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RESEARCH ARTICLE

# Evaluating the Structural Integrity and Performance of Polyethylene Terephthalate and Low-Density Polyethylene-Based Interlocking Bricks for Sustainable Construction

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**Abstract:** The increasing accumulation of plastic waste poses significant environmental challenges, contributing to pollution and resource depletion. The construction industry, traditionally reliant on non-renewable materials, faces increasing pressure to adopt sustainable practices. This study addresses the urgent need for innovative solutions that utilize recycled plastics in construction, thereby mitigating waste and enhancing material sustainability. This study aims to address the problem of plastic waste management by evaluating the production of interlocking bricks from waste polyethylene terephthalate (PET) and low-density polyethylene (LDPE) plastic. The objectives include assessing the mechanical properties, structural integrity, and durability of these polymeric bricks as sustainable alternatives to traditional building materials. Given the high rates of plastic waste generation and the reliance on natural raw materials for brick production, this research seeks to explore innovative solutions that utilize recycled materials effectively. A systematic methodology was employed to design the mixtures, focusing on varying the sand-to-polymeric waste ratios. Compressive and flexural strength tests were conducted to assess the bricks' ability to withstand vertical loads and bending forces, respectively. Water absorption and density tests were performed to determine durability and suitability for external use. Results indicated that the 70:30 PET to sand mix ratio provided the best performance, with an average compressive strength of 7.86 MPa and flexural strength of 21.94 MPa. The findings suggest that using PET plastic waste in interlocking brick production can enhance material properties while contributing to environmental sustainability.

**Keywords:** polymeric interlocking bricks, compressive strength, flexural strength, water absorption, PET plastic waste

## 1. Introduction

Polymers, most especially plastics, have become unquestionably essential in daily life. This is due to their durability (mechanical properties, thermal properties, and stability), resistance to decomposition, and cost [1]. From polyethylene terephthalate and low-density polyethylene to high-density polyethylene, polyvinyl chloride, and everything in between are widely used in our daily lives. This wide commercialisation due to its acceptability has also raised a major problem of waste disposal and management [2].

In Nigeria, table water is primarily packaged in cellophane sachets (made of low-density polyethylene, LDPE) and PET bottles. These cellophane sachets, bottles, polythene shopping bags, and other polymeric waste end up as litter and constitute a vast majority of municipal solid waste [3, 4]. Due to Nigeria's population and other economic factors, the country has become one of the biggest producers of solid trash in Africa, producing more than 32 million metric tonnes of solid waste, only some of which are collected and disposed of properly [5]. Although occasionally small companies, artisans, and traders also contribute to the neighbourhood's litter issue, households produce the majority of this waste. To prevent a variety of environmental issues, including choked streams and sewers, municipal trash must be collected and disposed of appropriately [6]. These trends are almost similar to those in other developing countries where urbanisation, population growth, and economic development are pivoting [7]. Every human activity produces waste, and as economies around the world grow and more people move into cities, the amount of waste produced per person is increasing. It becomes more difficult to provide enough rubbish collection and treatment services due to urbanisation and the rapid growth of the population; this is particularly the case in developing countries [8]. Data from the World Bank shows that developed nations, despite having comparatively good waste disposal systems, collectively produce more than one-third, or 34%, of the world's total waste, despite accounting for 16% of the world's population. It was also projected that by 2050, the quantity of waste produced globally annually would have increased significantly from 2.24 billion metric tonnes in 2020 to 3.88 billion metric tonnes [9].

Poor management or disposal, especially of non-biodegradable wastes, is detrimental and comes at the cost of the economy, environment, and social well-being [10]. A significant amount of solid pollution is characterised by polymeric waste. These plastic wastes find their way into the food chain and pose a major risk to both aquatic life and human health [11]. This raises the need to keep the amount of plastic in the ecosystem to a bare minimum.

Over the last few decades, various initiatives have been launched to reduce plastic pollution by either reducing it at its source or removing it after it has multiplied. Several technologies and methods have been created and studied in adsorption, coagulation, microbial breakdown, landfill, incineration, and recycling to lessen plastic loads [11]. However, these technologies and procedures have not kept up with the exponential growth in the use of plastic. As a result, there has been a substantial buildup over time, which has exacerbated the problem of disposal and increased the environmental load [12].

