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The Evaluation of the Use PET and HDPE Plastic Waste as Coarse Aggregate of Lightweight Concrete

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Abstract. The use of goods with plastic-based materials is familiar to society in general. Good for wrapping food, drinks, groceries, and others. Because of so much use, the problem of plastic waste cannot be avoided. Therefore, the purpose of this study is to overcome environmental land problems due to plastic waste. This research focuses on how to apply PET (Poly-Ethylene Terephthalate) and HDPE (High Density Polyethylene) plastic waste to concrete mixtures. PET plastic waste that has been chopped is then heated until melted then poured into molds and allowed to cool and harden. Then crushed and substituted as much as 5%, 10%, 15% and 20% replace the coarse aggregate to improve the characteristics of concrete. The results showed that the use of PET and HDPE in concrete resulted in decreased fill weight, lighter concrete weight, reduced compressive strength, and gave an optimum value of tensile strength at a variation of 10%. The use of PET plastic has a greater absorption value than HDPE, while the tensile strength value of PET is smaller than HDPE. Overall, it is concluded that PET and HDPE plastics have a big role in reducing the problem of plastic waste in the community.

Keyword: HDPE, PET, Lightweight concrete, Compressive strength, Tensile Strength

Abstrak. *Penggunaan barang dengan bahan dasar plastik sudah tidak asing lagi bagi masyarakat pada umumnya. Baik untuk pembungkus makanan , minuman , belanjaan , dan lain lain. Oleh karena pemakaian yang begitu banyak , permasalahan limbah plastik pun tidak dapat dihindari. Maka dari pada itu maksud dalam penelitian ini yaitu untuk menangulangi permasalahan lingkungan akibat limbah plastik. Penelitian ini berfokus bagaimana mengaplikasikan limbah plastik jenis PET (Poly-Ethylene Terephthalate) dan HDPE (High Density Polyethylene) pada campuran beton. Limbah plastik PET yang sudah dicacah kemudian dipanaskan hingga meleleh kemudian dituangkan ke cetakan dan dibiarkan dingin dan mengeras. Lalu dihancurkan dan disubstitusikan sebanyak 5%, 10%, 15% dan 20% menggantikan agregat kasar untuk meningkatkan karakteristik beton. Hasil penelitian menunjukkan penggunaan PET dan HDPE pada beton menghasilkan berat isi menurun, berat beton lebih ringan, mengurangi kuat tekan, dan memberikan nilai optimum kuat tarik belah pada variasi 10%. Penggunaan plastik PET memiliki nilai penyerapan lebih besar daripada HDPE, sedangkan nilai kuat tarik belah PET lebih kecil daripada HDPE. Secara keseluruhan di simpulkan bahwa plastik PET dan HDPE punya peranan besar dalam mengurangi permasalahan limbah plastik di masyarakat.*

Kata Kunci: *HDPE, PET, Beton ringan, Kuat tekan, Kuat tarik belah*

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1 Introduction

Currently, plastic material is widely used in our daily activities. This is because the price of products made from plastic is relatively cheap, easy to obtain, and lightweight. However, as the use of plastic materials increases, plastic waste will also increase. This causes the problem of plastic waste that is harmful to the environment [1], [2].

Plastic is an inorganic material and difficult to reprocess. The decomposition process takes a very long time to decompose completely. During the decomposition process, plastic waste will pollute the soil, air, and water. If plastic is landfilled in the soil, it will damage soil fertility and block the flow of water in the soil, while if plastic waste is burned, toxic fumes resulting from burning will be harmful to living things. When plastic is discharged into waters, the chemicals found in plastic will damage marine life [3].

Based on ScienceMag data, the amount of global plastic waste production from 1950 to 2015 tends to show an increase. In 1950, world waste production was at 2 million tons per year. While 65 years after that, in 2015 waste production was at 381 million tons per year. This figure shows an increase of more than 190-fold with an average increase of 5.8 tons per year. Based on data from the Indonesian Plastic Industry Association and the Central Statistics Agency, plastic waste in Indonesia reaches 64 million tons per year, of which 3.2 million tons are plastic waste thrown into the sea [4].

