The Use of Plastic Waste as Subtitute for Coarse Aggregate of Concrete

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Abstract. Many waste materials are produced from manufacturing processes, service industries, and municipal solid waste, one of which is plastic waste. Plastic consumption from year to year is increasing uncontrollably. The amount of use is getting higher every year because of the high population density that affects the use of plastic, especially in Indonesia. The very rapid increase in the amount of plastic waste is not balanced with the slow natural plastic decomposition process because it takes a long time. Various actions are taken to reduce the amount of plastic waste, one of which is using plastic as a construction material as a supporting structure that does not require high quality. Plastics that have durable and elastic properties are expected to create environmentally friendly materials. From the four variations, the highest compressive strength was recorded for a variation of 30% substitution of PET plastic aggregate which met the requirements of normal concrete, while 40%, 60%, and 70% entered into low-strength concrete. The compressive strength decreases with increasing plastic variation because the slippery surface of the plastic stone is not able to bind cement, as well as the density of concrete which is below normal concrete requirements. The lightness of plastic affects the weight of the concrete which continues to decrease as the amount of plastic in it and the reduction of stone aggregates.

Keywords: *Polyethylene Terephthalate* (PET) · concrete · recycled plastic · construction materials · compressive strength

1 Introduction

Many waste materials are produced from manufacturing processes, service industries, and municipal solid waste, one of which is plastic waste. Plastic consumption from year to year is increasing uncontrollably. Plastic is also easy to find in everyday life which eventually causes a lot of plastic waste in the surrounding environment.

The number of uses is getting higher every year because of the high population density that affects the use of plastic, especially in Indonesia. In the article Plastic Waste Inputs From Land Into The Ocean in 2015, Jenna R. Jambeck said that Indonesia is the second largest contributor to plastic waste after China [1]. Along with the production, the amount of plastic waste also increases exponentially. Due to insufficient recycling,

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millions of tons of plastic waste is generated every year that ends up in landfills and oceans. Around 22 - 43% of plastic is disposed of in landfills and at least 8 million tons of plastic are dumped into the sea.

According to the Samarinda BPS and the Samarinda Environmental Service, residents in the city of Samarinda produced around 226,577.4 tons of waste in 2020, of which plastic waste. In 2021, the volume of waste transported from March to May is around 19,362 kg. Environmental pollution is still a serious problem in Samarinda due to indiscriminate disposal of waste, especially in rivers (DLH Samarinda).

Various actions were taken to reduce the amount of plastic waste, including the 3Rs, namely reduce, recycle, and reuse. Plastics themselves have the characteristics of being durable, corrosion resistant, and good insulators for cold, heat, soundproof, energy efficient, economical, have a long service life, and are lightweight. From some of the characteristics of plastic, in the end an idea can be taken by recycling plastic into one of the potential and attractive alternatives for production is to use plastic as a construction material. As is known, concrete is not foreign to the community because it is almost always used for projects, both buildings, roads, and others. Many projects were built which made concrete often used for the construction. By using plastic as a construction material, this can create an environmentally friendly material which can later be used as a support structure that does not require high quality such as parking lots. The use of plastic for construction materials can increase elasticity and durability and reduce density so that the material becomes lighter [2].

In connection with several studies that have been carried out, there is an idea about how to make a partial substitute for plastic coarse aggregate so that it is different where later the plastic will be melted and crushed to make it like stone coarse aggregate. Will it produce different results compared to some previous studies considering that in terms of the final results of this plastic and the treatment of the material will be different.

2 Methods

2.1 Research Location

This research was carried out at the Civil Engineering Laboratory, Faculty of Engineering, Mulawarman University (Fig. 1).

2.2 Research Procedures

The research implementation includes the following activities:

1. Study of literature
2. Preparation of materials (coarse aggregate, fine aggregate, Portland cement type I,water, Coca-Cola, granulated sugar).
3. Laboratory examination (sieve analysis of fine and coarse aggregate, moisture content, aggregate silt content, specific gravity and aggregate absorption, and aggregate wear).
4. Mix design.

Fig. 1. Research location in Faculty of Engineering, Mulawarman University, Samarinda, East Kalimantan.

5. Test object manufacture (normal concrete, concrete with the addition of Plastic waste PET with 30%, 40%, 60%, and 70% from volume of coarse aggregate for the 7 and 28 days tests, each consisting of 3 cylindrical test objects).
6. Slump test.
7. Compressive strength test of concrete.

3 Result and Discussion

The test results in this research are divided into two: concrete compressive strength and weight. The strength test aims to determine the magnitude of the load per unit area, which causes the concrete test object to crumble when loaded with a certain compressive force, which is produced by the press machine and for the weight test to determine the effect of plastic on the weight of concrete (Table 1).