Plastic recycling has seen promise in the construction sector, particularly in construction materials. Numerous studies and experiments have been conducted to identify the best way to harness the waste in design and construction, from concrete to brick, furniture, interlocking floor tiles, interlocking roofing tiles, and so on [13, 14]. However, the use of plastic wastes, like LDPE and PET, in construction materials either added as flasks (to serve as aggregate) or used purely as a binder (to replace the conventional binder, cement) has raised a lot of concerns about its effect on the compressive strength (CS) of the construction materials produced and also its ability to withstand high temperatures and adverse weather conditions [15]. Studies have shown that bricks and concrete with plastic incorporated still have significant CS [16]. Particularly [17] explored the use of PET waste as a substitute for cement in interlocking bricks. The study found that interlocking bricks made from PET waste had superior compressive strength and water absorption compared to cement-based bricks. Kumi-Larbi et al. [18] produced LDPE-sand bricks from water sachets, achieving a compressive strength of up to 27 Mpa [18].

Awoyera et al. [19] examined interlocking concrete bricks containing shredded waste plastic and ceramic powder. The study recommended a 2% plastic fibre content for enhanced compressive and tensile strength. SEM and XRD analyses confirmed good compactness and interparticle reactions in these bricks. Ikechukwu and Shabangu [20] focused on bricks made from PET waste and foundry sand, reporting a compressive strength of 38.14 MPa and tensile strength of 9.51 MPa at a 70:30 ratio. Similarly, Akinwumi et al. [21] and Agyeman et al. [22] explored the use of plastic waste as a binding material for paving bricks, finding that it can improve compressive strength and water absorption.

The integration of plastic waste in construction materials has gained traction, but limitations remain, particularly concerning the material's long-term durability and environmental impact [23]. Zhang et al. [24] assessed recycled polymers in lightweight concrete composites and found significant improvements in mechanical resilience when polymers were treated with additives to counteract brittleness. Their findings suggest that without modification, plastic waste in construction may compromise structural integrity over time, especially under high-stress conditions typical in urban infrastructure.

Further exploration into polymer concrete mixtures reveals that the benefits of plastic integration—such as increased compressive strength—are often counterbalanced by limitations in tensile strength and elasticity [25]. Chaudhary et al. [26] highlight that the addition of low-density polyethylene (LDPE) to concrete improved compressive strength by 18%, yet reduced elasticity, posing challenges for applications requiring load-bearing flexibility. This trade-off pointed to the fact that the complexity of optimizing plastic-to-aggregate ratios is important in tailoring solutions for specific structural requirements. Moreover, applying PET and LDPE in combination with traditional aggregates has prompted investigations into porosity and water retention properties [27]. Alaloul et al. [28] showed that interlocking bricks incorporating these polymers displayed promising resistance to water infiltration, suggesting potential for external applications, although the impact on long-term environmental weathering remains inconclusive.

Aside the mechanical properties, environmental implications are increasingly central in research on recycled polymer composites in construction. Sourcing plastic waste from urban refuse presents an environmentally sustainable alternative to virgin polymer production. Yet, as Zhang et al. [29] argue, the thermal degradation of polymers during recycling processes can emit harmful compounds, which raises concerns regarding air quality and worker health. Their study proposed an eco-friendly alternative through cold recycling techniques, which reduce emissions and minimize energy consumption. Such methods reveal a promising avenue for greener recycling approaches that align with the circular economy objectives of the construction sector.

The insights provided by these studies highlight both the promise and the constraints of plastic waste in sustainable construction. However, while laboratory results are promising, the transition to large-scale, practical applications remains challenging as well, further research is needed to explore a wider range of polymeric blends, identify optimal plastic-to-sand ratios, and evaluate the long-term performance and environmental impact of these materials. Therefore, this research aims to bridge this gap by investigating the potential of these materials to enhance the mechanical properties and structural integrity of interlocking bricks. The main objectives of this study are to:

1) To evaluate the compressive and flexural strength of interlocking bricks made from varying ratios of PET and LDPE
2) To assess the water absorption and density characteristics to determine their suitability for external applications
3) To develop a comprehensive understanding of the performance of these polymeric bricks compared to traditional concrete alternatives.

The study produces interlocking bricks (interlocks) using waste polymeric materials, particularly polyethylene terephthalate (PET) and low-density polyethylene (LDPE), at different sand-to-polymeric-waste ratios and develops useful guidelines for optimizing the plastic-to-sand ratio in interlocking brick compositions in the building industry. Innovation lies in the systematic exploration of optimal plastic-to-sand ratios and the integration of waste materials into sustainable construction practices, thereby contributing to both waste management and the development of eco-friendly building materials.

