Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 6, No. 12, December, 2020

Examining Polyethylene Terephthalate (PET) as Artificial Coarse Aggregates in Concrete

Erniati Bachtiar [a*], Mustaan [a], Faris Jumawan [a], Meldawati Artayani [a], Tahang [a], Muhammad Junaedy Rahman [b], Arman Setiawan [c], Muhammad Ihsan [d]

[a] *Faculty of Engineering, Fajar University, Makassar, Indonesia.*

[b] *Department of Building Engineering, Universitas Negeri Makassar, Makassar, Indonesia.*

[c] *Faculty of Engineering, Universitas Bosowa, Makassar, Indonesia.*

[d] *Department of Civil Engineering, Sekolah Tinggi Teknik Baramuli, Makassar, Indonesia.*

Received 25 August 2020; Accepted 27 November 2020

Abstract

This study aims to examine the effect of recycled Polyethylene Terephthalate (PET) artificial aggregate as a substitute for coarse aggregate on the compressive strength and flexural strength, and the volume weight of the concrete. PET plastic waste is recycled by heating to a boiling point of approximately 300°C. There are five variations of concrete mixtures, defined the percentage of PET artificial aggregate to the total coarse aggregate, by 0, 25, 50, 75, and 100%. Tests carried out on fresh concrete mixtures are slump, bleeding, and segregation tests. Compressive and flexural strength tests proceeded based on ASTM 39/C39M-99 and ASTM C293-79 standards at the age of 28 days. The results showed that the use of PET artificial aggregate could improve the workability of the concrete mixture. The effect of PET artificial aggregate as a substitute for coarse aggregate on the compressive and flexural strength of concrete is considered very significant. The higher the percentage of PET plastic artificial aggregate, the lower the compressive and flexural strength, and the volume weight, of the concrete. Substitution of 25, 50, 75, and 100% of PET artificial aggregate gave decreases in compressive strength of 30.06, 32.39, 41.73, and 44.06% of the compressive strength of the standard concrete (18.20 MPa), respectively. The reductions in flexural strength were by respectively 19.03, 54.50, 53.95, and 61.00% of the standard concrete's flexural strength (3.59 MPa). The reductions in volume weight of concrete were by respectively 8.45, 17.71, 25.07, and 34.60% of the weight of the standard concrete volume of 2335.4 kg/m^3

Keywords: Concrete; Plastic Waste; Polyethylene Terephthalate (PET); Boiling Point; Compressive Strength; Flexure Strength.

1. Introduction

Infrastructure development has progressed at an unprecedented pace, especially in the construction of buildings and infrastructures. This situation has led to the problem of the availability of construction materials, including raw materials of concrete, leaving environmental deterioration concerns. Coarse aggregates constitute the largest portion of concrete mixtures, about 65-80% of the total concrete volume. Therefore, a more sustainable alternative to natural coarse aggregate is necessary.

On the other hand, economic developments and changes in human consumption and production patterns have led to a drastic increase in plastic waste worldwide. Solid waste in the form of plastic is a very complex problem in urban areas, including in Indonesia. Data from the Indonesian Plastics Industry Association (INAPLAS) and the Central

* Corresponding author: erni@unifa.ac.id; erni_nurzaman@yahoo.com

http://dx.doi.org/10.28991/cej-2020-03091626

Statistics Agency (BPS) show that plastic waste in Indonesia reaches 64 million tons per year as of 2019. This number has expected to continue to increase over time. Consequently, an increase in plastic waste is inevitable, so there needs to be a policy in the management of plastic waste. Plastic waste has several characteristics, including being very difficult to decompose naturally and in absorbent to water. These properties of plastic waste make the disposal of plastic waste considered as damaging the environment, including degradation of land and oceans and climate change, and threatening human health. Plastic has become a dangerous and challenging waste to manage. The negative effect of plastic waste turns out to be as big as its function [1]. Plastic takes about 10-1000 years to decompose completely, which are very long durations, and when decomposed, plastic particles will pollute soil and groundwater. When burned, plastic waste will produce toxic fumes that are harmful to health. If the incineration process is not complete, the plastic will break down in the air as dioxins, which is very dangerous if inhaled by human. Plastic waste also causes flooding because it clogs waterways, and dams, causing flooding, even the worst damage to reservoir turbines. Therefore, in a strong desire to reduce plastic waste, it appears that academics and researchers have examined some of the potentials for recycling plastic waste. Reusing plastic waste in concrete is an effective way to reduce plastic waste.

