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Research Article

Addition of Plastic Mixture (LDPE) for the Development of Alternative Mixtures in Concrete Blocks

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Abstract: This study investigates the potential of Low-Density Polyethylene (LDPE) plastic waste as a partial substitute for sand in concrete block mixtures, focusing on its effects on compressive strength and water absorption. LDPE is a non-biodegradable plastic waste that poses significant environmental challenges. Its incorporation into construction materials offers a promising solution to reduce pollution while enhancing the performance of building components. The research employed LDPE substitution levels of 10%, 15%, 20%, 25%, and 30% by weight of sand, compared against conventional concrete blocks without LDPE. Experimental results revealed that the highest compressive strength was achieved with a 15% LDPE mixture, reaching 80.762 kg/cm² at 28 days of curing—an increase of approximately 40.8% compared to normal blocks, which recorded 57.359 kg/cm². LDPE additions up to 20% maintained favorable strength characteristics, while higher proportions (25% and 30%) led to a decline in mechanical performance. In terms of water absorption, the inclusion of LDPE demonstrated a decreasing trend, attributed to the hydrophobic nature of plastic, which enhances moisture resistance in the concrete blocks. These findings suggest that a 15% LDPE substitution represents an optimal formulation for producing eco-friendly concrete blocks with improved strength and reduced water absorption. The study highlights the dual benefits of waste management and material innovation, aligning with sustainable development goals. By repurposing plastic waste into construction applications, this approach not only mitigates environmental impact but also contributes to the advancement of green building technologies. Further research is recommended to explore long-term durability, thermal properties, and scalability of LDPE-based concrete products in real-world construction settings.

Keywords: Brick; LDPE; Materials; Plastic; Strength

1. Introduction

Plastic is one of the most widely used materials worldwide, and its consumption continues to increase in line with population growth, lifestyle changes, and socio-economic development. The growing demand for plastic products in daily activities contributes directly to the rising volume of plastic waste generated globally (Indrawijaya et al., 2019). The negative impacts of plastic waste significantly affect the environment, including air pollution, ecosystem degradation, and harm to living organisms. Some waste management practices, such as open burning, have been implemented to reduce plastic waste volume. However, incomplete combustion processes produce hazardous substances such as dioxins, which pose serious health risks. Exposure to dioxins has been associated with various health problems, including cancer, liver inflammation, nervous system disorders, and other chronic diseases (World Health Organization [WHO], 2023).

Plastic bags, categorized as single-use plastics, are particularly problematic due to their high post-consumer disposal rate. Improper disposal can clog drainage systems and waterways, contributing to flooding, especially in densely populated urban areas (United Nations Environment Programme [UNEP], 2022). Furthermore, plastics have long carbon chains that make them resistant to biodegradation. Instead of fully decomposing, plastics fragment into microplastics, which persist in soil and water environments and pose long-term ecological risks (OECD, 2022). Plastic contamination in soil can disrupt water infiltration, reduce soil fertility, and negatively affect soil organisms such as earthworms, which play a crucial role in decomposition and nutrient cycling.

In addition to environmental impacts, research has explored the reuse of plastic waste in construction materials. A study by Ramadhan (2023), entitled The Effect of Using LDPE Plastic Waste as Fine Aggregate in Lightweight Concrete Bricks, found that substituting LDPE plastic pellets for sand reduced both the bulk density and compressive strength of lightweight bricks. The compressive strength decreased by 57.02%, while tensile strength declined by 45.15% with a 20% addition of LDPE pellets. Water absorption also decreased by 23.09%, indicating reduced cavity formation compared to conventional bricks (Saikia & de Brito, 2022).

2. Literature Review

This section must contain a state-of-the-art explanation. It can be explained in several ways. First, you can discuss several related papers, both about objects, methods, and their results. From there, you can explain and emphasize gaps or differences between your research and previous research. The second way is to combine theory with related literature and explain each theory in one sub-chapter.

2.1. Definition of Batako

Batako (concrete masonry unit) is a building material made from a mixture of cementitious or hydraulic binding materials, fine aggregates, and water, with or without additional additives, which is molded and cured to achieve specific structural properties. According to the Indonesian National Standard SNI 03-0349-1989 concerning concrete bricks for wall construction, concrete blocks may contain hollow sections exceeding 25% of the total cross-sectional area, provided they meet structural and dimensional requirements (Badan Standardisasi Nasional [BSN], 2019).

