Compressive Strength and Water Absorption of Batako Made from Additional Plastic Waste of Polyethylene Terephthalate (PET)

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ABSTRACT

Plastic has become an inseparable material from human daily life. Plastic waste has properties that are very difficult to decompose which hurts the environment, which has become a serious problem in the global context. One alternative for dealing with plastic waste that can be applied in the world of civil engineering is by reusing plastic waste as aggregate in making bricks. This research aims to determine the effect of using polyethylene terephthalate (PET) plastic waste as a partial substitute for fine aggregate in making bricks on compressive strength and water absorption. In this research, variations in the use of PET plastic waste were 0%, 5%, 10% and 15%, referring to SNI-03-0349-1989. Compressive strength tests have respective values of 7.5Mpa, 6.3Mpa, 6.2Mpa, and 5.7Mpa. The respective values in the water absorption test were 4%, 4.3%, 4.7% and 7%. Adding too much plastic to the brick mixture proved ineffective on the brick's compressive strength. This means that the mortar and PET plastic on the bricks cannot interlock with each other.

Keywords: plastic; polyethylene terephthalate; brick; compressive strength; water absorption.

INTRODUCTION

The construction of high-rise buildings in Indonesia, which is a developing country and continues to experience improvements in infrastructure in the construction sector. In addition to the increase, there are also many new innovations in the construction sector, namely waste processing to be used as building materials or raw materials. One of the building materials is brick. Brick is a construction material for building and residential buildings, which is starting to be developed as a substitute for red brick. The use of brick is generally for making house walls, building walls or fences. Brick is made from a mixture of constituent materials then molded without being burned. The definition of concrete brick [1] component made from the main ingredients of Portland cement, water and aggregate, which is used for wall pairs. The definition of concrete brick made by molding and maintaining it in a humid atmosphere, a mixture of tras, lime and water with or without other additional materials [2], [3]. According to its type SNI [1], there are two types of concrete brick, namely solid concrete brick and hollow concrete brick. Concrete bricks have the advantage of lightening the structural load of a construction building compared to red bricks. However, their compressive and tensile strengths and resistance to absorption and porosity still need to be updated in order to produce economical building structure materials that are durable in the long term. In terms of their characteristics, concrete blocks are quite heavy so that the installation process as wall construction requires quite strong power and a long time [4]. Waste is a product of industrial and household activities. Currently, waste is a common problem in society. One of the wastes found in the environment is plastic. Plastic is a relatively non-biodegradable material, so the use of plastic must be considered considering the amount of waste produced [5]. Over time, the volume of waste, especially plastic, continues to increase, as reported in the news entitled "Leader Tackle Plastic Waste in Indonesia", Indonesia itself is in third place as the largest contributor of plastic waste, of which 8 million global plastic waste, Indonesia contributes more than 600,000 tons of plastic waste, of which among the piles of plastic waste, plastic bottle waste contributes a fairly large figure, namely 11,600 tons of plastic bottle waste [6]. There are various types of plastic, one of which is

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often used is PET (Polyethylene Terephthalate). This plastic is a type of plastic used as a raw material for beverage bottles [7], [8]. PET stands for polyethylene terephthalate, a polyester resin that is durable, strong, lightweight and easy to shape when hot. This makes it sturdy, its molecular formula is (-CO-C6H5-CO-O-CH2- CH2-O-) n or (C10H8O4) [9].

Industrial waste is usually dumped in the community environment until pollution occurs, optimal handling is needed to overcome this. Therefore, researchers tried to take the initiative to utilize PET plastic waste to be used as an alternative material to replace fine aggregate in making bricks. With the availability of a lot of plastic waste, especially PET plastic from the TPA (Final Disposal Site) around Sukoharjo Regency. The use of PET plastic waste as a mixture of bricks with varying compositions and percentages, it is hoped that the quality of the bricks produced will not be much different from conventional bricks in general. So that the results of this study can be a solution in the utilization of PET plastic waste. In this study, a pressure test and water absorption test will be carried out on bricks with alternative PET plastic waste materials whose quality level is expected to be in accordance with SNI [1].

RESEARCH METHOD

Materials

In making these bricks, materials are the main components, the materials used in this study include:

1. Fine Aggregate, the fine aggregate used in this study is sand taken from Merapi which has gone through the stages of checking the mud content, organic matter content, sieve analysis, specific gravity and absorption.
2. Cement, the cement used in this study is potland type I cement which is still in good condition which is used in a hollow concrete brick factory that has gone through the specific gravity examination stage.
3. Water, the water used in this study is well water used in the Civil Engineering Laboratory of Veteran Bangun Nusantara University, Sukoharjo.
4. Plastic Waste, plastic waste in making these bricks is PET plastic waste obtained in the Sukoharjo district area. Polyethylene Terephthalate (PET) polymer type has a specific gravity between 0.92-0.96 [10].