## 2. Materials and Method

### 2.1. Materials and apparatus

The study used a variety of materials and apparatus essential for the production and testing of interlocking bricks. The primary materials included Polyethylene Terephthalate (PET) and Low-Density Polyethylene (LDPE), both sourced from waste disposal sites, along with sharp sand obtained from the Otammiri river sand-dredging site.

For the experimental procedures, several pieces of equipment were employed. A Taylor [USA] analogue scale, model 10 kg, served as the weighing balance for measuring materials. The compressive strength of the bricks was assessed using a compressive testing machine from Controls [USA], model CTM1000, while the flexural strength was evaluated with another machine from the same manufacturer, model FTM500. The abrasion resistance of the bricks was tested using an abrasion testing machine, also from Controls [USA], model ATM291.

Additionally, a metal mold with dimensions of 220 x 145 x 65 mm, designed with appropriate allowances for easy removal of the bricks, was utilized. A Seiko [Japan] stopwatch, model S141-300, was used to time various processes, and a sieve with a mesh size of 4 mm was employed for particle size classification. A standard heating vessel, or pot, was used for melting the plastics, while mixing tools such as a shovel, turning stick, mixing pan, and hand trowel facilitated the preparation of the mixtures. Finally, a plastic shredder granulator from Weima [China], model WLK 15 J, was used to shred the polymeric materials into suitable sizes for mixing. This comprehensive array of materials and equipment was crucial for ensuring the successful production and evaluation of the interlocking bricks in this study.

### 2.2. Experimental procedures

The polymeric plastic (LDPE and PET) wastes were collected from the waste disposal sites and transported to the manufacturing area. All non-PET/LDPE items, including plastics made of high-density polyethylene (HDPE), such as PET bottle caps, and labels were removed. The selected samples were washed, dried and shredded into 5.5 to 6.5 microns using a plastic shredder granulator.

After shredding, the resulting particles were weighed in batches. Both sand and the shreds of the polymeric materials (70% PET and 30% LDPE) were separately weighed in four different ratios to ascertain which ratio was the optimum as shown in Table 1. A weighing balance was used to measure these materials, in terms of mass (kg).

**Table 1**
**Ratio of sand-to-plastic in the interlocking bricks**

| Sand (%) | Polymeric Waste (%) |
|---|---|
| 80 | 20 |
| 70 | 30 |
| 60 | 40 |
| 50 | 50 |

A small fire was started beneath the flat pan (mixer), and it was gradually heated. Engine oil was brushed onto the pan while the fire was still burning to facilitate easy melting and prevent adhesion to the surface. The plastic was then gradually added to the pan and allowed to melt. The mixture was allowed to melt for 20-30 minutes to a heating temperature of 255–265 degrees Celsius until it transformed into a uniformly black liquid. Caution was exercised to prevent inhaling fire fumes and standing directly over the melting barrel, being aware of the potential hazards associated with hot equipment.

Since LDPE and PET lumps could occasionally remain even at extremely high temperatures, which could adversely impact the material's strength, the melting plastics were continuously stirred and heated to obtain a homogenous paste. The batched sand particles were added only after the homogenous paste had been formed. The molten plastic and sand mixture was thoroughly mixed until it resembled gray cement.

Following the melting and mixing, the 220 x 145 x 65 mm mould walls were coated with engine oil before being filled; this was crucial so that the interlocking bricks would be easy to remove after solidification. During this process, a metal spoon was used to quickly extract the mixture and place it in the mould. A tampering rod-like wood was used to apply pressure to the mould walls when casting the slurry, ensuring that the mixture was properly poured into the mould and left to cool in the air. The hot mixture in the mould was allowed to cool for a few minutes, about 8-10 minutes while occasionally shaking it to loosen the edges. When the mixture had solidified sufficiently, the mould was removed. This was conducted for the four sand-plastic ratios.

## 2.3. Physical tests

### *2.3.1. Water absorption test analysis*

After the specimen had been dried in open air until it reached a remarkably steady mass, its weight was taken, denoted as M1. The specimen was placed in clean water at room temperature (27±2 °C) for 96 hours (4 days). After 4 days, the specimen was removed from the water, with any remaining moisture wiped out using a damp cloth and weighed after three minutes and labelled as M11. The difference between M11 and M1 was the amount of water absorbed by the specimen, preferably referred to as mass loss. The fraction of the mass loss to the M1 expressed as a percentage was the percentage water absorption value.