One of these types of plastic waste is PET (Polyethylene Terephthalate) and HDPE (High Density Polyethylene) plastic waste. In this study, PET and HDPE plastic types were used. This type of PET plastic is usually used as beverage packaging or food packaging. PET plastic packaging after the contents is consumed is usually disposed of immediately. In essence, the use of PET plastic is one-time, then recycled back into other recycled plastic products. But in fact, this plastic is reused by the community both to package food and beverages and other uses. The hazardous materials contained in the PET plastic over time can mix with the food or beverages packaged in it so that it can be dangerous for users or users of recycled products. This PET has been studied on non-structural lightweight concrete and obtained the results of compressive strength and tensile strength of concrete decreasing along with the increase in the percentage variation of PETs. Plastic concrete with substitution variations of 20% to 50% has met the requirements for the weight of light concrete contents according to SNI 03-2461-2002, namely the maximum value of the content weight of 1850 kg/m^3 [5]–[7].

HDPE plastic is a type of plastic that is usually used to make milk bottles, detergent bottles, shampoo bottles, moisturizing bottles, oil bottles, toys, and some plastic bags. HDPE is the most recycled plastic and is considered the safest plastic. The process of recycling this plastic is quite simple and does not cost much. HDPE is the most recycled plastic and is considered the safest

plastic. The process of recycling this plastic is quite simple and does not cost much. HDPE plastic is very hard and not easily damaged by sunlight, high heat, or cold temperatures [8]–[10].

According to Shutong Yang et al. [11], reuse is the best way to overcome the problem of plastic waste. Various efforts in tackling plastic waste can be done such as the reuse of the waste in the civil engineering industry, one of which is the replacement of coarse aggregate in concrete [12], [13]. The use of plastic waste in the construction sector has been applied in light piles of road construction as an additional material because it is considered that the volume weight of plastic is lighter than the soil [1]. In addition, the use of plastic waste in the construction sector is also applied as a substitute for aggregate in the manufacture of lightweight concrete. In addition to reducing the use of natural resources, the use of plastic waste can also reduce the amount of waste in the environment [7]. This is because the plastic material has lightweight physical properties so that it can also be used as a substitute for conventional aggregate in reducing the unit weight of concrete [11], [14]. Therefore, the author focuses primarily on valuing the Feasibility of Using Coarse Aggregates of PET and HDPE Plastic Waste in Lightweight Concrete.

2 Methods

In this study, the manufacture and processing of aggregates from PET and HDPE plastic waste became the main focus in the early stages of research. The crushed plastic pellets are then heated at 180-200 ºC for PET plastic and 250-300ºC for HDPE plastic within 30 minutes until completely melted. After that, the plastic melt is poured into molds with a size of 30x30x5 in cm, and then cooled for about 30-60 minutes. After hardening, the plastic is reduced using hammerheads. After obtaining test objects, then substituted by 5%, 10%, 15% and 20% in each type of concrete mixture. The specimen is left for 28 days then tested for water absorption, bulk density, compressive strength, and tensile strength of concrete.

(a)

(b)

Figure 1 (a) PET Plastic Fragments, (b) HDPE Plastic Fragments

To calculate the amount of Bulk Density, the following equation is used:

$$\text{Bulk Density (BI)} = \frac{W}{V} \tag{1}$$

BI = Bulk Density (kg/m^3)

W = Weight (kg)

V = Volume (m^3)

For the measurement of water absorption concrete, it can be calculated by the following equation:

$$W_a = \frac{M_j - M_k}{M_k} \times 100\% \quad (2)$$

Wa = Water Absorption (%)

Mk = Dry mass (gr)

Mj = Saturated mass (gr)

For the measurement of compressive strength and tensile strength, it can be calculated by the following equation: [15]–[17]

$$P = \frac{F_{maks}}{A} \quad (3)$$

P = Compressive Strength (kg/cm^2)

F_{maks} = Maximum Force (kg)

A = Surface area of the specimen (cm^2)

3 Results and Analysis

After the testing process of the test object, the results of testing the bulk density, water absorption, compressive strength of concrete, and tensile strength of concrete are obtained. The test specimen test results using HDPE plastic waste aggregate sub-site have a higher fill weight compared to test specimens using PET plastic waste aggregate subsite. It can be stated that test specimens using HDPE plastic waste aggregate have a better average density than PET.

