate these risks, researchers worldwide are exploring innovative approaches to recycle industrial waste and convert it into valuable raw materials for the construction industry (F. Althoey et al., 2021). For instance, by-products like fly ash from coal-fired power plants, silica fume from ferrosilicon alloy production, and blast furnace slag from steel manufacturing have been proven to enhance the physical and mechanical properties of commercial concrete (Hassan El-Chabib, 2020; Dhrutiman D. et al., 2022). Similarly, waste PET, such as used plastic bottles also can serve as a recyclable material. When processed into plastic aggregates, PET can partially replace fine aggregates in concrete brick mixtures, contributing to more sustainable construction practices and supporting SDG 9 (Industry, Innovation, and Infrastructure).

Thus, in this study, PET was substituted for fine aggregate at five different levels: 0%, 2.5%, 5%, 7.5% and 10%. Results from a previous study by Akinyele and Toriola (2018) indicated that a 5% PET replacement yielded the best performance among all samples. To evaluate the impact of PET inclusion, compressive strength and water absorption tests were conducted. The primary objectives were to assess how PET affects the mechanical and durability properties of concrete bricks and to determine the optimal percentage of PET for use. All sample production and testing were carried out at the Concrete Laboratory of UiTM Shah Alam.

2. Methods

The methodology of this study is divided into three main sections. The first section involves material testing to evaluate the quality and suitability of the materials used. The second section focuses on sample casting and curing, detailing the concrete brick production process and specifying the exact quantities of materials used for each sample. The final section outlines the testing phase which includes compressive strength and water absorption tests. The data collected from these tests were then analysed.

2.1 Section 1: Material Collection and Testing

Four materials were tested to ensure their quality for producing high-performance bricks and obtaining reliable experimental data. The materials used and their respective tests are as follows: (i) Cement – Setting Time Test; (ii) Water – Ph Test; (iii) Fine Aggregate Test - Sieve Analysis Test; (iv) Waste PET (Plastic Aggregate)

2.1.1 Plastic Aggregate Preparation

As this study aims to reduce the use of fine aggregate by replacing it with plastic aggregate, waste PET from mineral water bottles was used. These bottles were collected from the community and shredded using a shredding machine to produce plastic aggregates with particle sizes smaller than 4.75 mm. Figure 1 shows the shredded plastic aggregate that has been used for specimen preparation.

Figure 1. Plastic Aggregate

2.2 Section 2: Sample Preparation

a) Sample Production

This section outlines the method of sample casting and curing prior to conducting durability and property tests. A total of 120 concrete brick samples were produced with three samples prepared for each parameter to ensure data accuracy through averaging. The brick containing 0% PET served as the control sample. Results from samples containing PET were compared against this control to evaluate performance differences. PET was incorporated into the concrete mix at varying percentages which are 2.5%, 5%, 7.5% and 10%. A steel mould with dimensions of 215 mm × 105 mm × 75 mm was used to form the bricks. The mix proportions of the materials used are detailed as in Table 1. Figure 2 shows the specimen preparation process, and Figure 3 shows the resulting brick specimen.

Table 1. Mix Proportion

Percentage of PET (%)	Weight of Material (Kg)			
	Cement	Fine Agg	PET	Water (L)
0	0.81	2.43	-	0.45
2.5	0.81	2.31	0.06	0.45
5	0.81	2.31	0.12	0.45
7.5	0.81	2.25	0.18	0.45

10	0.81	2.19	0.24	0.45

(a) (b)

Figure 2. (a) Plastic Aggregate in the mixture; (b) Water Added to the mixture

Figure 3. Brick Sample

b) Sample Curing

Each brick samples were labeled for the curing process. In this research, water curing method are used in the sample curing process. Luti and Abbas (2024) demonstrated that water curing produces the greatest compressive strength in concrete, and this method is followed here. During curing process, the hydration process of the cement takes place, significantly influencing the development of compressive strength in the bricks. The duration of curing plays a crucial role in this process. Four curing periods were evaluated in this study which are 0 days, 7 days, 14 days and 28 days. The compressive strength results for each curing period were plotted in a graph to illustrate the effect of curing time and to determine whether 28 days of curing period, as suggested by Patil et al. (2022), produces the highest compressive strength.