Table 1. The Result of Sieve Analysis Coarse Aggregate

Sieve Size (mm)	Retained Weight (gram)	Cumulative Holding Weight (gram)	Cumulative Holding (%)	Pass Filter (%)
37,5	0	0	0	100,0
25	0	0	0	100,0
19	140,4	140,4	9,4	90,6
12	618,6	759	50,6	49,4
9,5	552	1311	87,4	12,6
4,8	189	1500	100,0	0,0

Table 2. Limit Value of Coarse Aggregate

Upper Limit	Lower Limit	Pass Filter (%)	Sieve Size (mm)
100	100	100,0	37,5
100	100	100,0	25
100	90	90,6	19
55	20	49,4	12
15	0	12,6	9,5
5	0	0,0	4,8

Table 3. The Result of Sieve Analysis Coarse Aggregate and Plastic

Sieve Size (mm)	Retained Weight (gram)	Cumulative Holding Weight (gram)	Cumulative Holding (%)	Pass Filter (%)
37,5	0	0	0	100,0
25	138,9	138,9	9,26	90,7
19	236,6	375,5	25,0	75,0
12	649,9	1025,4	68,4	31,6
9,5	286,6	1312	87,5	12,5
4,8	188	1500	100,0	0,0

Table 4. Limit Value of Coarse Aggregate and Plastic

Upper Limit	Lower Limit	Pass Filter (%)	Sieve Size (mm)
100	100	100,0	37,5
100	100	90,7	25
100	90	75,0	19
55	20	31,6	12
15	0	12,5	9,5
5	0	0,0	4,8

3.1 Results and Discussion-1

3.2 Results and Discussion -2

From the results above, the concrete that uses some PET plastic coarse aggregate does not meet the planned compressive strength of 15 MPa (Fig. 2). The compressive strength values of the variations of 30%, 40%, 60%, and 70% were 9.32 MPa, 8.91 MPa, 8.66 MPa,

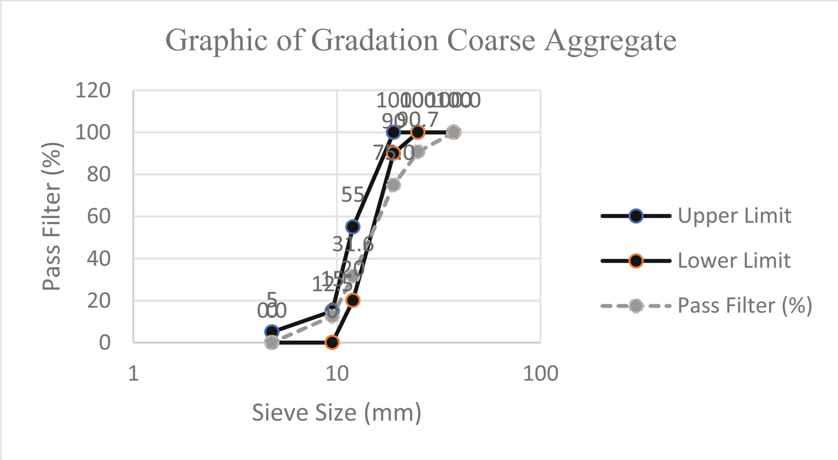

Fig. 2. Graphic of Sieve Analysis Coarse Aggregate

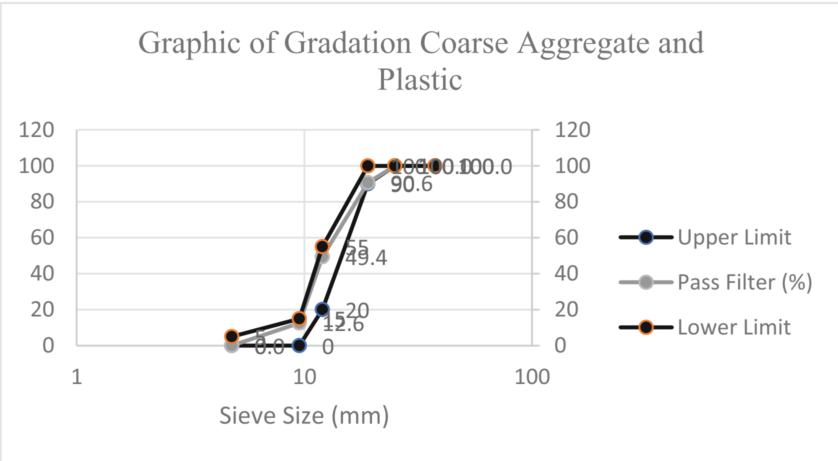

Fig. 3. Graphic of Sieve Analysis Coarse Aggregate and Plastic

Table 5. The Result of Coarse Aggregate Wear

Aggregate		Unit
Number of Steel Balls	12	Round
Weight of Sample Test (a)	5000	Gram
Sustained Weight Sieve Number 12 (b)	4086	Gram
Aggregate Wear ((a-b) / a) x 100%	18,28	%