In more recent technical guidelines, concrete masonry units are defined as molded construction materials produced from Portland cement, sand, water, and sometimes supplementary materials such as fly ash or other additives to enhance performance characteristics (BSN, 2020). These materials are cured under controlled conditions to achieve the required compressive strength and durability standards for wall construction. Furthermore, modern construction material literature explains that concrete bricks or masonry blocks are designed to meet specified physical and mechanical properties, including compressive strength, water absorption, and dimensional tolerance, making them suitable for non-structural and structural wall applications (Neville & Brooks, 2021).

2.2 Plastic

Plastic is a material derived from synthetic or semi-synthetic polymerization processes that produce materials with versatile and distinctive properties. Polymers consist of long repeating chains of molecules formed from smaller units called monomers. When the repeating units are identical, the material is referred to as a homopolymer, whereas different repeating units form a copolymer. The polymerization process influences the molecular structure, crystallinity, and mechanical properties of the resulting plastic. Variations in chain length, branching, and intermolecular bonding significantly affect characteristics such as stiffness, hardness, flexibility, and thermal resistance (Rosen & Kunjappu, 2022; Young & Lovell, 2023). The degree of polymerization and intermolecular forces between carbon chains determine whether the plastic exhibits rigid or ductile behavior (Haward, 2021).

The selection of safe plastic materials for food packaging is guided by resin identification codes printed on plastic products. These codes classify plastics based on polymer type and recyclability Choi, Y. W., Moon, D. J., Chung, J. S., & Cho, S. K. (2021). The resin identification coding system was originally developed by the Society of the Plastics Industry (SPI) and has since been aligned with international material identification and safety standards. Today, plastic material classification and safety assessment for food contact applications are regulated under international standards such as ISO guidelines and food safety regulations to ensure consumer health protection (International Organization for Standardization [ISO], 2022; Plastics Industry Association, 2023).

3. Materials and Method

3.1. Location and Time of Research

This research will be conducted from September to October 2023 at the Construction Materials Technology Laboratory, Faculty of Engineering, Muhammadiyah University of Palembang. The study will begin with material examinations, including sieve analysis, unit weight, specific gravity, compressive strength, and water absorption tests for the concrete blocks.

3.2. Research Tools and Materials

Research Tools

The tools used in this research are tools commonly used in compressive strength testing, including:

A. A set of sieves for fine aggregate
B. The cup is used as a place to soak and place the test material when in the oven
C. Newspaper as a medium for drying sand
D. Pycnometer, to remove air content
E. Oven, to dry the aggregate
F. Cone, to determine the dryness of the saturated surface of the sand
G. Shovel and Bucket
H. Scales, to weigh the weight of test objects and materials for mixing materials.
I. Container, used to find the aggregate volume
J. Brick Making Machine
K. Brick Cutting Tool
L. Compression Testing Machine, to test the compressive strength of test objects.

Research Materials

To support this research process, materials are required. These materials will be tested prior to use and will meet applicable and accountable requirements. The materials used in this study are:

Cement : Baturaja Cement
Fine Aggregate : Sand
Additional Materials : The additional materials used in this study are LDPE-type plastic waste that has been ground into fine pieces.
Liquid : Palembang PDAM water

Research Variables

The research variables carried out were the addition of LDPE waste and the reduction of sand through the same variations, namely 10%, 15%, 20%, 25% and 30% (if the addition of LDPE waste is 10% then the reduction of sand is also 10%, and so on) with an aging time of 7 days, 14 days and 28 days.