There are seven types of plastics with different properties, namely Polyethylene Terephthalate (PET or PETE or Polyester), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS), and bioplastics (https://waste4change.com/). Polyethylene terephthalate (PET) is one of the most abundant plastic waste where it has generally used for plastic bottles and food packaging. In this research, the potential of using PET waste as concrete material is examined. The development of concrete technology is increasingly popular with the presence of additives or substitutes for raw materials in concrete mixtures in the form of chemicals, fly ash, bagasse ash, natural fibers, Styrofoam, and polymers. There have been many studies on substitute materials for concrete raw materials by utilizing industrial waste and recycled materials. Fly ash is one of the power plant industrial wastes used as a substitute for cement in concrete mixtures [2, 3]. Apart from fly ash, rice husk ash can replace some of the cement as a binder in concrete [4]. Some research works on waste plastic bags have been conducted [5, 6]. Research on low-density polyethylene LDPE plastic waste [7] and research on polyethylene plastic waste [8, 9] as a substitute for fine aggregate in concrete have also been published. Other research works were on polycarbonate [10], and polypropylene (PP) wastes [11] as substitutes for coarse aggregate in concrete. Research on electronic plastic waste as a substitute for fine and coarse aggregates has also been carried out [12].

Regarding the utilization of PET as an alternative material for concrete, some research works have been produced. Among the properties of concrete containing PET, the compressive strength and flexural strength are the most studied, along with thermal, electrical and durability, and other properties [13]. Wiswamitra et al. have investigated the potential of producing lightweight concrete incorporating PET substitutive aggregate combined with minerals in the form of rice husk ash and cement. While creating more porous concrete with the help of PET, the addition of minerals gave higher compressive strength [14]. Basha et al. have developed a correlation model between the mixture parameters and mechanical and thermal properties of concrete incorporating recycled plastic aggregate. The study revealed the potential of reducing thermal conductivity to 35–65% and give an opportunity of using the product as thermal insulation [15]. The relationship of compressive stress–strain and the modulus of elasticity of the developed concrete mix have also been investigated [16]. Some advantage of PET as concrete substitutive materials has emerged such as the improved workability, the potentials of developing lightweight concrete for precast detachable structures [16], higher ductility of concrete as replacement level increases [17], and particularly lighter weight which could reach 68.88% lighter than concrete with virgin aggregates [18] . However, there are some drawbacks in the application of PET as artificial aggregates. Among suspected drawbacks of the use of plastic aggregate, is the lower mechanical properties such as lower flexural strength [19], lower dynamic elastic modulus [20]. There are also limits of the percentage of using recycled plastic, such as 50% [21].

This research is a part of research on Artificial Aggregates from Recycled Plastics for Concrete Composer Materials [22]. This study describes the properties of workability (slump test, bleeding, and segregation), compressive strength, and flexural strength of concrete using artificial aggregate from PET plastic waste as a substitute for coarse aggregate. Recycling of plastic waste is carried out by heating with a boiling temperature of around 300ºC. The research offers a new approach in examining the use of PET plastic waste as artificial coarse aggregates through heating recycling processes by determining the percentage of substitutions of PET artificial aggregate to produce lightweight concrete. The paper is organized into four segments, where the introduction, covering some backgrounds and previous research on the topic. The next segment presents the methodology of the experimental research, consisting of the procedure preparation of materials and equipment, mix design and manufacturing, and curing and testing. The next section presents the results and discussing the preliminary test results, compressive and flexural strength, and the weight of concrete. Conclusions are presented at the end of the paper.

2. Research Methodology

The research method used is experimental. Checking the characteristics of concrete constituent materials and making samples were carried out in the Civil Engineering laboratory, Fajar University. The flexural strength test has carried out at the laboratory of the National Road Construction Authority in Makassar. The research consists of several stages; material preparation, mix design, manufacture of test objects, maintenance, and testing. Figure 1 shows the experimental procedure of the research.

