
Utilization of Plastic Waste (HDPE, PET, and PP) as Paving Block Mixture Materials

Ihsan Abadi*, BP Samadikun, HS Huboyo

Universitas Diponegoro Semarang, Indonesia

Email: ihsanabadi 2016@gmail.com*

Abstract

Waste has always been a major problem in the environment due to the lack of public knowledge in waste management. One type of waste commonly generated by people daily is plastic waste. One of the efforts that can be made to utilize plastic waste is to incorporate it as a mixture material in the production of paving blocks. The purpose of this study is to compare the mechanical properties of paving blocks for each type of plastic used, both in terms of compressive strength and water absorption. The methods employed include data collection and analysis, as well as laboratory testing. The findings indicate that HDPE plastic exhibits the highest compressive strength among the three types, while PP plastic shows the best water absorption performance, with HDPE also demonstrating favorable absorption characteristics. These results imply that plastic waste, particularly HDPE, can be effectively utilized as a sustainable alternative material in non-structural construction applications such as paving blocks, contributing to waste reduction efforts and promoting environmentally friendly construction practices. Thus, it is hoped that this research can serve as a reference in the processing of plastic waste in the fields of both architecture and environmental engineering.

Keywords:

Waste;

Concrete;

plastic

INTRODUCTION

The environmental problem that is currently facing the whole world, including Indonesia, is the accumulation of plastic waste. Plastic waste in Indonesia reaches 9.52 tons per year. If not managed properly, plastic waste can have a negative impact on the environment and health. Often people throw garbage carelessly without thinking about the impact. In addition to polluting the environment, piles of garbage can emit unpleasant odors and attract flies that can spread diseases. Garbage that is thrown carelessly can also clog waterways, sewers, and rivers that can cause flooding. The burning of plastic waste can release substances that are harmful to human health (WY Wiswamitra PJA Dewi, NLP Srinadi, IKD Suryawan, DR Putri, 2022).

Indonesia is a country with a high population and has the character of people who like to shop for daily necessities. One type of waste is plastic bags that are often used when shopping in supermarkets and minimarkets. The large impact of plastic waste on environmental damage is reflected in its hard-to-decompose nature. This is because the process of decomposing plastic waste with soil until it fully decomposes takes 100-500 years. If plastic waste is burned openly, it will produce Polychlorinated Dibenzo-p-dioxins which are toxic substances. Plastic substances that enter the environment due to plastic waste will not decompose in the near future. If garbage enters the river, the substance will be carried into the sea by ocean currents (CA Rahmayani, 2021).

The composition of waste generated from human activities is 60%-70% organic waste and 30%-40% non-organic waste. Meanwhile, of the non-organic waste, the largest composition is plastic waste. The most plastic waste is in the form of plastic bags or plastic bags other than plastic packaging. Indonesia ranks second in the world after China, which produces 187.2 million tons of waste in its waters. This is related to data from the Ministry of Environment and Forestry which states that plastic produced from 100 stores or members of the Indonesian Retail Traders Association (APRINDO) in just 1 year has reached 10.95 million plastic bags. This amount turned out to be equivalent to an area of 65.7 hectares of plastic bags. The problem with plastic waste is that if its amount in the environment increases, it has the potential to pollute the environment. Given the nature of plastic that will decompose in the soil in more than 20 years, it can even reach 100 years, so it can reduce soil fertility and in waters, plastic will be difficult to decompose (Purwaningrum, 2016).

This problem has become increasingly complicated due to the irregular distribution of waste disposal, with improper methods of processing, transporting and disposing of waste, the lack of public awareness of this phenomenon due to population growth, and the progress of industries that pollute the environment. Regardless of these reasons, the problem of plastic waste buildup can be minimized by recycling methods, and the use of waste in concrete buildings is considered a creative way. Therefore, recycling this waste in the form of building materials as a partial alternative to sand, gravel or fiber added to the concrete mixture is one of the techniques that may be used to reduce the environmental impact of this waste in addition to reducing disposal costs (H.M. Adnan, 2021).

The use of plastic waste in concrete mixes not only helps reduce construction costs, but also ensures that plastic waste is disposed of safely and securely. By using plastic waste, the cost of concrete production can be significantly reduced. Based on the results of the tests carried out, it has been determined that decomposed plastic waste is not inferior to other natural resources when used in concrete mixtures (NR Varma, 2022).

