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The Effect of PET (Polyethylene Terephthalate) Plastic on Lightweight Concrete

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ABSTRACT
Innovation of concrete technology becomes important for conserving energy, according to the building's structural design's weight. Thus, lightweight concrete can be a solution because it has a low density with good quality and optimum strength. One substitute for concrete is plastic, a polymer material with a low density of 92 - 96 kg/m³. This study is an experimental study that aims to understand the effect of PET plastic (Polyethylene Terephthalate) usage in the manufacture of lightweight concrete with a design quality of 250 kg/cm^2. The experimental work begins with a test of the material's properties and then prepares a concrete mixture formula. The result shows that around 40% PET mixture percentage with the concrete compressive strength of 250 kg/cm^2 (14 days old) and 205 kg/cm^2 (28 days). In contrast, the weight that meets the SNI standard of lightweight concrete is 100% PET Variation.

Keywords—experimental study, lightweight concrete, polyethylene terephthalate

1. INTRODUCTION

Lightweight concrete is concrete with a density that is lighter than normal concrete. Lightweight concrete is good to be used for tall buildings to reduce the load of the building. Unlike the normal concrete, the weight of lightweight concrete can be arranged as needed. According to SNI 03-2847-2002 [1], lightweight concrete contains light aggregate and has a unit weight of no more than 1900 kg/m³. Lightweight concrete is obtained by adding air pores to the concrete mixture. Based on Dobrowolski [2], lightweight concrete is divided into three categories, i.e. (a) concrete with low compressive strength (Low-Density Concrete) with a density of 240-800 kg/m³ and compressive strength of 0,35-6,9 MPa, (b) moderate-strength lightweight concrete with the density of 800-1440 kg/m³ and compressive strength of 6,9–17,3 MPa, and (c) structural lightweight concrete with the density of 1440-1900 kg/m³ and compressive strength of more than 17,3 MPa[3].

The material used to produce lightweight concrete and the composition are the same as the material used to produce normal concrete, but in the manufacturing of lightweight concrete, the coarse aggregate is changed with other material, which has lighter density, which is lightweight aggregate [4][5][3]. In accordance to SNI 03-3449- 2002[1], lightweight aggregate is the aggregate with filling weight for the dry oven of a maximum of 1100 kg/m³.

In this study, the coarse aggregate was partially replaced by PET plastic [6]. PET plastic was selected because it has a lighter density than the rough aggregate. In many studies, PET plastic is processed to become aggregate by cutting, cleaning, melting, cooling, and crushing processes before being used [7]. In lightweight concrete, PET plastic is used as the replacement of coarse aggregate in concrete material [7][8][9]. Frigione [7] attempted to replace the 5% by weight of natural sand with an equivalent weight of PET aggregates derived from unwashed waste PET (WPET) bottles in concrete. Aswatama et al. [8] studied the effect of 2.5%; 5%; 7.5%; and 10% PET waste on self-compacting concrete (SCC). Akçaözoğlu et al. [9] investigated the utilization of shredded waste Poly-ethylene Terephthalate (PET) bottle granules as a lightweight aggregate in mortar. Unlike previous studies mentioned above, this study focuses on using local aggregates with PET as a partial substitute of coarse aggregate that has not been previously reported. The compressive strength of concrete obtained varies by a different percentage of substitute aggregates is obtained.

2. MATERIAL AND METHOD

Portland Composite Cement (PCC) has also been used as the main material in cement mixture and PET as a partial substitute of coarse aggregate to manufacture lightweight concrete. PET plastic has high mechanical strength, is transparent, non-toxic, and has no negligible effect on the taste and the permeability of carbon dioxide. PET plastic has excellent tensile and impact strength and its chemical resistance, clarity, processability, colorability, and thermal stability. The materials used are local materials. The properties of local materials in this research have fine modulus of the fine aggregate of about 2.8, and then have

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2.68 specific gravity and absorption percentage of 3.11%. For coarse aggregate, it has a specific gravity of 2.77 and an absorption percentage of 3.61%. The Indonesian Standard guides this research used, SNI 03- 6468-2000 for a mix design method of normal concrete. The composition and the mix design with the addition of PET plastic also followed the normal concrete method. The addition of PET plastic was carried out according to the variation in the PET mixture percentage. Percentage variation of PET plastic were 0%, 40%, 50%, 70% and 100%. In this research, the experimental study of the testing 26 specimens was cube-shaped with the quality of the concrete design was 250 kg/cm^2, and each variation of PET has three samples. Testing begins with testing the material's properties first so that the concrete mixture's composition is 1 m^3. The composition of the mixture is shown in Table I.