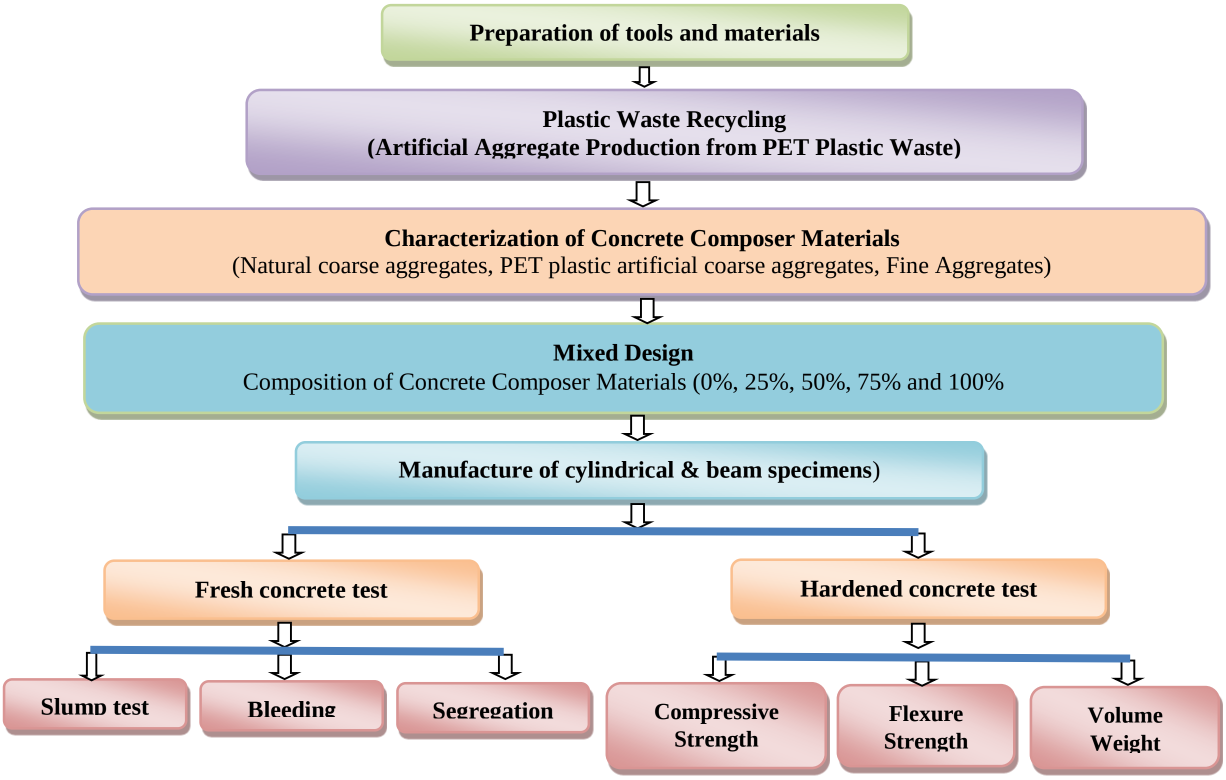

Figure 1. A flowchart of the experimental procedure of the research

2.1. Preparation of Materials and Equipment

The materials used in this study are fine aggregate (sand) from Takalar district, coarse aggregate (gravel) taken from the Bili-Bili area of Gowa Regency, Portland cement type PCC (Portland Composite Cement), and coarse artificial aggregate from PET type plastic waste. The tools used in this research are a mixer for mixing concrete, scales, oven, sieve, 10×20 cm cylinder mould, 10×12×60 cm beam mould, slump test equipment, compressive strength test, and flexural strength testing machines. There are several stages of producing recycled PET artificial aggregate. The first stage was pile stocking of PET waste previously collected from various sources. The second stage is washing and cleaning PET waste from dirt and other objects. PET waste is then shredded into small pieces about 0.5-2 cm using a plastic shredder machine as shown in Figure 2. The next process is heating shredded PET waste to a boiling point (250-255°C). PET waste is then left to cool and harden as shown in Figure 3. Hardened compound is then chopped to form coarse aggregates with a size of 0.5-2 cm, called recycled PET artificial aggregate, as shows in Figure 4).

Figure 2. Shredded PET plastic waste

Figure 3. Melted PET plastic waste after extraction from moulds

Figure 4. Chopped recycled PET artificial aggregate

Before manufacturing, concrete constituent materials were tested for their characteristics based on SNI standards (Indonesian national standards). It is essential in order to ensure the appropriateness of materials in concrete production. The results of testing the properties of fine aggregate can be seen in Table 1. Table 2 presents the results of testing the properties of coarse aggregate. Tables 1 and 2 show a recapitulation of the test results of the coarse aggregate and fine aggregates' properties, where the results show that they meet the requirements as the constituent material of concrete. The mud content tests have carried out twice because the initial results did not meet the mud content requirements of a maximum of 5%, with 8.5% values. Therefore, the fine aggregate was washed and then tested again to meet the criteria as concrete materials.

Table 1. Fine aggregate properties

No	Test item	Results
1	Mud content	4.5%
2	Water content	4.49 %
3	Volume weight	
	a. Lose condition	1.42 kg/litre
	b. Compacted condition	1.60 kg/litre
4	Absorption	2.58%
5	Specific gravity	
	a. Bulk Specific gravity	2.58
	b. apparent specific gravity	2.45
	c. Surface Specific gravity	2.5
6	Fineness Modulus	2.77%
7	Organic content	No. 2

Table 2. Coarse aggregate properties

No	Test item	Results
1	Mud content	0,73%
2	Water content	1.65 %
3	Volume weight	
	a. Lose condition	1.66 kg/litre
	b. Compacted condition	1.74 kg/litre
4	Absorption	1.56%
5	Specific gravity	
	a. Bulk Specific gravity	2.85
	b. apparent specific gravity	2.73
	c. Surface Specific gravity	2.77
6	Fineness Modulus	6.64 %
7	Abrasion	18.67%

2.2. Mix design and Manufacturing Test Objects

The mix design calculations are based on each material density. The concrete mix design uses the Indonesian National Standard method (SNI 03-2838-2000). The compressive strength (f'c) design is 20 MPa. Table 3 describes the composition of each material used based on the results of the mixed design calculations.