### *2.3.2. Abrasion test analysis*

An interlocking brick sample of a specific ratio was selected as the specimen for the abrasion test. The abrasion testing machine was set up and calibrated to ensure accurate results. The chosen interlocking brick was broken into parts with an average diameter of not less than 25 mm with a small sledgehammer. The broken samples were weighed, and the value(s) were recorded. The cover plate of the L.A. abrasion testing machine was removed, and the broken sample was introduced into the drum together with six (6) abrasive charges (spherical steel balls of about 45mm in diameter). The cover plate was replaced and with the help of the electric motor attached to the L.A. abrasion machine, the steel cylinder or drum was rotated 100 times in one (1) minute, i.e., 100 revolutions per minute (rpm). After 100 rpm had elapsed, the contents of the steel cylinder were emptied into the collecting tray, and the abrasive charge was removed. The remaining aggregate was sieved (with a mesh size range of 2.5–4 mm), removing the dust particulates, and then finally weighed. The differences between the initial and final weight of the samples were expressed as a percentage of the initial weight called the percentage loss value. The average of three percentage loss values of a particular sample of a specified sand-plastic ratio was evaluated and referred to as the Los Angeles (L.A.) loss value. These procedures were repeated for each respective sample.

## 2.4. Mechanical tests

### *2.4.1. Compressive strength test analysis*

An interlocking brick with a specific sand-plastic ratio was chosen for testing. To ensure precise readings, the compressive strength testing apparatus was calibrated and assembled. The pressure of the compressive strength testing machine was released, and the wheel handle was adjusted to accommodate and lock the sample between the upper and bottom plates. The pressure release key was locked, the analogue indicator was set to zero, and pressure was applied manually using the pressure handle. At the point of failure (when the interlocking brick cracked or fractured), the applied force indicator pointer stopped moving, and the force (KN) at that point was recorded. The pressure was released using the pressure release key, the indicator was reset to point zero, and the wheel handle was also adjusted to remove the fractured sample. The maximum compressive strength was calculated from the maximum force before failure and the surface area of each of the samples. The average compressive strength of three samples of a specified plastic-sand ratio was evaluated and referred to as the average compressive strength. These procedures were repeated for each respective sample.

### *2.4.2. Flexural strength analysis*

An interlocking brick with a specific sand-plastic ratio was chosen for testing. To ensure precise readings, the flexural strength testing machine was calibrated and assembled. The pressure of the flexural strength testing machine was released, and the top support was adjusted to accommodate and lock the sample between the upper and bottom support points. The pressure release key was locked, the analogue indicator was set to zero, and pressure was applied manually using the pressure handle. At the point of failure (when the interlocking brick cracked or fractured), the applied force indicator pointer stopped moving (even when the pressure was still applied), and the force (KN) at that point was recorded. The pressure was released using the pressure release key, the indicator was reset to point zero, and the upper support was also adjusted to remove the fractured or failed sample. The maximum flexural strength was calculated from the maximum force before failure, the distance between the two support points of the upper support, and the width and thickness of each of the samples. The average flexural strength of three samples of a specified plastic-sand ratio was evaluated and referred to as the average flexural strength. These procedures were repeated for each respective sample.

## 3. Results and Discussion

## 3.1. Water absorption analysis

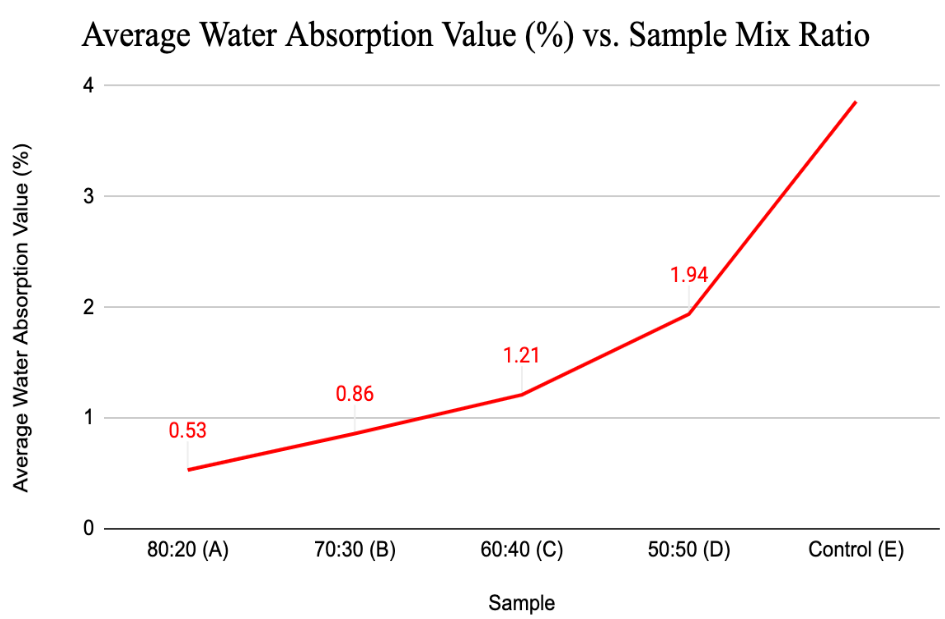
The results from the water absorption test show that samples A (80:20) and B (70:30) had the lowest water absorption values of 0.53% and 0.86%, respectively, while the control sample C had the highest water absorption value of 3.86%. To this effect, this makes them optimal regarding the adsorption test and desired since interlocking bricks with lower water absorption values are preferred, particularly in environments where they are exposed to significant moisture. Consequently, every other thing being equal, samples A and B (in a moist environment) are more durable, has stronger bond strength, and are less prone to efflorescence when compared to sample E (control). While samples A and B are not far from samples C and D, whose values are 1.21% and 1.94%, respectively, they show relatively low adsorption, which is recommendable. This is shown in the summary of the average water absorption values of the interlocking bricks in Table 2.