Table I. Mixtures Composition for 1 M³ of Concrete

Material	Normal Concrete (kg)	40% PET	50% PET	70% PET	100% PET
Water	229.48	229.48	229.48	229.48	229.48
Cement	400.00	400.00	400.00	400.00	400.00
Fine Aggregate	738.19	738.19	738.19	738.19	738.19
Coarse Aggregate	874.08	524.45	437.04	262.22	-
PET	-	349.63	437.04	611.86	874.08

The composition of PET's use in the study [7]. The amount of waste plastic bottles or Polyethylene Terephthalate (PET) added to the concrete was 0.40%; 0.50%; 0.70%; 100%. It is afraid to see the effect of chopped plastic bottles used on lightweight concrete. As a reference of mix design, concrete is created without PET plastic (0% PET). The addition of PET as a partial substitute of the coarse aggregate in 1 cube mold concrete mixture. The proportions of the material are presented in Table II.

Table II. Mixtures Composition with the Addition of Pet Plastic for 1 Cube Mold

Percentage variation of PET	Volume (m^3)	Material				
		Cement (kg)	Water (kg)	Sand (kg)	Crushed stone (Kg)	PET (Kg)
0%	0.0034	1.63	0.94	3.01	3.56	-
40%	0.0034	1.63	0.94	3.01	2.14	1.42
50%	0.0034	1.63	0.94	3.01	1.78	1.78
70%	0.0034	1.63	0.94	3.01	1.07	2.49
100%	0.0034	1.63	0.94	3.01	-	3.56

3. RESULTS AND DISCUSSION

Table III indicates that the highest compressive strength test at the 14 days was obtained when the PET of the specimen was 40%, namely the compressive strength average of concrete is 250 kg/cm^2. The compressive strength of concrete decreases along with PET's addition as a substitute for coarse aggregate, but it can still be used in non-structural applications.

Table IV shows that the compressive strength test at 28 days did not change significantly. The compressive strength obtained in the 28-day test with an optimum compressive strength of 205 kg/cm^2 on 40% of PET variations and a decrease in the compressive strength of the concrete and PET's addition as a substitute for coarse aggregate.

Table III. Compressive Strength Test on 14 Days

Variation	Weight (Kg)	Sectional area (cm^2)	Compressive force (kN)	Correction factor	Compressive Strength (kg/cm^2)	Compressive Strength average (kg/cm^2)
0%	7.90	225	525	0.88	270	270
40%	7.46	225	480	0.88	247	250
40%	7.43	225	520	0.88	268	
40%	7.30	225	455	0.88	234	
50%	6.90	225	395	0.88	203	205
50%	6.94	225	425	0.88	219	
50%	6.96	225	375	0.88	193	
70%	6.62	225	330	0.88	170	179
70%	6.70	225	340	0.88	175	
70%	6.56	225	375	0.88	193	
100%	5.90	225	300	0.88	155	154
100%	5.81	225	300	0.88	155	
100%	5.82	225	295	0.88	152	

Table IV. Compressive Strength Test on 28 Days

Variation	Weight (Kg)	Sectional area (cm^2)	Compressive force (kN)	Correction factor	Compressive Strength (kg/cm^2)	Compressive Strength average (kg/cm^2)
0%	7.90	225	585	1.00	265	265
40%	7.46	225	435	1.00	197	205
40%	7.43	225	470	1.00	213	
40%	7.30	225	450	1.00	204	
50%	6.90	225	475	1.00	215	214
50%	6.94	225	475	1.00	215	
50%	6.96	225	465	1.00	211	
70%	6.62	225	435	1.00	197	193
70%	6.70	225	435	1.00	197	
70%	6.56	225	405	1.00	184	
100%	5.90	225	325	1.00	147	143
100%	5.81	225	310	1.00	141	
100%	5.82	225	310	1.00	141	

Fig. 1 presented that the highest compressive strength was obtained when the mixture contained 40% of PET and decreases in the concrete's compressive strength and the addition of using PET as a substitute for aggregate.

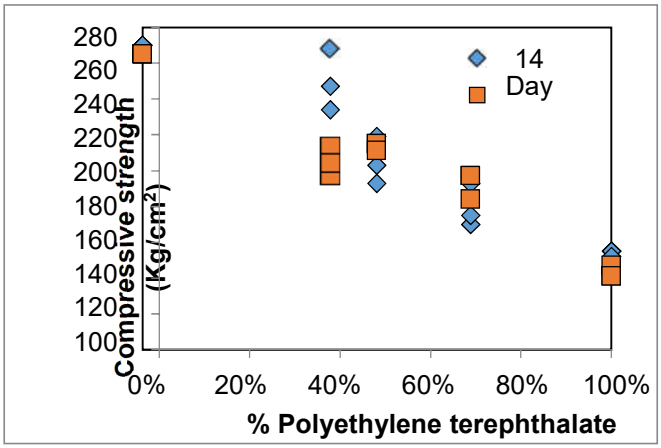

Fig 1. The compressive strength of concrete with variation of addition PET on 14 and 28 days of age