There are different types of plastics. The plastic used to make mineral water bottles is different from the plastic used to make bowls, straws, chairs, and pipes. To find out the type of plastic used as the base material of a product, you can look at the symbols printed on the plastic. This symbol is a number (from 1-7) in a series of arrows that form a triangle, usually printed on the bottom of a plastic object. Each symbol represents a different type of plastic and forms a grouping in the recycling process (HP Putra, 2010). Table 1 describes the different types of symbols on plastic.

This classification and coding were developed by the Society of the Plastic Industry (SPI), a trade organization in Washington DC that represents the plastics industry in America. The purpose of this classification and coding is to provide a consistent national system to facilitate the classification of used plastics for plastic recyclers. Although not mandatory, this coding has become a standard procedure for plastic products sold in the United States and Canada. In Indonesia, this coding is commonly used.

The types of plastic waste used in this study are polyethylene terephthalate (PET), polypropylene (PP), and High-Density Polyethylene (HDPE). Researchers say that this type of plastic waste is increasing day by day in an environment that has harmful effects on wildlife, the food chain, and humans. The properties of hard concrete and fresh concrete are checked to determine the exact percentage of HDPE, PET and PP inclusions in conventional

concrete. The results show that mixing plastics in concrete mixtures will reduce the strength of concrete if concrete mixtures are used in building structures such as beams and columns, but will be very beneficial if used in non-structural buildings such as wall pairs or paving blocks (M Harihanandthth, 2022).

Another type of plastic used for mixing in concrete is HDPE plastic. This paper examines the use of metakaolin and HDPE plastic waste with different percentages of life in concrete to produce economical concrete with desirable properties and to reduce the consumption of naturally available building materials (V Punitha OG Babu, 2021).

Several previous studies have examined the use of plastic waste in concrete mixtures. Research by Harihanandth and Karthik (2022) tested the strength of PET plastic in the laboratory and showed that the use of PET plastic waste in bottled mineral water has a major impact on reducing PET waste in the environment. However, their study only focused on laboratory testing without observing the environmental impact of reducing PET plastic waste as it is used in concrete mixtures (7656:2012, 2012). Research by Varma and Chekravarthy (2022) investigated the use of plastic waste in concrete mixes and found that the cost of concrete production can be significantly reduced by using plastic waste. Their study concluded that decomposed plastic waste is not inferior to other natural resources when used in concrete mixtures, but they did not specifically compare different types of plastics (HDPE, PET, and PP) in terms of compressive strength and water absorption (03-0691-1996, 1996). Research by Adnan and Dawud (2021) explored recycling plastic waste in the form of building materials as a partial alternative to sand, gravel or fiber added to concrete mixtures. Their study emphasized that this technique may be used to reduce the environmental impact of plastic waste in addition to reducing disposal costs, but they did not conduct comprehensive testing on the quality of concrete produced from different plastic types (M Ahmed et al., 2014; R Singh et al., 2016; S Kumar et al., 2018). Research by Punitha, Sakthieswaran, and Babu (2021) examined the use of metakaolin and HDPE plastic waste with different percentages in concrete to produce economical concrete with desirable properties and to reduce the consumption of naturally available building materials. Their study focused specifically on HDPE plastic and metakaolin combinations, without comparing with other plastic types such as PET and PP (B Raheem et al., 2015; S T Shah et al., 2019).

The type of plastic studied in this study is plastic mineral water bottles and has a plastic code, namely PET, plastic waste in black plastic bags has a plastic code, namely HDPE, and plastic waste in plastic cups in bottled mineral water has a plastic code, namely PP. This type of plastic is researched because it is widely used as a waste and is not treated properly, so the researcher wants to show the potential of this plastic waste if used in concrete paving block mixtures (Al., 2020; K Y Tang et al., 2021; S M Gupta et al., 2021; S Mohammadi et al., 2020).

This study aims to analyze the potential use of HDPE, PET, and PP plastic waste as mixed materials in paving block manufacturing by comparing the compressive strength and water absorption of each type of plastic used. Specifically, this research seeks to determine which type of plastic waste is most effective for use in paving block mixtures based on compressive strength and water absorption tests, as well as to evaluate the quality of paving blocks produced from plastic waste mixtures compared to conventional paving blocks. The benefits of this research are expected to be both theoretical and practical. Theoretically, this

research contributes to the development of knowledge in the fields of architecture and environmental engineering, particularly regarding the utilization of plastic waste as an alternative construction material. Practically, this research is expected to provide a reference for waste management and recycling industries, construction practitioners, and policymakers in processing plastic waste into valuable construction materials, thereby reducing environmental pollution caused by plastic waste accumulation. Furthermore, this research can serve as a foundation for further studies on the utilization of various types of plastic waste in other infrastructure applications.