**Table 2**
**Summary of the average water absorption values of the interlocking bricks**

| Sample | Average Wet Mass (Kg) | Average Dry Mass (kg) | Average Mass Loss (kg) | Average Water Absorption Value (%) |
|---|---|---|---|---|
| **80:20 (A)** | **3.77** | **3.75** | **0.02** | **0.53** |
| **70:30 (B)** | **3.53** | **3.50** | **0.03** | **0.86** |
| **60:40 (C)** | **3.34** | **3.30** | **0.04** | **1.21** |
| **50:50 (D)** | **3.16** | **3.10** | **0.06** | **1.94** |
| **Control (E)** | **4l.40** | **4.57** | **0.17** | **3.86** |

Figure 1 shows that the water absorption value increased steadily from sample A to sample E. This supports the rise in pore/void volume. This usually results from the expansion of concrete coarse particles and polymeric materials (like PET and LDPE) in the interlocking bricks. The pore volume increased, making it easier for water molecules to be absorbed. This is due to the fact that, for the polymeric and concrete interlocking bricks, the void volume increased as the amount of sand aggregate decreased and the amount of polymeric binder and coarse aggregate increased, respectively. Whereas the concrete interlocking bricks (control), made of cement, sand, and aggregates, are inherently more porous and capable of absorbing more water.

**Figure 1**
**The graph of water absorption values against sample mix ratio**



## 3.2. Abrasion resistance analysis

The Los Angeles (LA) abrasion loss values for samples A, B, C, D, and E in Table 3 were found to be 22.5%, 13.75%, 12.50%, 11.25%, and 15.00%, respectively. These results indicate that the abrasion resistance of the interlocking bricks improved with increasing PET and LDPE content, peaking at sample D (50:50) and then decreasing slightly in the control sample E. The enhanced intermolecular forces provided by the polymeric binder contribute to the improved structural integrity and durability of the bricks, thereby reducing their susceptibility to wear and tear.

**Table 3**
**Summary of the L.A abrasion loss values of the interlocking brick**

| Sample | Original Weight (Kg | RTD Weight (Kg) | Weight Loss (Kg) | Percentage Loss (%) | Los Angeles Loss Value (%) |
|---|---|---|---|---|---|
| 80:20 (A1) | 4.00 | 3.00 | 1.00 | 25.0 | |
| 80:20 (A2) | 4.00 | 3.25 | 0.75 | 18.75 | 22.50 |
| 80:20 (A3) | 4.00 | 3.05 | 0.95 | 23.75 | |
| | | | | | |
| 70:30 (B1) | 4.00 | 3.60 | 0.40 | 10.00 | |
| 70:30 (B2) | 4.00 | 3.40 | 0.60 | 15.00 | 13.75 |
| 70:30 (B3) | 4.00 | 3.35 | 0.65 | 16.25 | |
| 60:40 (C1) | 4.00 | 3.40 | 0.60 | 15.00 | |
| 60:40 (C2) | 4.00 | 3.60 | 0.40 | 10.00 | 12.50 |
| 60:40 (C3) | 4.00 | 3.50 | 0.50 | 12.50 | |
| 50:50 (D1) | 4.00 | 3.50 | 0.50 | 12.50 | |
| 50:50 (D2) | 4.00 | 3.55 | 0.45 | 11.25 | 11.25 |
| 50:50 (D3) | 4.00 | 3.60 | 0.40 | 10.00 | |
| Control (E1) | 4.00 | 3.30 | 0.70 | 17.50 | |
| Control (E2) | 4.00 | 3.55 | 0.45 | 11.25 | 15.00 |
| Control (E3) | 4.00 | 3.35 | 0.65 | 18.25 | |