3.3. Research Procedures

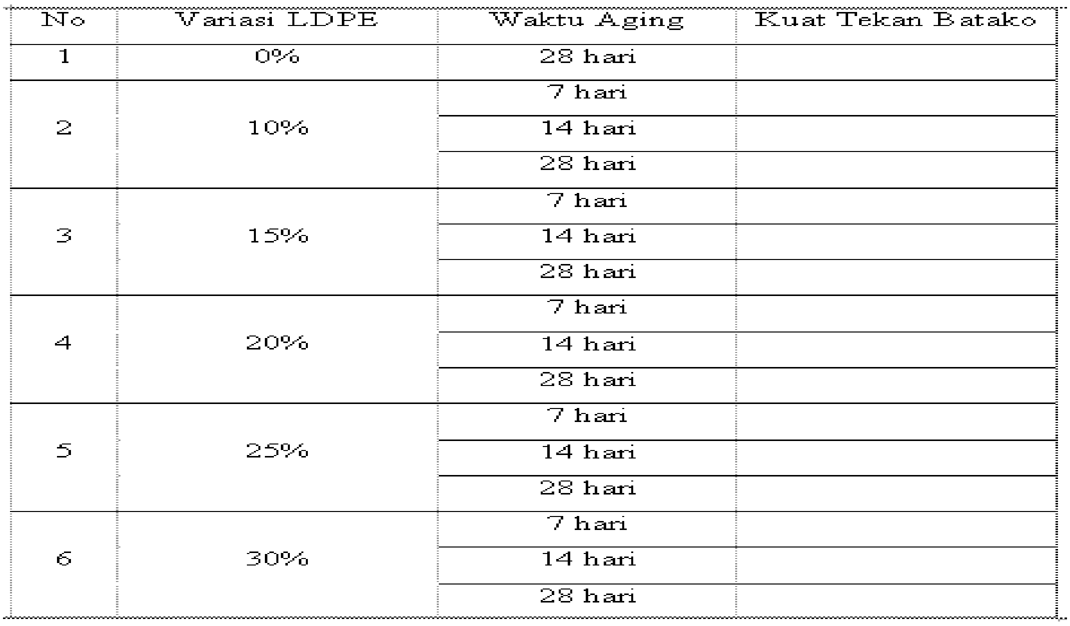
Research Stages

This research was conducted through several important stages, which are divided into four stages, namely:

Stage I : preparation of materials and research tools, which includes checking the availability of equipment and providing materials for forming bricks.
Stage II : checking the quality of research materials
Stage III : carry out a mixed design based on data obtained from stage II research.
Stage IV : maintenance of concrete block test specimens
Stage V : compressive strength testing carried out at 7 days, 14 days, and 28 days.
Stage VI : Data analysis is a discussion of the research results, then from this step research conclusions can be drawn.

3.4. Research Matrix and Job Mix Formula

Table 1. Research Matrix.



No	Variasi LDPE	Waktu Aging	Kuat Tekan Batako
1	0%	28 hari	
2	10%	7 hari	
		14 hari	
		28 hari	
3	15%	7 hari	
		14 hari	
		28 hari	
4	20%	7 hari	
		14 hari	
		28 hari	
5	25%	7 hari	
		14 hari	
		28 hari	
6	30%	7 hari	
		14 hari	
		28 hari	

3.5. Job Mix Formula

In this study, a mixture was made with a composition of 1: 7, meaning that each brick uses 1 kg of cement and 7 kg of sand, which is then converted into a volume ratio. This is done to determine the amount of material planning requirements per mixture in making a number of brick test objects, while for the need for LDPE as a partial replacement for sand, it is done by calculating each mixture to be used against the volume of sand according to the variation in the composition of LDPE use that has been planned previously for the research to be carried out. With a mixture of LDPE 10%, 15%, 20%, 25%, and 30%, through an Aging Time of 7, 14, 21 days. The planned size of the brick is 30 x 10 x 15, with the following JMF:

4. Results and Discussion

4.1 . Fine Aggregate Sieve Analysis

Fine Aggregate Sieve Analysis aims to determine the grain distribution (gradation) of fine aggregate, as this value is required in the design of concrete block mortar. Fine aggregate can be natural sand, processed sand, processed non-organic waste, or a combination of the three. In this study, shredded LDPE (Low-Density Polyethylene) plastic waste was used as an alternative mixture of fine aggregate.

The LDPE plastic shreds used are obtained through a mechanical cutting process using a shredder, producing granules with a uniform size ranging from 2 mm to 4.75 mm, in accordance with the fine aggregate gradation range that can be used in lightweight concrete mixes such as concrete blocks. This size ensures that the LDPE plastic can function as a substitute filler that does not disrupt the overall gradation structure.

Table 2. Fine Aggregate Sieve Analysis Table.

4.1.2.