Table 3. Mix design calculations for 1 m^3 concrete

Material (Kg)	Percentage of PET waste				
	0%	**25%**	**50%**	**75%**	**100%**
Cement	468.75	468.75	468.75	468.75	468.75
Water	225.00	604.19	604.19	604.19	604.19
Sand	604.19	1122.07	1122.07	1122.07	1122.07
Gravel	1122.07	280.52	140.26	105.19	105.19

All materials are converted into volume-based. The material prepare with it put in the mixer. Gravel and sand were initially added before cement was subsequently added to the mixture. After the three material compositions have been added and mixed well, the water is added gradually while stirring, and continued until all the materials are mixed homogeneously. A concrete sample as a standard used 0% PET waste. PET waste will replace the amount of coarse aggregate in the concrete mixture. The PET waste variations constitute into 4 variations; namely 25, 50, 75 and 100%. In manufacturing test objects, both standard concrete and concrete with PET aggregate were tested for fresh concrete, namely, slump bleeding and segregation. Before the test objects are moulded.

2.3. Curing and Testing

The test object removed from the mould was cured by immersing the test object in a soaking tub. The concrete curing keeps the concrete surface moisture to maintain the hydration process runs well, and the hardening process occurs correctly indicated by no cracks in the concrete. Therefore, the quality of the concrete can be guaranteed.

This research conducted physical testing on fresh concrete and mechanical testing on hardened concrete. The physical tests carried out were the slump test, concrete volume weight, segregation, and bleeding. Mechanical testing conducted in this study is a compressive strength test and flexural strength/modulus rupture. The compressive strength testing method follows ASTM 39 / C 39M –99 test standards, using 10×20 mm cylinder specimens. Universal Testing Machine (UTM) equipment is used to test compressive strength. This test is carried out at the age of the concrete for 28 days. The compressive strength of concrete is calculated based on the size of the load area as shown in Equation 1.

$$Compressive\ strength = \frac{P}{A} \quad (1)$$

Where P = ultimate load (N) and A = area of test section (mm^2).

The flexural strength tests were carried out at 28 days of concrete, in three-point bending tests, referring to the ASTM C293-79 standard, and calculated by Equation 2.

$$\text{Flexural strength } (R) = \frac{3PL}{2bh^2} \quad (2)$$

Where R = flexural strength/modulus of rupture (MPa), P = ultimate load (N), L = length of test object (mm), b = sectional width of test object (mm), h = height of test object (mm).

3. Result and Discussion

3.1. Preliminary Test

The slump tests carry to determine the workability of the concrete mix. Concrete mix viscosity is a measure of the ease with which the mixture work in concrete construction work without causing segregation and uplifting of water on the concrete mixture's surface, called bleeding. The number of water influences the level of concrete viscosity, the amount of cement, the aggregate's shape, and the aggregate's size. Slump tests in this study were carried out twice for each variation. The amount of water, the amount of cement, and the aggregate grains' shape affect the concrete properties. The results of the slump test shown in Table 4.

Table 4. Results of slump test

Variation of mixes (%)	*Slump Test* 1 (cm)	*Slump Test* 2 (cm)	Average (cm)
0	8.3	9.5	8.9
25	7.5	7.5	7.5
50	7.4	8.0	7.7
75	12.3	12.4	12.4
100	16.5	17.2	16.9

Table 4 indicates that the higher the percentage of the coarse aggregate substitution of plastic waste, the higher the slump test value. Apart from the slump test on fresh concrete, observation of bleeding and segregation is carried out. This test is to determine the homogeneous nature of the mixture. A homogeneous mixture means the quality of the mixture is right. The bleeding tests were carried out by observing the occurrence of water rising to the surface of the mixture, making the mixture not homogeneous and prone to separation. Segregation observes the occurrence of aggregate separation of different materials. The observation has shown that the fresh concrete mixture experiences no segregation and bleeding. It shows that the quality of the mixture is right. By physical appearance and by the slump values, concrete using artificial plastic aggregate has better workability. The finding confirms the results of a previous study that concrete utilizing recycled plastic instead of fine aggregate can increase fresh concrete workability and density [6]. Its mechanical properties are slightly reduced by a 10% replacement with recycled plastic. The workability of concrete using plastic aggregates is strongly influenced by the plastic's shape and content, affecting friction between irregular shaped particles [13].

3.2. Compressive Strength

The compressive strength of concrete is the magnitude of load per unit area. The test object broke due to the compressive force generated by the concrete compressive strength machine. The compressive strength of concrete is determined by the ratio of coarse aggregate, fine aggregate, cement, water, and concrete mixture. The water-cement ratio is also a significant factor in determining the strength of concrete. The results of the compressive strength of concrete are reported in Table 5.