Table 1 Comparison of Average Bulk Density of Concrete Test Specimens

No.	Types of Concrete	Volume (m^3)	Average Weight (kg)	Bulk Density (kg/m^3)
1	Beton Normal	0,005	12,408	2345,680
2	Beton PET (5%)	0,005	11,538	2181,191
3	Beton PET (10%)	0,005	11,044	2087,807
4	Beton PET (15%)	0,005	10,660	2015,154
5	Beton PET (20%)	0,005	10,243	1936,452
6	Beton HDPE (5%)	0,005	11,699	2211,531
7	Beton HDPE (10%)	0,005	11,338	2143,321
8	Beton HDPE (15%)	0,005	10,881	2056,900
9	Beton HDPE (20%)	0,005	10,444	1974,449

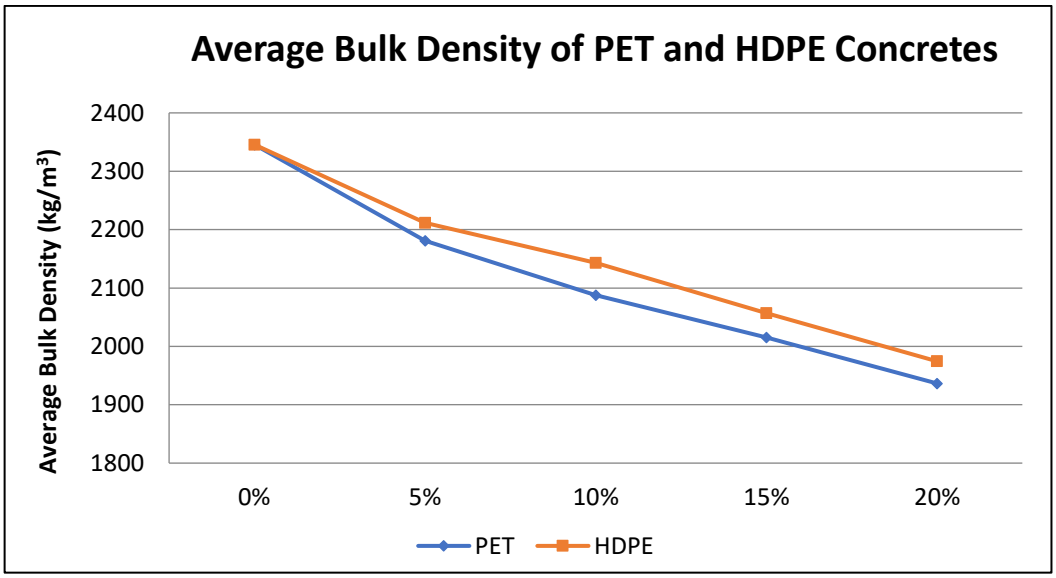

Figure 2 Comparison Graph of Average Bulk Density of Concrete Test Specimens.

From the results of the bulk density testing that has been done, HDPE concrete and PET concrete have a smaller bulk density compared to normal concrete (0% variation). This is also because the weight of the coarse aggregate of HDPE plastic waste itself is heavier than the coarse aggregate of HDPE plastic waste. So, it can be said that the use of PET and HDPE plastic types and pat reduce the bulk density.

Table 2 Comparison of Average Water Absorption Concrete Test Specimens

No.	Plastic Substitution Variations	Absorption (%)	
		PET	HDPE
1	0%	0,800	0,800
2	5%	1,255	1,215
3	10%	1,309	1,337
4	15%	1,433	1,456
5	20%	1,525	1,594