METHOD

The function of plastic waste is as an additive in the concrete paving block mixture which is used to increase the strength of concrete. The following are the stages of the research which include the research design, the research location, and the data analysis process:

1. The HDPE, PET, and PP plastic waste obtained comes from the *Parit Enam* landfill in *Pangkal Pinang* City. Cement, sand and gravel are purchased from the Building Materials Store
2. Plastic waste is washed clean and dried by spreading it in the yard until it is dry and ensured to be dirt-free and water-free, then plastic waste is cut into 5-10 mm sizes.
3. The process of making concrete mixtures. The percentage used in the concrete mixture for this paving block is 1 cement: 2 sands: 2 gravels. Then the gravel calculation is subdivided by the percentage of plastic used, for example concrete samples with a mixture of 5% HDPE plastic, so that the gravel used is 95% of the total gravel and the remaining 5% is HDPE plastic, as well as the calculation of other plastics. The stages determined to make the right proportions of the mixture are:

Calculating the mold volume on concrete, the formula of which is:

$$V = \pi \times r^2 \times t \quad (1)$$

Where:

- V : mold volume / volume of one paving block (cm³)
r : Cylinder Radius (cm)
t : Cylinder Height (cm)

Calculate the ratio of material proportions

Cement : 1 part

Sand : 2 parts

Gravel Plastic : 2 parts

So that the total is 5 parts

Cement water factor used 0.4-0.5

Calculating the volume of each material

Cement volume (V_s) = $1/5 \times$ mold volume

Sand volume (V_{Ah}) = $2/5 \times$ mold volume

Gravel volume (V_{Ak}) = $2/5 \times$ mold volume

Calculating the weight of the conversion material

$$W = V \times \rho \quad (2)$$

Where:

W : Mass/Weight of Material (kg)

V : Volume of Material (m³)

ρ : Material density (kg/m³)

The density of each material is as follows:

Cement : 3,100 kg/m³

Sand : 2.600 kg/m³

gravel : 2.700 kg/m³

HDPE plastic : 950 kg/m³

PET plastic : 1.380 kg/m³

PP plastic : 910 kg/m³ [9].

The samples needed in this study amounted to 20 pieces, with details in Table 1 below:

Table 1. Data on the amount of plastic in mineral water

Uses	Quantity (fruit)
Standard concrete mix sample	2
concrete sample with 5% HDPE plastic mixture	3
concrete sample with 7.5% HDPE plastic mixture	3
concrete sample with 5% PET plastic mixture	3
concrete sample with 7.5% PET plastic mixture	3
concrete sample with 5% PP plastic mixture	3
concrete sample with 7.5% PP plastic mixture	3
Total	20

Total 20

Source: Count Analysis, 2026

The manufacture of the concrete mixture is carried out per sample, which means that every time the concrete mixture has been stirred until homogeneous, the concrete mixture is molded using a cylindrical mold measuring 15 cm x 30 cm. Then, the concrete mixture is left for approximately 24 hours in the mold, and removed from the mold after the time has passed 24 hours later, and the concrete curing process is carried out. This curing process is carried out by soaking concrete that has been removed from the mold. The concrete is immersed in a container filled with clean water and soaked for 7 days to 28 days. However, in this study, the concrete was soaked for 28 days so that the strength of the concrete could be maximized during the pressure test stage.



Figure 1. Concrete mix manufacturing process
Source: Research Documentation (2026)



Figure 2. Concrete mixture molding process in cylindrical mold
Source: Research Documentation (2026)



Figure 3. Process concrete mixture released from mold after 24 hours
Source: Research Documentation (2026)



Figure 4. Curing process of concrete mixture sample
Source: Research Documentation (2026)

Another test carried out when making concrete mixtures is the water absorption test. This test aims to ensure low porosity so that the paving block is rainproof and can prevent cracks in the near future. The method of testing is a ball-shaped paving block sample weighing 200 grams soaked for 24 hours and weighed after soaking, then dried in an oven at 105°C for 24 hours, then weighed to calculate the absorption percentage, which is wet weight minus dry weight. The formula is as follows [10]::

$$\text{Water absorption (\%)} = (B-A)/A \times 100\% \quad (3)$$

Where:

B = wet weight (kg)

A = dry weight (kg)

Samples per paving block are made as many as 3 pieces, which are then calculated to average the value of the absorption test.