Among the polymeric interlocking bricks (samples A, B, C, and D), sample B (70:30) exhibited superior performance compared to sample A (80:20) and was relatively comparable to samples C (60:40) and D (50:50). When compared to the control sample E, sample B (70:30) demonstrated better abrasion resistance. This is significant because a lower L.A. abrasion loss value is indicative of higher resistance to wear, greater structural integrity, and enhanced long-term durability. It also ensures that the interlocking bricks maintain their aesthetic qualities over time.

The weight loss and percentage loss data further corroborate these findings, with samples C and D showing the least percentage weight loss, affirming their superior abrasion resistance. Sample D (50:50) in particular, with its lowest L.A. loss value of 11.25%, is highlighted as the most durable composition, offering the best balance between polymer content and abrasion resistance.

## 3.3. Compressive strength analysis

The compressive strength test shows that samples A, B, C, D, and E had an average compressive strength of 7.68 MPa, 7.86 MPa, 7.15 MPa, 6.13 MPa, and 10.00 MPa, respectively. Sample E (control) had the highest compressive strength (10.00 MPa), followed by sample B (70:30, 7.86 MPa), while sample D (50:50) had the lowest compressive strength (6.13 MPa).

When the polymeric interlocking bricks (samples A, B, C, and D) were compared, the likely cause(s) for the above results could be found in the fact that materials with higher densities have fewer voids and defects, which results in relatively higher compressive strength. For example, samples A, B, and C, which have approximate densities of 1875 kg/m3, 1667 kg/m3, and 1650 kg/m3, respectively (see Table 4), had corresponding compressive strengths of 7.68 MPa, 7.86 MPa, and 7.15 MPa, respectively, because they were less porous and denser. Since sample D was the most porous and had the lowest density, it had the lowest compressive strength. This is because the existence of voids creates regions of stress concentration that can cause cracks and facilitate mechanical failure under stress.

**Table 4**
**Summary of the density of the interlocking bricks**

| Sample | Average Mass (Kg) | Volume ($m^3$) | Density ($Kg/m^3$) |
|---|---|---|---|
| **80:20 (A)** | **3.75** | **0.00200** | **1875.00** |
| **70:30 (B)** | **3.50** | **0.00210** | **1666.67** |
| **60:40 (C)** | **3.30** | **0.00200** | **1650.00** |
| **50:50 (D)** | **3.10** | **0.00190** | **1631.58** |
| **Control (E)** | **4.57** | **0.00275** | **1661.82** |

The density of sample E was increased by proper compaction and reduction in porosity. Because it was made using cement, sand, and aggregate, its compressive strength was considerably improved. This was justified by the fact that sample E, the control, had the highest compressive strength of 10.00 MPa and had a density value of around 1662 kg/m3, as indicated in Tables 5 and 4, respectively.

However, when compared to other polymeric interlocking bricks, sample B (70:30) had the highest compressive strength (7.86 MPa); when compared to the control, sample B (70:30), though with a lesser compressive strength, still had a relatively comparable compressive strength value.