The concrete compressive strength test results show a decrease in the concrete's strength as an increase in the proportion of artificial PET waste aggregate substitution. The 25% substitution of artificial PET waste aggregate resulted in a decrease of 30.06% in the concrete's compressive strength from 18.20 MPa of standard concrete. The substitution of 50% aggregate resulted in a decline of 32.39% in the compressive strength of concrete from 18.20 MPa of standard concrete. The 75% substitution of plastic waste artificial aggregate resulted in a decrease of 41.73% in the compressive strength of concrete from 18.20 MPa of standard concrete. The substitution of 100% plastic waste artificial aggregate resulted in a decrease of 44.06% of the compressive strength of concrete from 18.20 MPa.

Table 5. Concrete compressive strength test results

Percent-age of PET (%)	Sample	Area (mm^2)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
	1	7857	18.32	
0	2	7857	18.20	18.20
	3	7857	18.07	
	1	7857	14.00	
25	2	7857	12.73	12.73
	3	7857	11.45	

50	1	7857	12.73	12.30
	2	7857	12.73	
	3	7857	11.45	
75	1	7857	11.45	10.61
	2	7857	10.18	
	3	7857	10.18	
100	1	7857	11.45	10.18
	2	7857	10.18	
	3	7857	8.91	

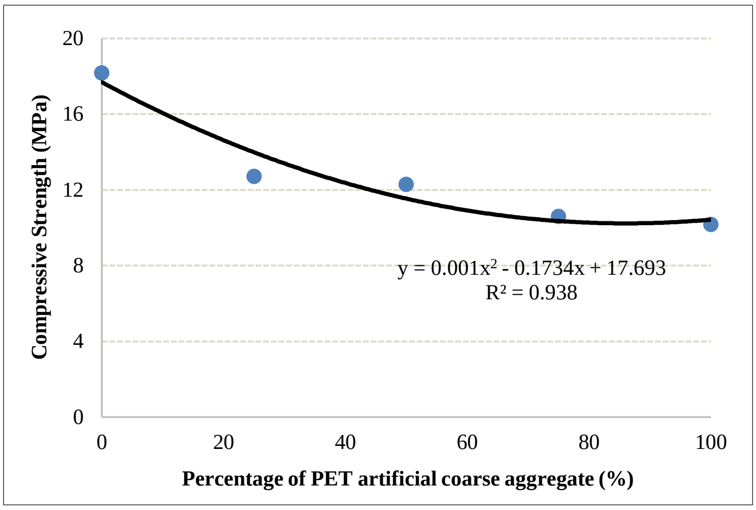

Figure 5. Relationship of percentages of PET artificial aggregate and compressive strength of concrete

The decrease in compressive strength is considerably tremendous. It takes to be caused by a low bond between the matrix and the aggregate since the aggregate produced from recycled plastic waste has a smooth surface, producing poor adhesion between the matrix and the artificial aggregate.

Figure 5 shows the relationship between the percentages of PET plastic waste to the compressive strength value of concrete. The higher the percentage of PET plastic waste, the lower the flexural strength of the concrete obtained. The relationship between the percentage (%) of plastic waste artificial aggregate with the compressive strength of concrete produces a non-linear equation $y=0.0001x^2-0.17341x+17{,}693$ $R^2=0.969$ or a correlation coefficient value of R =. The R-value is close to 1 (one), which means that the relationship between PET plastic waste percentage significantly affects its compressive strength. The increasing number of plastic-artificial aggregate substitution affects the compressive strength of concrete. The decrease in the concrete's compressive strength is in line with the rising amount of plastic-aggregate. Following previous studies, plastic aggregate addition corresponds to a reduction of concrete's compressive strength [15, 23, 24].

3.3. Flexural Strength

The flexural strength of concrete is a concrete beam's ability to withstand the force perpendicular to test the axis object until the specimen breaks or reaches the maximum load. The beam test carries a beam specimen of 100×120×600 mm dimensions with the two-point load method. The test object supports were located 75 mm from the right and left sides of the specimen. The specimens mount on a hydraulic concrete beam testing machine in a horizontal position. The loading carries until the test object becomes broken to no longer withstand the given load. The composition of the constituent material of concrete influences the flexural strength of 28-days concrete after immersion in fresh water. The test results of the average flexural strength of each specimens with variations of 0% coarse aggregate of PET waste, 25% coarse aggregate of PET waste, 50% coarse aggregate of PET waste, 75% coarse aggregate of PET waste, and 100% coarse aggregate of PET waste, respectively, at 3.54, 2.91, 1.63, 1.65 and 1.40 MPa. The results of the detailed flexural strength test reported in Table 6.