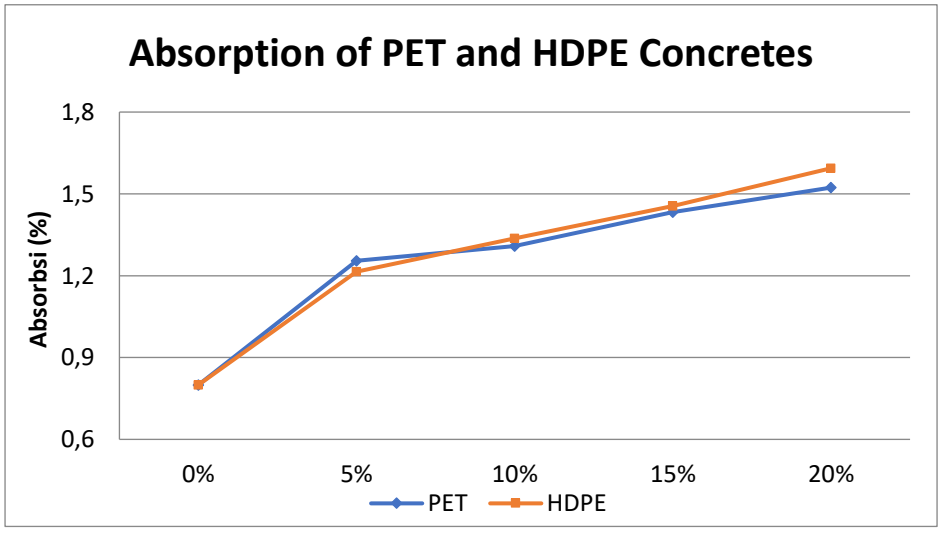

Figure 3 Comparison of Water Absorption Concrete.

In absorption testing, PET has a higher absorption value than HDPE at a variation of 5%. However, it experiencesa decline in variations of 10% to 20%. It can be stated that the increasing levels of PET and HDPE which replace coarse aggregates cause the absorption value to be greater. Which means that the air pores contained in concrete are increasing.

In compressive strength testing, pressure is applied until the maximum load that concrete can withstand is obtained. The specimen used is a cylinder measuring 15 cm in diameter and 30 cm high and has gone through a maintenance process of up to 28 days. The test results can be seen in Table 3.

Table 3 The Results of Average compressive strength of PET and HDPE Concretes

No.	Test Specimens	Average Compressive Strength (MPa)	
		PET	HDPE
1.	0%	21,725	21,725
2.	5%	15,707	15,707
3.	10%	14,331	14,331
4.	15%	12,942	12,942
5.	20%	11,521	11,521

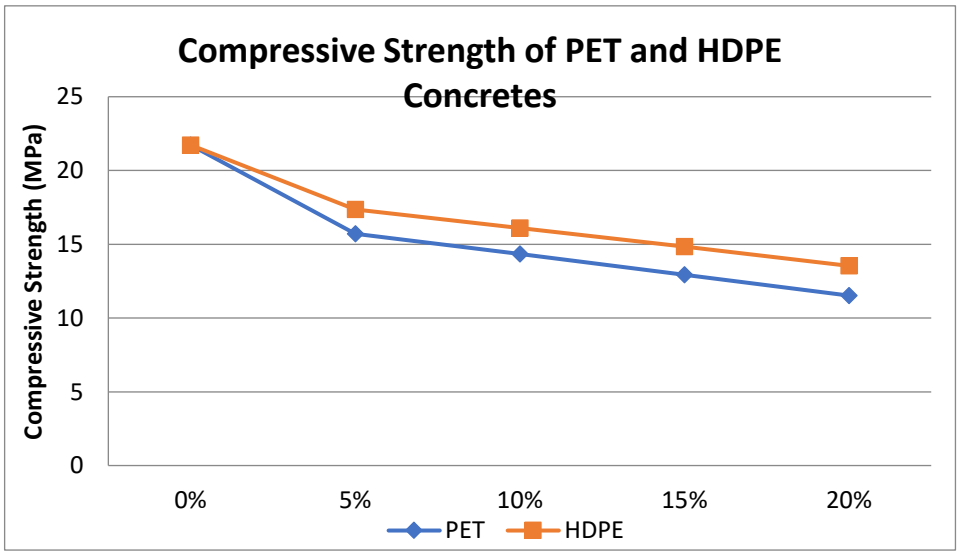

Figure 4 Comparison of Compressive Strength Concretes.