Based on SNI 03-2847-2002 [1], structural lightweight concrete has lightweight aggregates with a maximum weight of 1900 Kg/m^3. So that in terms of weight in the cube test object is:

Weight of 1 m^3 = 1900 Kg/m^3; Volume = 0.00337 m^3

Weight of specimen = Weight of 1 m^3× Volume = 1900 Kg/m^3 × 0.00337 m^3 = 6.4 Kg.

The weight average of the cube specimen on 14 days can be seen in Table V. Data on the results of the average weight of cube specimens at the age of 28 days, which are included in the classification of lightweight concrete, can be seen in Table VI.

The use of PET plastic is included in the lightweight concrete category, which is the average weight of the cube specimens at the age of 14 days with the Percentage variation of PET plastic used were 0%, 40%, 50%, 70%, and 100% respectively, namely 7.90 kg, 7.40 kg, 6.93 kg, 6.63 kg, and 5.84 kg. Meanwhile, at the age of 28 days, respectively, namely 7.75 kg, 6.97 kg, 6.77 kg, 6.41 kg, and 5.84 kg. The classification of lightweight concrete, according to SNI 03-3449-2002 in 1 m^3 with a weight of 1900 Kg/m^3. The cube specimen classified as lightweight concrete has a maximum weight of 6.4 Kg so that the weight of the cube specimen is classified as lightweight concrete at the age of 14 days and at the age of 28 days with the addition of 100% PET is about 5.84 kg.

Table V. Weight Average of Cube Specimen on 14 Days of Age

Variation	Weight (kg)	Weight average (Kg)	Weight SNI (Kg)
0%	7.90	7.90	6.4
40%	7.46	7.40	6.4
40%	7.43		
40%	7.3		
50%	6.90	6.93	6.4
50%	6.94		
50%	6.96		
70%	6.62	6.63	6.4
70%	6.70		
70%	6.56		
100%	5.90	5.84	6.4
100%	5.81		
100%	5.82		

TABLE VI. WEIGHT AVERAGE OF CUBE SPECIMEN ON 28 DAYS OF AGE

Variation	Weight (kg)	Weight average (Kg)	Weight SNI (Kg)
0%	7.75	7.75	6.4
40%	6.93	6.97	6.4
40%	6.93		
40%	7.06		
50%	6.74	6.77	6.4
50%	6.75		
50%	6.83		
70%	6.43	6.41	6.4
70%	6.43		
70%	6.39		
100%	5.81	5.84	6.4
100%	5.8		
100%	5.82		

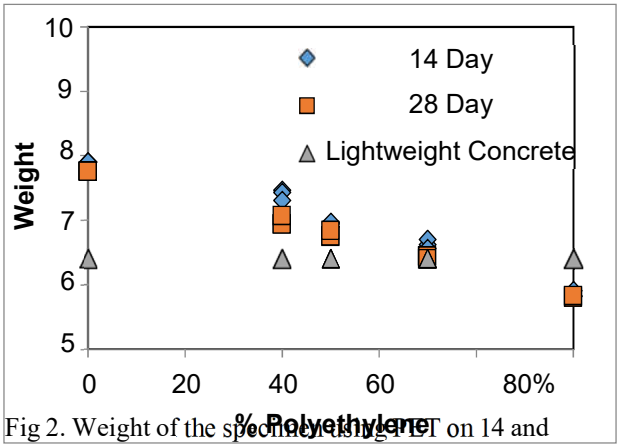

Fig 2. Weight of the specimen using PET on 14 and 28 days of age, and SNI for lightweight concrete

4. CONCLUSION

The weight of the concrete decreases with the use of PET plastic (Polyethylene Terephthalate). Weight average of cube specimen on 28 days of age using percentage variation of PET 0%, 40%, 50%, 70%, and 100% respectively, namely 7.75 kg, 6.97 kg, 6.77 kg, 6.41 kg, and 5.84 Kg. The

compressive strength of the concrete decreases with the greater use ofPET plastic. The highest average compressive strength is obtained by cube, specimens used 40% plastic bottle waste (PET), namely 250 Kg/cm^2. The lightweight concrete category with the maximum weight of the cube specimen is 6.24 kg. The cube specimen is classified as light concrete at 14 days and 28 days with 100% PET. In the cube specimen, the age of 14 days is 5.84 kg and at the age of 28 days is 5.84 kg

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