**Table 5**
**Summary of the average compressive strength values of the interlocking bricks**

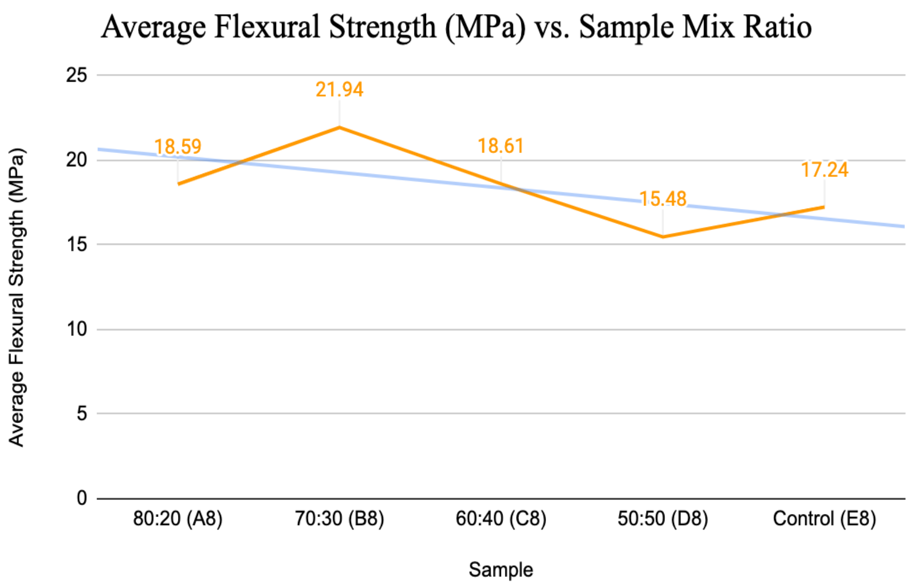
| Sample | Maximum Load before Failure (KN) | Compressive Strength (MPa) | Average Compressive Strength (MPa) |
|---|---|---|---|
| **80:20 (A4)** | **220** | **7.86** | |
| **80:20 (A5)** | **225** | **8.04** | **7.69** |
| **80:20 (A6)** | **200** | **7.15** | |
| **70:30 (B4)** | **230** | **8.22** | |
| **70:30 (B5)** | **205** | **7.33** | **7.86** |
| **70:30 (B6)** | **225** | **8.04** | |
| **60:40 (C4)** | **195** | **6.97** | |
| **60:40 (C5)** | **190** | **6.79** | **7.15** |
| **60:40 (C6)** | **215** | **7.68** | |
| **50:50 (D4)** | **175** | **6.25** | |
| **50:50 (D5)** | **180** | **6.43** | **6.43** |
| **50:50 (D6)** | **185** | **6.61** | |

| | | | |
|---|---|---|---|
| **Control (E4)** | **285** | **10.18** | |
| **Control (E5)** | **265** | **9.77** | **10.00** |
| **Control (E6)** | **290** | **10.36** | |

## 3.4. Flexural strength analysis

From the line plot of average flexural strength against sample mix ratio in Figure 2, there was an increase in average flexural strength from sample A (80:20, 18.49 MPa) to sample B (70:30, 21.94 MPa). The average flexural strength value was at its peak at sample B, from where it decreased through sample C (60:40, 18.61 MPa) to sample D (50:50, 15.48 MPa), which was its lowest point. The flexural strength increased, yet again, slightly at sample E-control to 17.24 MPa. Sample B had the highest flexural strength, while samples D and E had the lowest flexural strength.

**Figure 2**
**The graph of average flexural strength against sample mix ratio**




When considering the polymeric and concrete interlocking brick samples, differences in material properties and behaviour under different types of stress are factored into account. While concrete interlocking bricks' rigid matrix structure provides superior compressive strength (as can be seen in table 5 above), they lack the ductility to effectively absorb and distribute the tensile forces experienced during flexural stress. Polymeric interlocking bricks, on the other hand, exhibit significant flexibility and ductility, which allow them to perform better under flexural stress, even with lower compressive strength. This was portrayed by the fact that the polymeric interlocking bricks generally had a higher flexural strength relative to the concrete interlocking brick (sample E-control).

Sample B (70:30) showed the maximum flexural strength among the polymeric interlocking bricks, or samples A, B, C, and D. This can be explained by the polymeric material's dispersion within the sand matrix and the equilibrium between stiffness and flexibility. The peak flexural strength of sample B must have been caused by the uniform distribution of the polymeric materials (LDPE and PET) among the sand particles and the possibility (good mix proportion) of the plastic, i.e., polymeric materials, to coat and bond with sand particles while retaining enough granular sand structure to provide stability and support. Because of their homogeneous and uniform distribution, the interlocking bricks have fewer weak areas that could fracture when subjected to flexural stress. This is important since sand provides rigidity and plastic offers flexibility while acting as the matrix and binder, respectively. The flexibility helps the bricks absorb and distribute stress without fracturing, which is vital under a flexural load, while rigidity makes for overall strength, which is indispensable when considering compressive loads.

**Table 6**
**Summary of the average flexural strength values of the interlocking bricks**

| Sample | Maximum Load before Failure (KN) | Flexural Strength (MPa) | Average Flexural Strength (MPa) |
|---|---|---|---|
| 80:20 (A7) | 45.80 | 17.94 | |
| 80:20 (A8) | 48.00 | 18.80 | 18.59 |
| 80:20 (A9) | 47.80 | 18.73 | |
| 70:30 (B7) | 56.70 | 22.21 | |
| 70:30 (B8) | 54.20 | 21.23 | 21.94 |
| 70:30 (B9) | 57.10 | 22.37 | |
| 60:40 (C7) | 46.49 | 18.18 | |
| 60:40 (C8) | 47.20 | 18.77 | 18.61 |
| 60:40 (C9) | 37.90 | 18.88 | |
| 50:50 (D7) | 40.40 | 15.83 | |
| 50:50 (D8) | 4.20 | 15.75 | 15.48 |
| 50:50 (D9) | 37.90 | 14.85 | |
| Control (E7) | 45.30 | 17.75 | |
| Control (E8) | 42.00 | 16.45 | 17.24 |
| Control (E9) | 44.70 | 17.51 | |