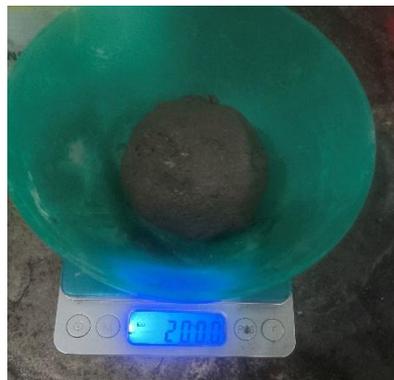


Figure 5. test specimen weighing process
Source: Research Documentation (2026)



Figure 6. drying the test specimen using the oven
 Source: Research Documentation (2026)

Then after 28 days, a compressive strength test was carried out on the concrete paving block sample. The formula for the compressive strength test is:

$$f_c = P/A \quad (4)$$

Where:

P = maximum load (in N or kN)

A = cross-sectional area (mm²)

Determining the quality of concrete based on compressive strength test data and water absorption test

Table 3. Concrete quality

End	Uses	Compressive Strength (Mpa)		Average water absorption max.
		Average	Min.	(%)
A	Road pavement	40	35,0	3
B	Car parking	20	17,0	6
C	Pedestrian	15	12,5	8
D	City Park	10	8,5	10

Source: Data Analysis Results (2026)

RESULTS AND DISCUSSION

This Study Was Conducted to See the Potential Use of HDPE, PET, and PP Plastic Waste in Concrete Mixtures as Paving Blocks

The first test carried out was the water absorption test. Each concrete sample uses 3 circular / spherical samples with an initial weight of 200 grams. So that the sample used in this study amounted to 60 pieces. Each sample was soaked for 24 hours to obtain wet weight (B). After 24 hours, the sample is dried in an oven at 105°C for 24 hours. After conducting the water absorption test, the data of each sample is obtained in the following table:

Table 4. Water absorption value per sample

No.	Code	Wet Weight (B) (grams)	Dry Weight (A) (grams)	Water Absorption Value (%)	Average	Average of Each Type of Plastic
1	N1	210	195	7,692	7,009	7,003
		209	196	6,633		
		207	194	6,701		
2	N2	211	197	7,107	6,997	
		208	194	7,216		
		208	195	6,667		
3	PET 5% No.1	210	195	7,692	8,057	
		212	193	9,845		
		209	196	6,633		
4	PET 5% No.2	212	197	7,614	7,178	7,152
		207	193	7,254		
		208	195	6,667		
5	PET 5% No.3	210	197	6,599	6,220	
		210	198	6,061		
		212	200	6,000		
6	PET 7.5% No. 1	213	199	7,035	7,246	
		213	196	8,673		
		211	199	6,030		
7	PET 7.5% No. 2	210	198	6,061	7,507	7,224
		211	196	7,653		
		210	193	8,808		
8	PET 7.5% No. 3	213	197	8,122	6,919	
		210	199	5,528		
		211	197	7,107		
9	HDPE 5% No.1	210	197	6,599	6,023	
		211	200	5,500		
		213	201	5,970		
10	HDPE 5% No.2	206	194	6,186	5,996	6,482
		207	194	6,701		
		206	196	5,102		
11	HDPE 5% No.3	207	193	7,254	7,426	
		208	196	6,122		
		208	191	8,901		
12	HDPE 7.5% No. 1	207	196	5,612	5,913	
		210	197	6,599		
		210	199	5,528		
13	HDPE 7.5% No. 2	212	199	6,533	6,003	5,958
		213	200	6,500		
		211	201	4,975		
14	HDPE 7.5% No. 3	207	197	5,076	5,959	

		208	197	5,584		
		208	194	7,216		
15	PP 5% No.1	208	197	5,584		
		209	199	5,025	5,929	
		209	195	7,179		
16	PP 5% No.2	210	199	5,528		
		209	199	5,025	5,899	5,752
		210	196	7,143		
17	PP 5% No.3	206	195	5,641		
		208	196	6,122	5,429	
		208	199	4,523		
18	PP 7.5% No. 1	211	198	6,566		
		211	197	7,107	6,891	
		214	200	7,000		
19	PP 7.5% No. 2	210	199	5,528		
		213	197	8,122	6,919	6,852
		211	197	7,107		
20	PP 7.5% No. 3	210	197	6,599		
		211	199	6,030	6,748	
		212	197	7,614		

Source: Data Analysis Results (2026)

From Table 4, it can be concluded that among the three types of plastics, PP type plastic with a percentage of 5% in concrete mixture has the lowest water absorption value of 5.752%, while PET plastic with a percentage of 7.5% in concrete mixture has the highest water absorption value of 7.224%. This can happen because of 2 things. First, because the percentage of plastic mixture in concrete is larger, which is 7.5%. Second, because the density of PET plastic waste itself is higher than that of the other two types of plastics, so more plastic is needed in the concrete mixture, which certainly affects the binding power between particles in the concrete mixture, because the more plastic, the lower the binding power of particles in the concrete mixture. [11]