Table 6. Results of flexural strength test

Percentage of PET	Sample	Flexural Strength		
		(k N)	(MPa)	Average (MPa)
0%	1	11.04	3.45	3.54
	2	12.31	3.85	
	3	10.67	3.33	

25%	1	9.32	2.91	2.91
	2	10.42	3.26	
	3	8.16	2.55	
50%	1	7.66	2.39	1.63
	2	4.65	1.45	
	3	3.38	1.06	
75%	1	5.00	1.56	1.65
	2	4.90	1.53	
	3	5.97	1.87	
100%	1	4.50	1.41	1.40
	2	4.50	1.41	
	3	4.40	1.38	

The effect of the percentage of PET plastic waste on the flexural strength value of concrete is seen in Figure 6. Figure 6 shows the relationship between the percentage of PET plastic waste and the flexural strength value of concrete, indicating that the higher the percentage of PET plastic waste, the lower the flexural strength of concrete. The relationship between the percentage of plastic waste artificial aggregate and the flexural strength of concrete produces a non-linear equation $y=0.0002x^2-0.0471x+3.671$, $R^2=0.9511$, or the correlation coefficient value R=0.9752. The R-value is close to 1, which means that the percentage PET plastic waste significantly affects the concrete's flexural strength. Increasing the number of plastic- aggregate substitution affects the flexural strength of the concrete, as with previous research [15, 23, 24] that the flexural strength of concrete decreases with incorporating plastic aggregates.

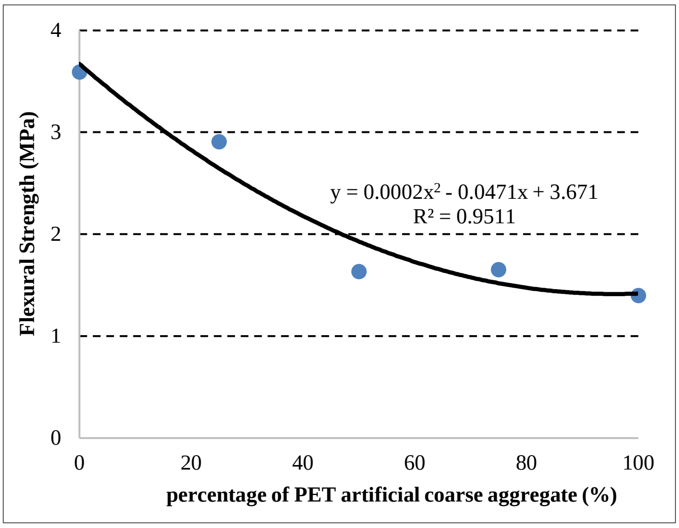

Figure 6. The relationship of PET artificial aggregate and the flexural strength of concrete

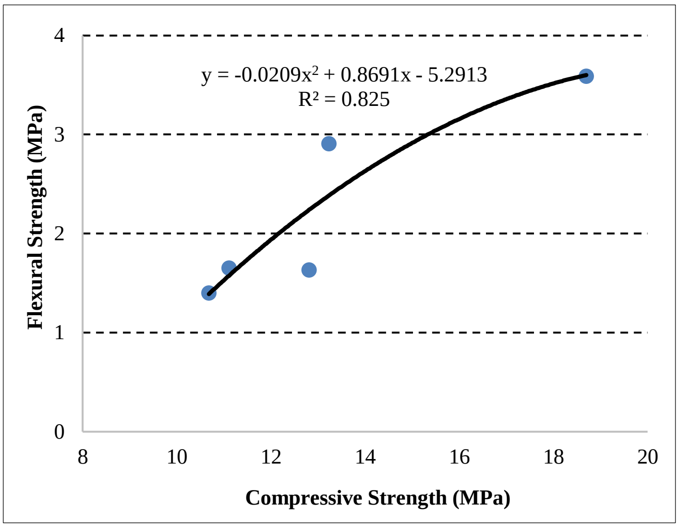

Figure 7. Compressive strength versus flexural strength

Compressive strength and flexural strength are concrete mechanical properties that need attention to concrete construction materials. The test results show that the concrete has properties related to other properties of the concrete itself. As shown in Figure 7, the relationship between compressive strength and flexural strength. Figure 7 shows the relationship between the compressive strength and the flexural strength of the concrete substitution of artificial plastic waste. This relationship produces a nonlinear equation $y\ 0.0209x^2+0.8691x-5.213$, the value of $R^2=0.825$ or R=0.908. The value of R close to 1 means that the relationship between the compressive strength and the flexural strength is significant.

Compared with the compressive strength, the decrease in the tensile strength of concrete is very high by 61%, while the reduction in compressive strength is 44.06% at 100% substitution of artificial-plastic aggregate. Artificial-plastic aggregate occurs because the smooth surface texture produced by heating the boiling point makes a smooth aggregate surface. As in previous studies, the decrease in the tensile strength of concrete is due to the smooth surface and surface area of plastic aggregates, which results in weak interface bonds due to the accumulation of free water [25]. The high plastic aggregate content decrease in flexural strength due to the weaker effect of the aggregate matrix bonding [16].

3.4. Weight of concrete

The weighing of the concrete test objects was conducted when the concrete reached 28 days. The results of Volume weight concrete are as shown in Table 7.