Filter	Retained Weight (gr)	Total Weight Retained	Amount (%)	
			Stuck	Past
No. 3/8	0	0	0	100
No. 4	0	0	0	100
No. 8	5	5	0.50	99.5
No. 16	50	55	5.47	94.53
No. 30	525	580	57.71	42.29
No. 50	385	965	96.02	3.98
No. 100	35	1000	99.5	0.5
PAN	5	1005	100	0

Fine Aggregate Water Content Inspection

This test aims to determine the water content of fine aggregate, particularly sand, through an oven-drying method. Aggregate moisture content is the ratio of the weight of water contained in the aggregate to the weight of the oven-dry aggregate. Knowledge of this moisture content is crucial because it directly influences the water composition of the concrete block mixture, which in turn influences the final product's quality, such as compressive strength and water absorption.

4.1.3. Examination of Specific Gravity and Water Absorption of Aggregate

This test is intended to determine the specific gravity of fine aggregate and its water absorption capacity. The parameters measured include oven-dry specific gravity, saturated surface dry (SSD) specific gravity, and apparent specific gravity. These values are crucial for designing lightweight concrete mixes such as concrete blocks, as they influence the material proportions and final volume of the mix Zhang, P., Li, Q., & Wang, J., 2022).

Dry specific gravity indicates the mass of the aggregate after complete drying in an oven. SSD specific gravity reflects the condition of the aggregate, whose pores are saturated with water but whose surface is not wet Neville, A. M., 2022). Apparent specific gravity, on the other hand, describes the mass of the aggregate, including the volume of closed pores that are impermeable to water.

In this study, the fine aggregate used consisted of two components: natural sand as the main ingredient and LDPE (Low-Density Polyethylene) plastic as a partial sand substitute. LDPE was used in the form of 2 mm – 4.75 mm pieces, which are non-absorbent (hydrophobic). Therefore, in this test, LDPE was not included in the water absorption calculation (Gu et al., 2023), and only the natural sand was tested for its specific gravity and absorption capacity (Choi et al., 2021).

The testing method was carried out according to the SNI 03-1969-1990 ASTM International. (2023) standard concerning "Testing Method for Specific Gravity and Water Absorption of Fine Aggregates", namely by soaking the sand in water for 24 hours, then weighing it in SSD, oven-dry, and water-soaked conditions (Babafemi et al., 2023).

4.1.4. Aggregate Sludge Content Testing (Claylump)

Fine Aggregate Sludge Content Testing is intended to determine the percentage of mud clumps and powder particles attached to the fine aggregate (sand). The following Fine Aggregate Sludge Content Test is explained in the table below.

Table 3. Claylump Test Table.

INSPECTION	TEST OBJECT (gr)
Dry Weight Before Washing	500
Dry Weight After Washing	395
Sludge Percentage $=\frac{500-w}{500} x\ 100\ \%$	2 1%

4.1.5. Testing of Organic Content of Fine Aggregate

One way to test for organic matter in fine aggregate is to use a calorimeter. In calorimeter measurements, the organic matter is neutralized with a 3% NaOH solution, and the resulting color is compared to a standard color after being left for approximately 24 hours.

Figure 1. Color Test.

4.1.6. Aggregate Unit Weight Test Results (AASHTO T-19-74) & (ASTM C-29-71)

Unit weight, also known as aggregate unit weight, is the ratio between aggregate weight and volume. The aggregate unit weight is required in calculating the concrete mix material if the amount of material is measured by volume. The aggregate unit weight is reviewed in two states, namely loose volume weight and solid volume weight Gu, L., Ozbakkaloglu, T., &

Gholampour, A., 2023). Loose volume weight is the ratio of aggregate weight to liter volume, while solid volume weight is the ratio of aggregate weight in a solid state to liter volume. This test is intended to determine the unit weight of fine and coarse aggregates, which is defined as the ratio between the weight of dry material and volume. The following aggregate unit weight test results are presented in the table cited below.