From the compressive strength comparison graph, it can be seen that the compressive strength value of HDPE type concrete is greater than PET. Both types of plastics have lower compressive strength values than normal concrete. The greatest compressive strength value is obtained at a variation of 5%. The greater the aggregate content of PET and HDPE plastics, the lower the compressive strength. The compressive strength of PET and HDPE concrete from existing variations can not be categorized as structural lightweight concrete (minimum compressive strength of 17.24 MPa and maximum of 41.36 MPa). The compressive strength of PET and HDPE mixture concrete has decreased, this is due to increased air pores which cause high concrete absorption value.

Table 4 The Results of Average compressive strength of PET and HDPE Concretes

No.	Test Specimens	Average Tensile Strength (MPa)	
		PET	HDPE
1.	0%	1,887	1,887
2.	5%	1,934	1,934
3.	10%	2,075	2,075
4.	15%	1,886	1,886
5.	20%	1,839	1,839

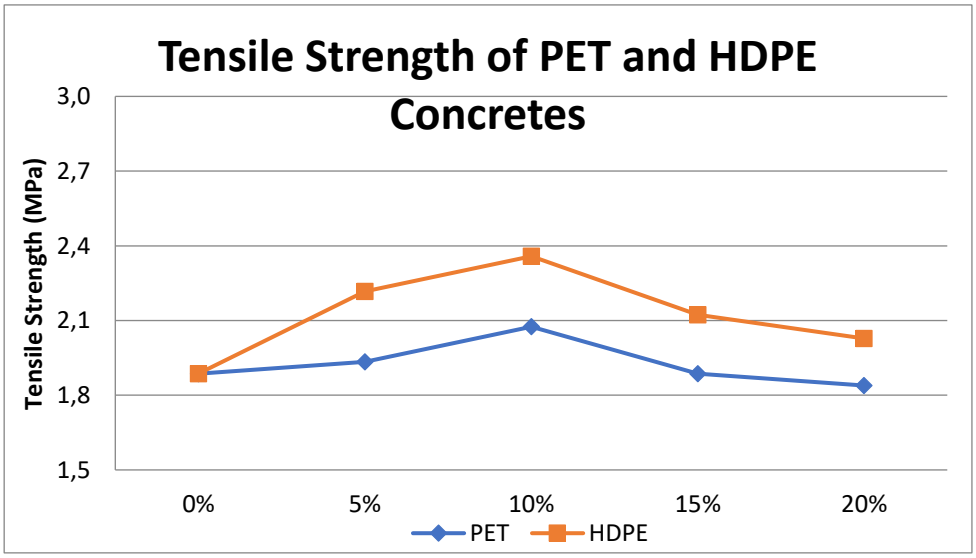

Figure 5 Comparison of Tensile Strength Concretes.

From the graph of the tensile strength test results, it can be seen that the tensile strength value of concrete with HDPE substitution is greater than PET. The optimum tensile value is at a variation of 10%. Tensile strength increases in variations of 5% and 10%. This increase occurred because the PET and HDPE plastic aggregate materials were split at the concrete split point after testing. This means that this plastic aggregate material contributes tensile strength to the concrete.

4 Conclusion

The tests of lightweight concrete with coarse aggregates of PET and HDPE plastic waste have been carried out. The test specimen testing carried out is testing the weight of concrete contents, water absorption, compressive strength, and tensile strength. HDPE concrete and PET concrete have a smaller fill weight compared to normal concrete. However, the use of PET and HDPE plastic waste and pat reduces the weight of concrete. In absorption testing, PET has a higher absorption value than HDPE at a variation of 5%. Theincreasing levels of PET and HDPE that replace coarse aggregate cause the absorption value to be greater. Pthere is compressive strength testing, the compressive strength value of HDPE type concrete is greater than PET. Both types of plastics have lower compressive strength values than normal concrete. The greater the aggregate content of PET and HDPE plastics, the lower the compressive strength. The compressive strength of PET and HDPE concrete from existing variations can not be categorized as structural

lightweight concrete (minimum compressive strength of 17.24 MPa and maximum of 41.36 MPa). Meanwhile, in the results of the tensile strength test, the tensile strength value of concrete with HDPE substitution is greater than PET. The optimum tensile value is at a variation of 10%.

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