Following the findings, it is essential to compare the results obtained with those from previous research on the use of polymeric materials in brick production. The findings of this study, which indicated an average compressive strength of 7.86 MPa and a flexural strength of 21.94 MPa for the 70:30 PET to sand mix ratio, align with the results reported by Ikechukwu and Shabangu [20], who achieved a compressive strength of 38.14 MPa using a similar ratio of PET waste and foundry sand. However, Kumi-Larbi et al. [18] reported a significantly higher compressive strength of up to 27 MPa for LDPE-sand bricks, suggesting that the type of polymer used can greatly influence the mechanical properties of the resulting bricks. Additionally, Shrestha et al. [16] demonstrated that bricks incorporating plastic still maintained significant compressive strength, corroborating the findings of this study regarding the viability of using PET waste in construction materials. These comparisons highlight the potential of polymeric waste in enhancing the mechanical properties of interlocking bricks while also addressing environmental sustainability.

To further illustrate the relationship between this study's findings and existing literature, a summary Table 7 of similar studies is provided below:

**Table 7**
**Summary of similar studies**

| Study | Polymer Type | Sand Ratio | Compressive Strength (MPa) | Flexural Strength (MPa) | Key Findings |
|---|---|---|---|---|---|
| This Study | PET | 70:30 | 7.86 | 21.94 | Optimal mix ratio for mechanical properties. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ikechukwu & Shabangu [20]** | **PET + Foundry Sand** | **70:30** | **38.14** | | **1** | **9.5** | **High compressive strength with PET waste.** |
| **Kumi-Larbi et al. [18]** | **LDPE** | **N/A** | | **27** | **N/A** | | **LDPE-sand bricks showed significant strength.** |
| **Shrestha et al. [16]** | **Various Plastics** | **N/A** | **CS** | **Significant** | **N/A** | | **Bricks with plastic maintained good strength.** |
| **Awoyera et al. [19]** | **Shredded Waste Plastic** | **2% Plastic Fiber** | **N/A** | | **hanced** | **En** | **Recommended plastic fiber for improved strength.** |

## 4. Conclusion

This study demonstrated the impact of material composition on the properties of interlocking bricks, with a 70:30 sand-to-plastic ratio yielding optimal results.

Bricks with this 70:30 ratio exhibited:

1) Lowest water absorption at 0.86%, enhancing durability in moist environments.
2) Superior abrasion resistance, with an L.A. abrasion loss of 13.75%, indicating high wear resistance and structural integrity.
3) High compressive strength of 7.86 MPa.
4) Excellent flexural strength, reaching 21.94 MPa, outperforming both control and other polymeric compositions.

Economic analysis shows cost-effectiveness of polymeric waste interlocking bricks (70:30 ratio) over conventional cement bricks:

1) Estimated cost for 1 m² of polymeric waste interlocking bricks (220×145×65 mm) with optimal quality is NGN7,400, with a unit cost of NGN231.
2) In contrast, conventional interlocking bricks (190×120×50 mm) cost NGN12,000 per 1 m², or NGN240 per unit.

Future research should expand to examine diverse polymeric blends, long-term performance in varying environmental conditions, and large-scale production feasibility, focusing on both environmental impact and economic viability for the construction industry.

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## Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

## Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

## Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

## Author Contribution Statement

**Abubakar Abdullahi Garbati:** Conceptualization, Writing - original draft; **Muhammed Awwal Imran:** Conceptualization, Writing - review & editing; **Caleb Chisom Chike:** Methodology, Investigation; **Emmanuel Nwaka Nwaka:** Formal analysis, Investigation, Writing - review & editing, Visualization; **Ugochukwu Chibuzo Akomah:** Software, Investigation; **Ihechimere Jael Ogueri:** Validation, Investigation, Resources; **Samuel Oluwasijibomi Olaremi:** Writing - review & editing, Visualization, Project administration; **Akinsanmi S. Ige:** Validation, Supervision; **Amaku Chukwuebuka Marcellinus:** Investigation, Resources, Project administration; **Christopher Olayinka Osasona:** Methodology, Project administration; **Uzoma Eucharia Ibeanu:** Software, Formal analysis, Supervision.

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