Table 5. Aggregate Content Weight

Description	Weight (kg)	
	Coarse Aggregate	Fine Aggregate
1. Container Weight (W1)	11660	11660
a. Release Method		
● Container Weight + Aggregate (W2)	31015	2 7480
● Aggregate Weight (W3)	19355	15280
b. Mashing Method		
● Container Weight + Aggregate (W2)	3 3545	29025
● Aggregate Weight (W3)	21885	17365
c. Tap Method		
● Container Weight + Aggregate (W2)	34465	29510
● Aggregate Weight (W3)	22805	17850

From an environmental perspective, this research reinforces the urgency of using recycled materials in construction. LDPE, which is generally difficult to decompose and a long-term source of pollution, can be engineered into a high-value construction material. This innovation supports plastic waste reduction policies, sustainable development, and natural resource conservation, particularly in the construction industry, known as one of the largest contributors to carbon emissions.

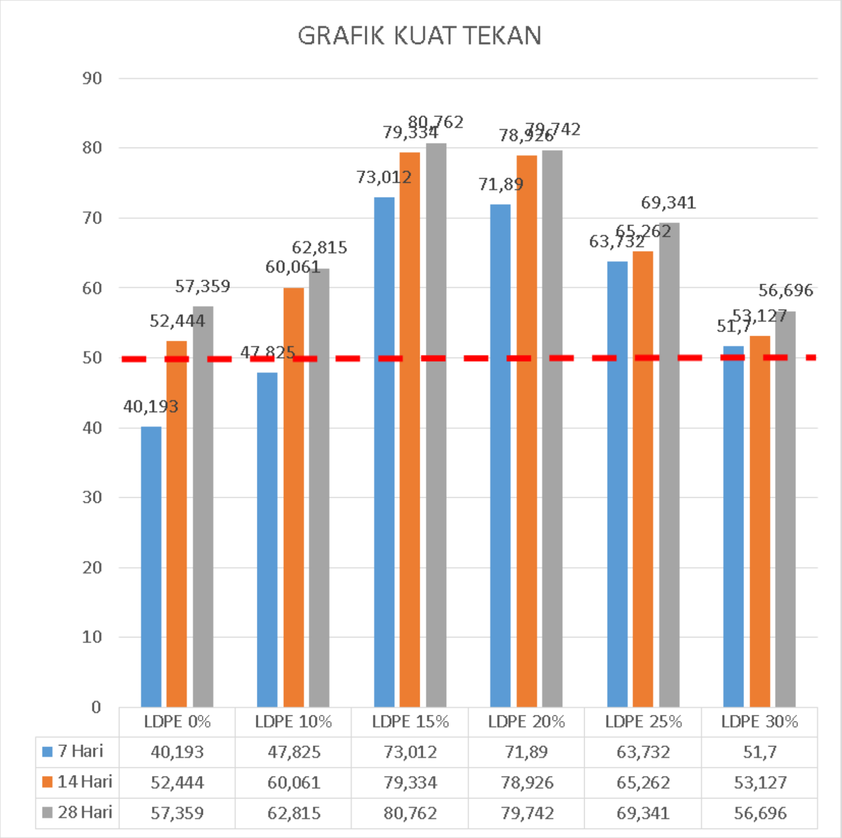


Figure 2. Graph of Compressive Strength of Concrete Bricks vs. SNI 03-0349-1989 Standard.

Based on the results of the research that has been conducted, it can be seen that the compressive strength of concrete blocks increases along with the addition of LDPE (Low-Density Polyethylene) type plastic waste in the mixture composition. Conventional concrete blocks or normal concrete blocks without LDPE mixture show maximum compressive strength at the age of 28 days, which is 57.359 kg/cm². This value has actually exceeded the minimum standard for concrete block compressive strength according to SNI 03-0349-1989, which stipulates that the minimum compressive strength of concrete blocks for structural purposes must be at 50 kg/cm². Thus, even conventional concrete blocks in this study are classified as having high structural performance. However, when concrete blocks are mixed with 10% LDPE waste, their maximum compressive strength increases to 62.815 kg/cm² at the same age, namely 28 days.

This demonstrates the positive role of LDPE as an additive, not only acting as a filler but also increasing the density and internal stability of the concrete blocks. Moderate amounts of LDPE particles appear to contribute to reduced porosity and help create a more solid composite structure.