The second test carried out was compressive strength testing on concrete mixture samples. After conducting compressive strength tests on 20 paving block samples, compressive strength data was obtained as follows:

Table 5. Compressive Strength Values of The Test Specimen

No.	Code	Compressive Strength		
		Maximum Load (N)	Value	Average
1	N1	253000	14,317	14,232
2	N2	250000	14,147	
3	PET 5% No.1	224000	12,676	12,695
4	PET 5% No.2	228000	12,902	
5	PET 5% No.3	221000	12,506	
6	PET 7.5% No. 1	217000	12,280	12,261
7	PET 7.5% No. 2	215000	12,167	

8	PET 7.5% No. 3	218000	12,337	
9	HDPE 5% No.1	237000	13,412	
10	HDPE 5% No.2	232000	13,129	13,355
11	HDPE 5% No.3	239000	13,525	
12	HDPE 7.5% No. 1	226000	12,789	
13	HDPE 7.5% No. 2	224000	12,676	12,695
14	HDPE 7.5% No. 3	223000	12,620	
15	PP 5% No.1	234000	13,242	
16	PP 5% No.2	237000	13,412	13,280
17	PP 5% No.3	233000	13,185	
18	PP 7.5% No. 1	225000	12,733	
19	PP 7.5% No. 2	223000	12,620	12,752
20	PP 7.5% No. 3	228000	12,902	

Source: Data Analysis Results (2026)

The normal concrete test piece in this study is only to be a reference for the plastic mixed concrete test piece. In the table above, it can be seen that the compressive strength value of 5% plastic mixed concrete is the highest among other plastic mixed concrete, which is 13,355 Mpa.

After the compressive strength test and water absorption test on the three types of plastics, namely HDPE, PET, and PP, by referring to Table 3, the quality of each plastic used can be obtained as stated in the following table:

Table 6. Values Compressive strength and water absorption percentage in each type of plastic

No.	Code	Compressive Strength Value		Average Water Absorption Percentage	Compressive Strength Quality
		Average	Min		
1	N1				
2	N2	14,232	14,147	7,003	D
3	PET 5% No.1				
4	PET 5% No.2	12,695	12,506	7,152	D
5	PET 5% No.3				
6	PET 7.5% No. 1				
7	PET 7.5% No. 2	12,261	12,167	7,224	D
8	PET 7.5% No. 3				
9	HDPE 5% No.1				
10	HDPE 5% No.2	13,355	13,129	6,482	D
11	HDPE 5% No.3				
12	HDPE 7.5% No. 1				
13	HDPE 7.5% No. 2	12,695	12,620	5,958	D
14	HDPE 7.5% No. 3				
15	PP 5% No.1				
16	PP 5% No.2	13,28	13,185	5,752	D
17	PP 5% No.3				
18	PP 7.5% No. 1				
19	PP 7.5% No. 2	12,752	12,620	6,852	D

Source: Data Analysis Results (2026)

From the table above, it can be seen that each type of plastic has a fairly low compressive strength value, but it is still above average because the value is close to the quality of C. Meanwhile, the value of the water absorption percentage of each type of plastic is quite high.

CONCLUSION

Based on the results of the analysis above, several conclusions can be drawn: 1. HDPE type plastic has the highest average compressive strength value compared to other types of plastic. 2. The water absorption percentage of PP type plastic is the best, but if you look at Table 6, the water absorption percentage of HDPE type plastic is also good, so it can be concluded that HDPE plastic is the best type of plastic to be used in concrete mixtures in the manufacture of paving blocks. 3. Although the compressive strength value of the three types of plastics is quite low, the water absorption percentage of the three types of plastics is quite good, so if it is used in paving blocks for the purposes of city parks (quality D) and pedestrians (quality C), paving blocks can withstand pressure and rainfall. 1 is the final value of the three types of plastics tested, both in terms of compressive strength and water absorption.

Thus, it can be scientifically proven and concluded that the use of plastic waste in concrete mixtures will significantly reduce plastic waste, the strength of concrete can be compared with conventional concrete, and the price is quite economical because the materials do not need to be purchased. Thus, it can be concluded that the use of plastic waste in concrete mixtures can be beneficial for the environment and building structures. This research uses plastic waste as a concrete mixture, so it is hoped that in the future this research can be a reference in the use of plastic waste, in addition to being used in concrete mixtures, it can also be used for other things in the infrastructure sector.

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