2.3 Section 3: Sample Testing

In this section, all the cured samples were tested to obtain the results for compressive strength and water absorption. The collected data were presented in tables and graphs for analysis. This section aims to identify the optimal percentage of PET that can be incorporated into concrete bricks without compromising their structural strength.

a) Compressive Strength Test

The compressive strength test was conducted to evaluate the durability properties of concrete bricks containing Polyethylene Terephthalate (PET). The specimens for the test that were water cured for 7, 28, 60 and 90 days as according to BS EN 12390-3:2009. The load capacity of 3000 kN at a pace rate of 3.0 kN/sec as mentioned in BS EN 12390-3:2009 was followed. The compressive strength result can be calculated from the failure load divided by the surface area of specimen as stipulated in BS BS EN 12390-3:2009. The maximum load at failure was recorded, and the compressive strength was calculated by dividing this load by the cross-sectional area of the brick. The formula stated as in (1).

$$CO = P/A \quad (1)$$

CO	=	Compressive Strength
P	=	Pressure Load (kN)
A	=	Cross Sectional Area

Figure 4. Compressive Strength Test

b) Water Absorption Test

The water absorption test was carried out to evaluate the effectiveness of PET in reducing water absorption in concrete bricks. The water absorption test was conducted in accordance with the requirement of BS 1881-122:2011. PET was added to the mix at varying percentages which are 2.5%, 5%, 7.5% and 10% to observe its impact. After demoulding, each brick sample was weighed and recorded as M1. The samples were then placed in a curing pond for their designated curing periods. Upon completion of curing, the bricks were removed, allowed to dry for one hour and weighed again. The samples recorded as M2**.** The percentage of water absorption was calculated using the formula as in (2).

$$W = \frac{M1-M2}{M1}\ X\ 100 \quad (2)$$

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3. Results and Discussion

3.1 Material Testing

The results of material testing are summarized as in Table 2. All the results compare to the standard to verify and justify the quality of the raw materials used in the sample production. The results of the material testing have led to ensure that all materials used in the concrete mix meet high-quality standards, thereby minimizing any adverse effects on the research outcomes. Maintaining material quality is crucial to ensure that all samples produced perform optimally and obtaining reliable results in compressive strength and water absorption tests.

Table 2. Material Test Result

Material	Test	Result	Standard	Justification
Cement	Setting Time	Initial: 6 – 45 Min Final: 80 – 300 Min	ASTM C191: Initial: > 45 Min Final: < 375 Min	OK
Water	PH Test	6.57 pH	6 – 13 pH	OK
Fine Aggregate	Sieve Analysis	95.68 % < 4.75 mm	< 4.75 mm	OK, need to sieve, to remove the particle more than 4.75 mm before use
Plastic Aggregate	Sieve Analysis	74.26 % < 4.75 mm	< 4.75 mm	OK, need to sieve, to remove the particle more than 4.75 mm before use

3.2 Sample Testing

a) Compressive Strength (Due to Percentage of PET)
Bricks incorporating 5% PET recorded the highest compressive strength for both 14-day and 28-day curing periods, as illustrated in Figure 5. This result is consistent with the findings of Khandelwal (2019), who reported that bricks with 4% PET exhibited optimal compressive strength. In contrast, bricks with 7% PET showed a decline in strength, while those with 10% PET experienced a 22% reduction compared to the 5% PET bricks. Additionally, bricks with 2.5% PET demonstrated a gradual increase in strength, peaking at 5% PET. Bricks containing 7.5% PET, however, exhibited a significant decrease in compressive strength. Based on these results, it can be concluded that incorporating 5% Polyethylene Terephthalate (PET) in concrete bricks is the most effective proportion. This conclusion is further supported by data showing that the compressive strength at 5% PET surpassed that of the control samples after 28 days of curing. This statement was agree by Saikia et al., (2014) and Rahmani et al., (2023) in their research stated 5% of PET significantly decreased compressive strength (up to 25%) compared to conventional concrete. The findings of the present study also consistent with those reported by Mahdi et al. (2025) and Shaker et al. (2023) who found that incorporating PET in concrete reduces its bond strength, contributing to structural failure.
b) Effectiveness of Curing Duration on Compressive Strength

The water curing of the brick samples demonstrated a significant impact on their compressive strength, primarily due to the ongoing hydration process. As shown in Figure 6, bricks cured for 0 days exhibited the lowest compressive strength across all parameters. The results indicate that a 28-day water curing period substantially increases the strength of the bricks. Notably, bricks containing 5% PET and cured for 28 days achieved the highest compressive strength of 43.19 N/mm². These findings confirm that 28 days curing period is the most effective for enhancing the compressive strength of the bricks. The results obtained from the present study is in line with the result reported by M.Z Rahimi et al. (2023) stated that the compressive strength is determined to be slightly larger in concrete specimens cured with higher water curing period.