A more significant increase was recorded in the concrete blocks with a 15% LDPE mixture, which achieved the highest compressive strength of 80.762 kg/cm². This represents an increase of ±40.8 % compared to normal concrete blocks, making the 15% LDPE content the most optimal composition in the entire series of tests. The large increase in compressive strength in this composition can be assumed to occur due to the even distribution of plastic particles in the mortar mixture, as well as the mechanical interaction between the materials that synergize without disrupting the cement hydration process. The flexible and water-resistant properties of LDPE likely also contribute to creating a closed micropore system that increases the concrete blocks' compressive strength and resistance to microstructural damage.

At 20% LDPE composition, the compressive strength decreased slightly to 79.742 kg/cm², but was still in the very high category and not much different from its peak. This indicates that the LDPE composition up to 20% is still able to maintain the structural quality of the brick at a superior level. However, at 25% LDPE composition, the compressive strength began to show a more pronounced decrease, namely 69.341 kg/cm², and at 30% LDPE composition, the compressive strength value decreased further to 56.696 kg/cm². This decrease indicates a maximum threshold for the use of LDPE in the brick mixture, where excess LDPE actually becomes an obstacle in the formation of a dense and strong structure. This is due to the nature of LDPE, which is chemically unreactive with cement and can create large amounts of voids if it exceeds the optimal proportion.

In general, the relationship between LDPE content and the compressive strength of concrete blocks forms a parabolic curve, indicating an optimum point (15%) where LDPE provides maximum reinforcement. Beyond this point, excess LDPE acts as a weak material, reducing the bond between particles and increasing the porosity of the concrete blocks. From the perspective of national construction standards, these results are highly relevant. According to SNI 03-0349-1989, concrete blocks used for exterior walls of buildings or structural elements must meet a minimum compressive strength requirement of 50 kg/cm². All test results obtained in this study even exceed the SNI threshold several times, which proves that LDPE waste-based concrete blocks are not only feasible, but even very superior in terms of mechanical strength.

This advantage is important in the context of developing waste-based and environmentally friendly building materials, as it addresses two issues simultaneously: reducing plastic pollution and providing high-quality building materials. The addition of LDPE at the right concentration, such as 15%, has been shown to improve the technical performance of concrete blocks without negatively impacting their structure or stability. Therefore, it can be concluded that the addition of LDPE up to an optimal concentration of 15% is an efficient strategy for increasing the compressive strength of concrete blocks and has great potential for widespread application in the sustainable construction industry. This research provides empirical and practical contributions to the utilization of plastic waste as an alternative construction material, in line with the principles of the circular economy and green building, which are currently the direction of national and global development policies.

5. Conclusion

With the results of the Table and Graphic Figures that have been presented previously, it can be concluded that conventional bricks without LDPE mixture show a maximum compressive strength of 57.359 kg/cm² at the age of 28 days. This value has exceeded the minimum standard compressive strength of bricks stipulated in SNI 03-0349-1989, which is 50 kg/cm², so that technically it has met the requirements as a structural building material. The addition of LDPE waste in the composition of the brick mixture has a significant effect on increasing the compressive strength. The higher the LDPE content to the optimal point, the greater the resulting compressive strength. The highest overall compressive strength was obtained in bricks with a 15% LDPE mixture, which reached 80.762 kg/cm² at the age of 28 days. This value shows an increase of ±40.8 % compared to normal bricks, making this composition the optimum formulation in improving the quality of bricks. The addition of LDPE up to 20% still produces a high compressive strength of 79.742 kg/cm², but at 25% and 30% compositions, there is a gradual decrease to 69.341 kg/cm² and 56.696 kg/cm², respectively. This decrease is caused by the excess LDPE, which disrupts the structural integrity of the concrete blocks, creating voids and reducing the bond between cement and aggregate particles. The relationship between LDPE content and compressive strength forms a parabolic curve, with a peak point at 15% composition. Below or above this point, the mechanical performance of the concrete blocks decreases, so it is important to determine the optimal limit for LDPE use in material formulations.

The results of this test indicate that LDPE plastic waste can be effectively utilized as an additive in the production of concrete blocks, not only to reduce environmental impacts but also to improve the strength and quality of construction products. This contributes to the development of environmentally friendly and sustainable building materials. Based on the overall results, it can be recommended that the addition of 15% LDPE waste is the best formulation to increase the compressive strength of concrete blocks without compromising quality standards, while supporting the principles of green construction and a circular economy.

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