Table 7. Volume weight of concrete kg/m^3

Percentage of PET (%)	Volume weight of concrete (kg/m^3)
0	2335.45
25	2138.18
50	1921.82
75	1750.00
100	1527.27

Table 7 shows that the use of PET artificial aggregates produces lighter concrete. The increasing number of recycled substitutes for plastic waste is in line with the reduced weight of the concrete. In 25% substitution concrete, plastic waste artificial aggregate resulted in a decrease in volume weight of 8.45% from the weight of concrete 2335.45 kg / m^3. The substitution of 50%, 75%, and 100% plastic waste artificial aggregate resulted in a consecutive 17.71%, 25.07%, 34.60% reduction of the weight of concrete by volume of standard concrete (0%) of 2335.45 kg/m^3. Based on the volume weight of concrete which ranges on 50-100%, the concrete product by substituting plastic artificial aggregate plastic-made aggregate is classified as lightweight structural concrete for structures with a volume weight of 1350 ± 1900 kg/m^3. Whereas based on the compressive strength value, the substitution of 25% -100% PET aggregate results the concrete falls to moderate strength concrete category, with compressive strength ranging between 7 ± 17 MPa (ASTM C331-81), commonly used in load-carrying wall structures.

Based on this study's results, concrete mixtures with artificial plastic aggregates are suitable for non-high performance concrete. Castillo et al. (2020) [16] show that high-performance concrete, structural concrete, or infrastructure projects recommend not to use lightweight concrete mixtures using plastic waste artificial aggregates.

4. Conclusions

Based on the results of research and discussion, the following conclusions can be drawn:

- Substitution of coarse aggregate with PET artificial aggregate in the concrete mixture has a positive effect on the fresh concrete mixture's workability;
- Variations in concrete weight are influenced by the amount of the addition of PET artificial aggregate, where the higher the percentage addition of PET artificial aggregate, the lower the weight of the concrete;
- The relationships between the percentage of PET artificial aggregate and compressive strength, flexural strength, and concrete volume weight are very significant, the higher the addition of PET artificial aggregate, the compressive strength, the lower the flexural strength;
- Substitutions of 0, 25, 50, 75 and 100% PET artificial aggregate give the average value of the compressive strength of concrete respectively 18.20, 12.73, 12.30, 10.60 and 10.18 MPa. The substitutions produce average flexural strengths of concrete of 3.54, 2.91, 1.63, 1.65 and 1.40 MPa, respectively.
- Based on the compressive strength value, concrete with 25-100% PET artificial aggregate substitution can be classified in the moderate strength concrete category, with compressive strength on 7±17 MPa. However, further research on the temperature used in heating plastic is needed. The resulting artificial aggregate is lighter and less brittle to obtain lightweight concrete with a volume weight of 800 ± 1350 kg/m^3.

5. Acknowledgements

This research is funded by the Ministry of Education and Culture, The Republic of Indonesia, Directorate-General for Higher Education for the research scheme 2020.

6. Conflicts of Interest

The authors declare no conflict of interest.

7. References

[1] Sharma, Raju, and Prem Pal Bansal. "Use of Different Forms of Waste Plastic in Concrete – a Review." Journal of Cleaner Production 112 (January 2016): 473–482. doi:10.1016/j.jclepro.2015.08.042.

[2] Bachtiar. E. "Environmentally Friendly Material". Faculty of Engineering, Fajar University & Tohar Media, Makassar, (2019).

[3] Bachtiar. E "The connection between oven curing duration and compressive strength on C-type fly ash based-Geopolymer mortar", ARPN Journal of Engineering and Applied Sciences 15(5), (2020): 1–6.

[4] Ahmad, I. A., H. Parung, M. W. Tjaronge, and R. Djamaluddin. "Durability of concrete using rice husk ash as cement substitution exposed to acid rain." Int. J. Eng. Res. Appl 4, no. 5 (2014): 144-149.

[5] Ghernouti, Y. et al. 'Use of Recycled Plastic Bag Waste in the Concrete", Journal of International Scientific Publications: Materials, Methods and Technologies, (2009): 480–487.

[6] Kore, Sudarshan Dattatraya. "Feasibility Study on Use of Plastic Waste as Fine Aggregate in Concrete Mixes." Journal of Building Material Science 1, no. 1 (November 25, 2019): 26. doi:10.30564/jbmr.v1i1.1204.

[7] Al-tayeb, M.M., Daoor, I., and Zeyad, AM. "Effect of Partial Replacements of Coarse Aggregate by Polycarbonate Plastic Waste on the First Crack Impact Resistance of Concrete Beam." Journal of Environment and Earth Science (February 2020). doi:10.7176/jees/10-2-06.

[8] Das, S., Alam, MT., and Chowdhury, I. "Utilization of plastic Waste In Concrete as Partial Replacement of Fine Aggregate." Proceedings of 3rd International Conference on Advances in Civil Engineering. Chittagog. Bangladesh, (2016).