Table 6. The Result of Coarse Aggregate Wear with Addition Plastic PET

Aggregate		**Unit**
Number of Steel Balls	12	Round
Weight of Sample Test (a)	5000	Gram
Sustained Weight Sieve Number 12 (b)	4049,4	Gram
Aggregate Wear ((a-b) / a) x 100%	19,012	%

Table 7. The Result of Slump Test

Variations	Slump Test and Days	
	7	28
BN	9	9
B30%	13	9
B40%	17	10
B60%	14	10
B70%	15	8

Table 8. Average of Compressive Strength

Variations	Days	Compressive Strength (MPa)	Conversion of 28 Days
BN	7	13,29	
	28	19,32	18,99
B30%	7	9,32	
	28	15,66	13,31
B40%	7	8,91	
	28	14,35	12,73
B60%	7	8,66	
	28	12,75	12,38
B70%	7	7,90	
	28	9,81	11,28

and 7.90 MPa at the age of 7 days (Fig. 3). For the age of 28 days, only in the 30% variant the value is included in the design compressive strength of 15 MPa with the results obtained 15.66 MPa, while the 40%, 60%, and 70% variations do not fit the design compressive strength value (Fig. 4). This is because the compressive strength value decreases along with the increase in PET plastic aggregates, the more plastic aggregates

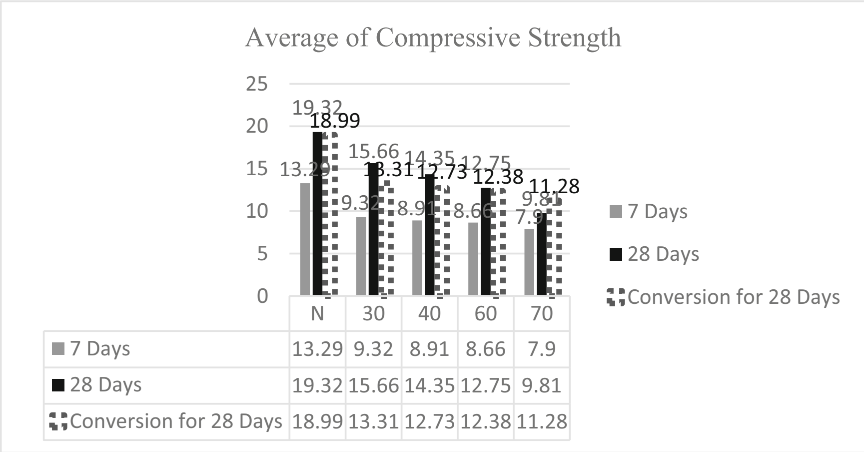

Fig. 4. Average of Compressive Strength

Table 9. Average of Weight Concrete

Variation	Days	Weight Concrete (kg/m^3)
BN	7	2415,66
	28	2401,82
B30%	7	2137,61
	28	2401,82
B40%	7	2039,47
	28	2117,48
B60%	7	1969,02
	28	1999,21
B70%	7	1855,78
	28	1957,69

used, the lower the compressive strength (Table 2). He decrease in compressive strength in concrete that uses some PET plastic occurs because the roughness of the plastic aggregate is not as hard as natural or stone aggregates and the effect of the smooth and slippery surface of the PET plastic aggregate makes the bond strength of the aggregate and cement decrease (Table 3). Also, the shape of PET plastic aggregates which tend to be not round, not uniform, and not having many angles also affects the voids in the concrete itself (Table 4) (Fig. 5).

The influence of the aggregate sieve also has an impact on the value of the compressive strength of the concrete because the percentage value that passes the sieve is out of the predetermined gradation line. When PET plastic stones are screened together with Palu stones, the sieve size is 19 mm and out of the upper and lower limit values (Table

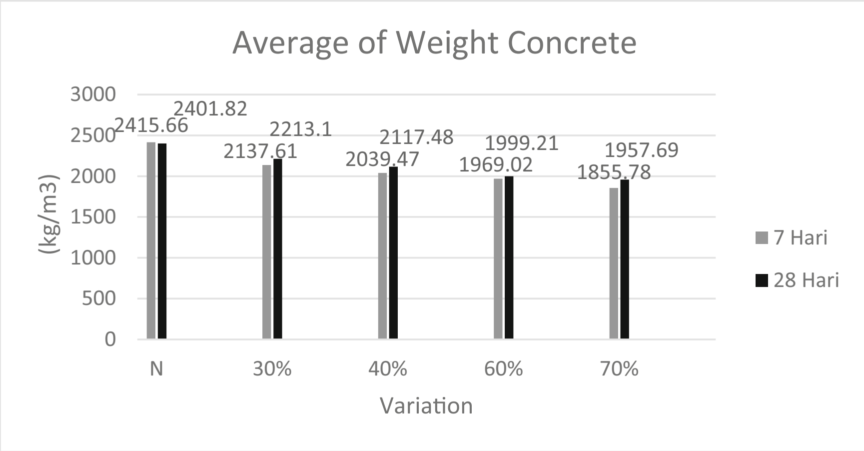

Fig. 5. Average of Weight Concrete

5). This is because the size of the Palu stone is uniform while the PET plastic stone is not uniform in shape (Table 6).