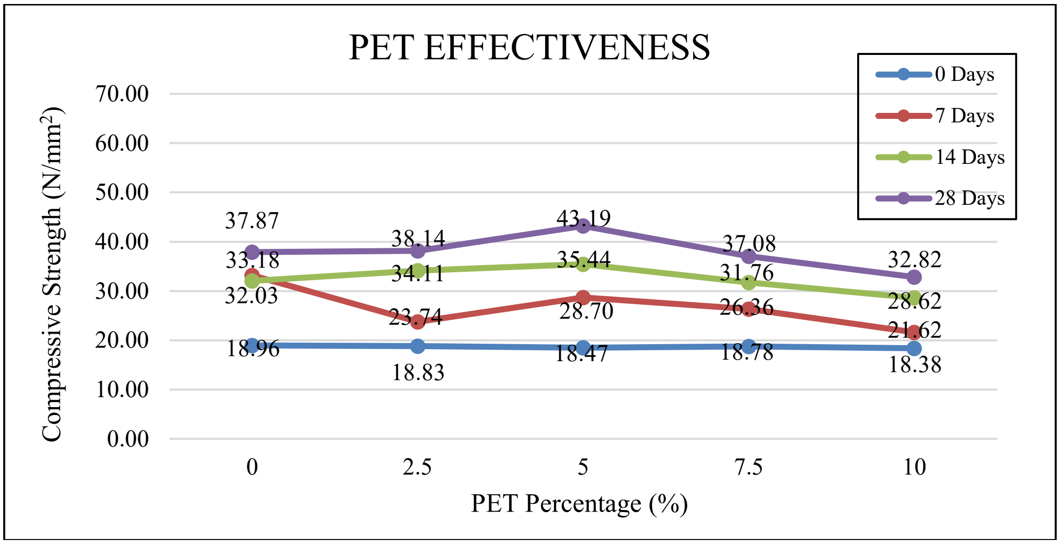

Figure 5. Result of Compressive Strength Due to Percentage of PET

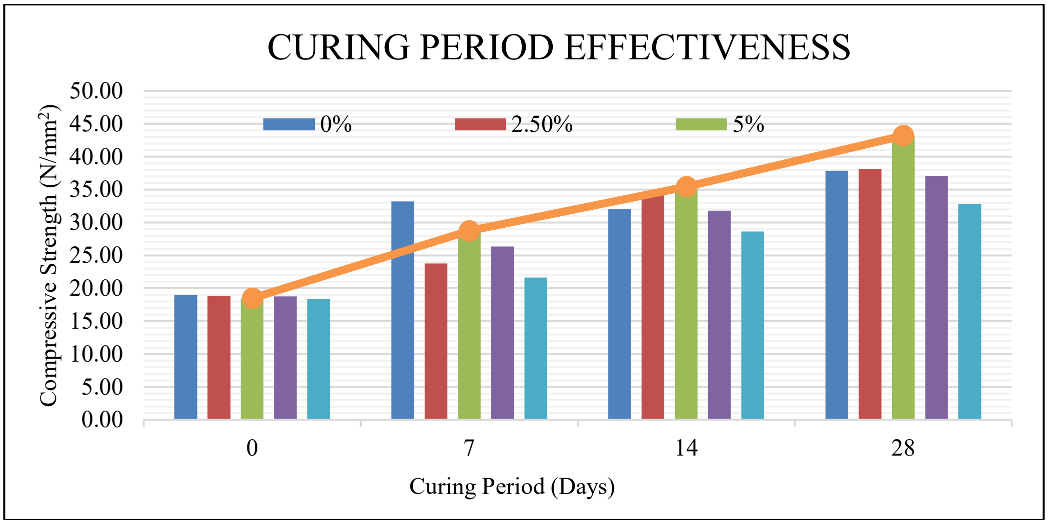

Figure 6. Result of Compressive Strength Due to Curing Period

c) Water Absorption

As illustrated in Figure 7, concrete bricks containing 10% PET consistently exhibit the lowest water absorption compared to other samples, indicating the effectiveness of this composition in reducing water absorption. At 14 days of curing, the maximum water absorption recorded was 0.43%, which further decreased to 0.37% at 28 days for specimens incorporating 10% Polyethylene Terephthalate (PET). This reduction is attributed to the water-repellent properties of PET, which limit the movement of water molecules within the brick matrix (Sahani et al., 2022). These findings indicate that the incorporation of PET as a partial replacement material contributes to lower water absorption in concrete bricks, likely due to its hydrophobic nature and its influence on refining the pore structure over time. This statement is aligned with the study reported by Alsaad A.J. et al., (2025) stated that PET increases water absorption due to its hydrophobic properties.