[9] Jibrael, Manhal A, and Farah Peter. "Strength and Behavior of Concrete Contains Waste Plastic." Journal of Ecosystem & Ecography 6, no. 2 (2016). doi:10.4172/2157-7625.1000186.

[10] Mohammed, Abdulrahman, Taghreed Khaleefa Mohammed Ali, Noor Rajab, and Nahla Hilal. "Mechanical Properties of Concrete and Mortar Containing Low Density Polyethylene Waste Particles as Fine Aggregate." Journal of Materials and Engineering Structures 7, no. 1 (2020): 57-72.

[11] Purnomo, Heru, Gandjar Pamudji, and Madsuri Satim. "Influence of Uncoated and Coated Plastic Waste Coarse Aggregates to Concrete Compressive Strength." MATEC Web of Conferences 101 (2017): 01016. doi:10.1051/matecconf/201710101016.

[12] Manjunath, B.T. Ashwini. "Partial Replacement of E-Plastic Waste as Coarse-Aggregate in Concrete." Procedia Environmental Sciences 35 (2016): 731–739. doi:10.1016/j.proenv.2016.07.079.

[13] Li, Xuemiao, Tung-Chai Ling, and Kim Hung Mo. "Functions and Impacts of Plastic/rubber Wastes as Eco-Friendly Aggregate in Concrete – A Review." Construction and Building Materials 240 (April 2020): 117869. doi:10.1016/j.conbuildmat.2019.117869.

[14] Wiswamitra K.A, Dewi S.M., Choiron M.A., Wibowo A. "The Effect of Adding Minerals on Plastic Aggregate to Lightweight". Concrete IOP Conf. Ser.: Earth Environ. Sci. 506 012046 (2020).

[15] Basha, Shaik Inayath, M.R. Ali, S.U. Al-Dulaijan, and M. Maslehuddin. "Mechanical and Thermal Properties of Lightweight Recycled Plastic Aggregate Concrete." Journal of Building Engineering 32 (November 2020): 101710. doi:10.1016/j.jobe.2020.101710.

[16] Del Rey Castillo, Enrique, Nasser Almesfer, Opinder Saggi, and Jason M. Ingham. "Light-Weight Concrete with Artificial Aggregate Manufactured from Plastic Waste." Construction and Building Materials 265 (December 2020): 120199. doi:10.1016/j.conbuildmat.2020.120199.

[17] Alqahtani, Fahad K., Gurmel Ghataora, M. Iqbal Khan, and Samir Dirar. "Novel Lightweight Concrete Containing Manufactured Plastic Aggregate." Construction and Building Materials 148 (September 2017): 386–397. doi:10.1016/j.conbuildmat.2017.05.011.

[18] Casanova-del-Angel, Francisco, and Jorge Luis Vázquez-Ruiz. "Manufacturing Light Concrete with PET Aggregate." ISRN Civil Engineering 2012 (December 9, 2012): 1–10. doi:10.5402/2012/287323.

[19] Umasabor, Richie.I., and Samuel.C. Daniel. "The Effect of Using Polyethylene Terephthalate as an Additive on the Flexural and Compressive Strength of Concrete." Heliyon 6, no. 8 (August 2020): e04700. doi:10.1016/j.heliyon.2020.e04700.

[20] Belmokaddem, Mohammed, Abdelkader Mahi, Yassine Senhadji, and Bekir Yilmaz Pekmezci. "Mechanical and Physical Properties and Morphology of Concrete Containing Plastic Waste as Aggregate." Construction and Building Materials 257 (October 2020): 119559. doi:10.1016/j.conbuildmat.2020.119559.

[21] Babafemi, Adewumi, Branko Šavija, Suvash Paul, and Vivi Anggraini. "Engineering Properties of Concrete with Waste Recycled Plastic: A Review." Sustainability 10, no. 11 (October 25, 2018): 3875. doi:10.3390/su10113875.

[22] Erniati and Asrar (2019). "Plastic Recycled Artificial Aggregates for Concrete Composer Materials". (Patent No. P15201910482, Indonesia).

[23] Jibrael, Manhal A, and Farah Peter. "Strength and Behavior of Concrete Contains Waste Plastic." Journal of Ecosystem & Ecography 6, no. 2 (2016). doi:10.4172/2157-7625.1000186.

[24] Hossain, MB, P Bhowmik, and KM Shaad. "Use of Waste Plastic Aggregation in Concrete as a Constituent Material." Progressive Agriculture 27, no. 3 (December 28, 2016): 383–391. doi:10.3329/pa.v27i3.30835.

[25] Sharma, Raju, and Prem Pal Bansal. "Use of Different Forms of Waste Plastic in Concrete – a Review." Journal of Cleaner Production 112 (January 2016): 473–482. doi:10.1016/j.jclepro.2015.08.042.