In addition, based on the results of the wear test, it can be seen in the table that the wear value with added plastic makes it higher than ordinary stone, which is 19.012% (Table 7). The cause is because the plastic coarse aggregate is not able to withstand or accept friction with other concrete constituents (Table 8). If a coarse aggregate with a high abrasion value results in high absorption, it will greatly affect the size of the compressive strength that occurs (Table 9).

According to SNI 7656:2012, the weight of normal concrete is in the range of 2200 - 2400 kg/m^3, whereas if it is below 2200 kg/m^3, it is called light concrete, and if it is above 2500 kg/m^3, it is called heavy concrete. It can be seen in the table above, at the age of 7 days of concrete, the weight of normal concrete is above 2200 kg/m^3, which means it is included in the normal concrete category. In contrast to the density of concrete which uses a portion of PET plastic aggregate, it tends to decrease every percent. This is because PET plastic stone has a lighter weight than Palu stone. However, at the age of 28 days of concrete, the weight of the concrete with a percentage of 30% is above 2200 kg/m^3 with a value of 2213.10 kg/^{m3} which means that it enters into normal concrete. The highest weight density is in the normal concrete variant with a weight of 2415.66 kg/m^3 for the age of 7 days and 2401.82 kg/m^3 for the age of 28 days. With this, partially plastic aggregate concrete at a percentage of 40%, 60%, and 70% falls into the lightweight concrete category.

3.3 The Contribute of Plastic

The generation of plastic waste has the potential to cause soil, air and water pollution. It also takes a long time to decompose. Not worth the use that continues to increase every time. Plastics have the characteristics of being durable, corrosion resistant, and good insulators for cold, heat, soundproofing, energy saving, economical, long service life, and light weight. So, in addition to saving the environment, the use of plastic as a partial substitute for coarse aggregate for non-structural concrete construction can be useful because the use of plastic can produce construction materials that are cheaper and easier to find.

From the seven types of plastic, Polyethylene Terephthalate (PET) or plastic with number 1 in the middle is the most abundant plastic used both as plastic bottles and food packaging. No wonder this type of plastic is often found also recycled for various kinds of handicrafts. Easy to find and supported in shape makes PET plastic the most recycled plastic.

Based on the four variations in the study, the best results and those that reached the design compressive strength of 15 MPa were in the variation of 30% PET plastic stone coarse aggregate with 70% Palu stone coarse aggregate both from the compressive strength and concrete density values, namely 15 MPa and 2213.10 kg/m^3. The value of the compressive strength continues to decrease as the variation of the coarse aggregate of plastic stone increases.

With the value of compressive strength and weight of concrete that have been tested, it can be concluded that the use of concrete with a mixture of PET plastic coarse aggregate can be used as non-structural concrete construction or supporting structures that do not require high quality such as parking lots. Likewise with lightweight concrete such as precast wall panels, concrete frames, concrete cladding, and other concrete ornaments in buildings. The light weight of plastic can be applied to reduce the specific gravity of concrete. The use of plastic stone coarse aggregate for the main structures is not recommended because the minimum concrete compressive strength of 15 MPa has not been fulfilled.

4 Conclusion

The effect of using plastic for construction materials can increase elasticity and durability and reduce density so that the material becomes lighter. In addition, it can be used as a non-structural concrete construction or supporting structure that does not require high quality such as parking lots. Likewise with lightweight concrete such as precast wall panels, concrete frames, concrete cladding, and other concrete ornaments in buildings. The light weight of plastic can be applied to reduce the specific gravity of concrete. The use of plastic stone coarse aggregate for the main structures is not recommended because the minimum concrete compressive strength of 15 MPa has not been fulfilled. From four variations, the variation of the value that can be tolerated for the manufacture of concrete with a plan of 15 MPa is in the variation of 30% PET plastic stone coarse aggregate with 70% Palu stone coarse aggregate both from the compressive strength and concrete density values, namely 15 MPa and 2213, 10 kg/m^3. The value of compressive strength and bulk density continues to decrease as the variation of the coarse aggregate of plastic rock increases because the coarseness of the plastic aggregate is not as hard as natural or stone aggregate and the effect of the smooth and slippery surface of the PET plastic aggregate makes the bond strength of the aggregate and cement decrease.

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