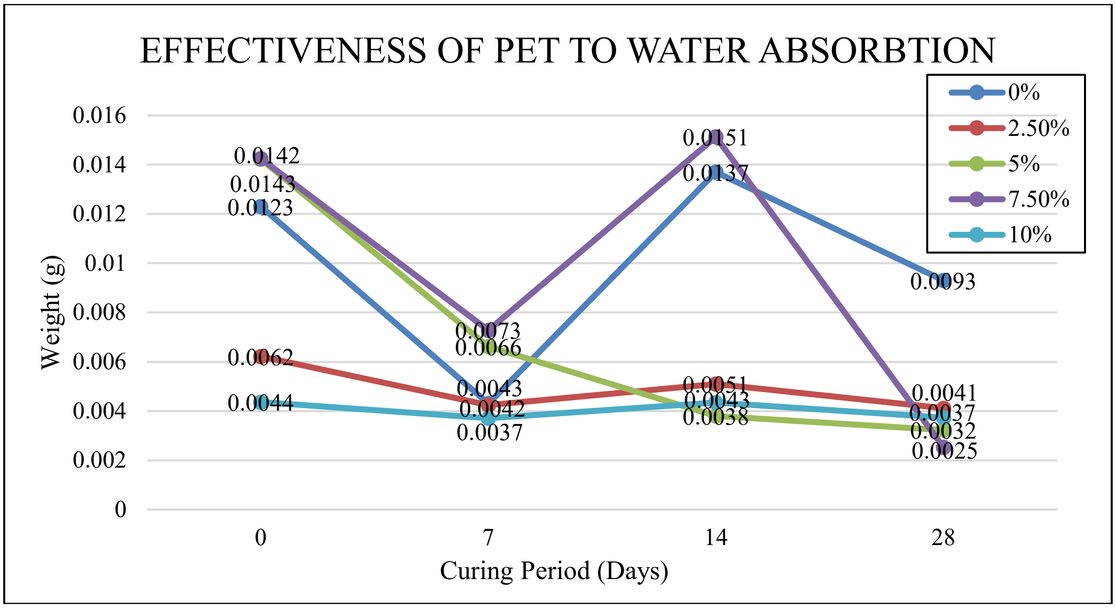

Figure 7. Effectiveness of PET to water absorption.

4. Conclusion

The research findings indicate that incorporating 5% Polyethylene Terephthalate (PET) is the optimal proportion for enhancing the performance of concrete bricks. Durability evaluations revealed that bricks containing 5% PET achieved the highest compressive strength compared to control samples. Moreover, water absorption decreased with increasing PET content, demonstrating a strong inverse correlation between compressive strength and water absorption. Specifically, lower water absorption corresponded to higher compressive strength, as PET inclusion reduced porosity by minimizing voids and producing a denser brick matrix. This improved density enhances the bricks' ability to resist compressive forces. In terms of durability under real conditions, concrete bricks containing 5% PET show potential for use in outdoor or high moisture environments. Durability material can withstand water exposure, corrosion and UV degradation. Given PET's inherent durability, it may contribute positively to the long-term performance of these bricks. The overall performance of the bricks is influenced not only by PET content but also by production methods and curing conditions. Thus, the overall results demonstrate that the samples were still able to achieve satisfactory strength and durability performance of the concrete bricks. Moreover, this study advances Sustainable

Development Goal 9 (Industry, Innovation, and Infrastructure) by promoting sustainable construction practices through the innovative reuse of waste materials in brick manufacturing. It is recommended that future research explores the long-term durability and structural behavior of PET incorporated bricks under various environmental conditions, as well as scaling up production to assess feasibility for commercial application. As PET concrete bricks have shown promising results and can potentially be used in the construction industry, several challenges must be addressed before widespread adoption. Potential barriers to scaling and integrating PET bricks into conventional construction practices include regulatory compliance and the consistency of material sourcing should be implemented. Despite these challenges, incorporating PET in brick production can significantly reduce dependence on natural resources typically used in conventional brick manufacturing, thereby supporting more sustainable construction practices.

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Author Contribution

Conceptualisation, Raden Maizatul Aimi Mohd Azam; Methodology, Ahmad Farhan Mohd Faizal and Raden Maizatul Aimi Mohd Azam; Validation, Raden Maizatul Aimi Mohd Azam; Analysis, Raden Maizatul Aimi Mohd Azam, Norhana Abdul Rahman, Ahmad Farhan Mohd Faizal; Investigation, Ahmad Farhan Mohd Faizal and Raden Maizatul Aimi Mohd Azam; Resources, Ahmad Farhan Mohd Faizal; Data Curation, Ahmad Farhan Mohd Faizal; Writing – Draft Preparation, Norhana Abdul Rahman; Writing – Review & Editing, All authors; Visualisation, Raden Maizatul Aimi Mohd Azam; Supervision, Raden Maizatul Aimi Mohd Azam; Project Administration, Raden Maizatul Aimi Mohd Azam; Funding Acquisition, Raden Maizatul Aimi Mohd Azam.

All authors have reviewed and approved the final version of the manuscript for publication.

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