Method

The research was conducted using the experimental research method, which is a method carried out through experimental activities to obtain information. Data is processed to obtain comparative results with existing conditions [11]. By making bricks according to SNI [1] and adding PET waste with a percentage of 0%, 5%, 10% and 15% of the amount of sand, as well as variations in the age of the bricks of 7 days and 28 days to determine the water absorption capacity.

This research was conducted at the Civil Engineering Laboratory of Veteran Bangun Nusantara University. The materials used are fine aggregate, cement, water and PET plastic waste. The research steps are explained in the form of a flow chart in Figure 1 below.

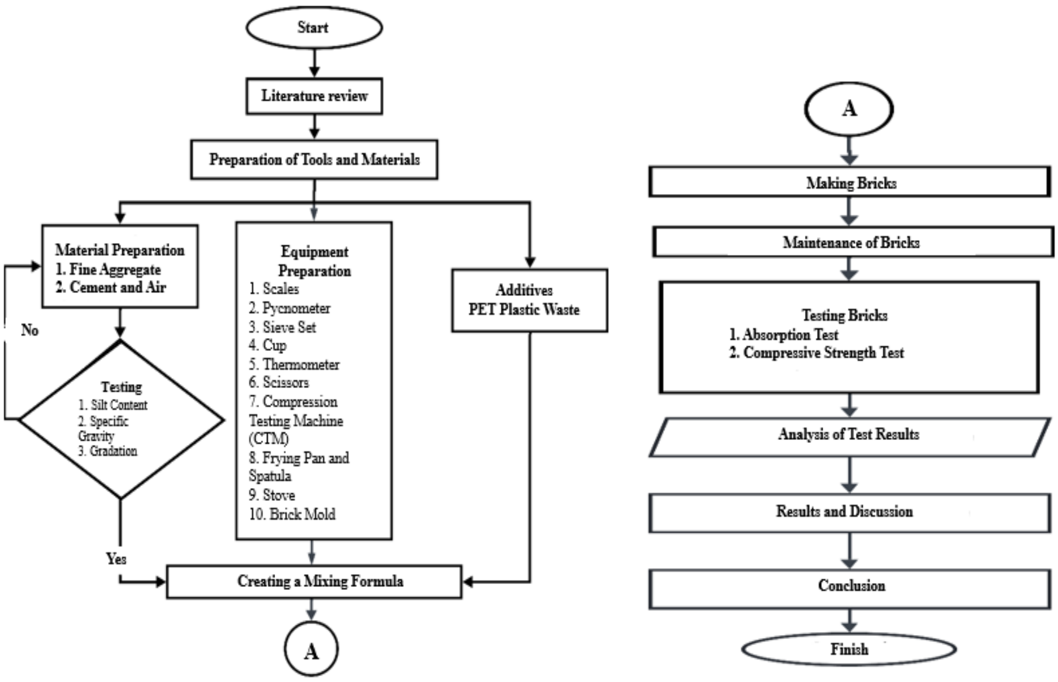

Figure 1. Flow chart

Testing

Material testing is carried out to ensure that the materials used have followed the required standards, both from fine aggregate material in the form of sand SNI [12]. The manufacture of test objects refers to the manufacture of concrete bricks SNI [1], and the testing follows the applicable standards

Aggregate Testing, Fine aggregates that will be used in making bricks are tested to determine their properties, the types of testing include:

1. Mud test, a mud test is carried out on the aggregate because mud will reduce the adhesion of the aggregate. The mud content in fine aggregates can also reduce the strength of the bricks which can cause the quality of the bricks not to be met from what has been planned. The mud content in fine aggregates (sand) permitted according to SK SNI [13] is to have a maximum mud content of 5% to create good quality bricks, namely having high compressive strength.

2. Sand gradation test, sand gradation test is carried out using a sieve to determine the distribution of variations in the size of sand grains expressed as a percentage of the total weight.

Compressive Strength Test of Bricks, Compressive strength is a material that is a comparison of the maximum load that can be supported by the cross-sectional area of the material experiencing the force [14]. The test was carried out when the brick was 28 days old. From the tension test carried out with the Compressing Testing Machine, the maximum load was obtained, namely when the brick was destroyed receiving the load (P max).

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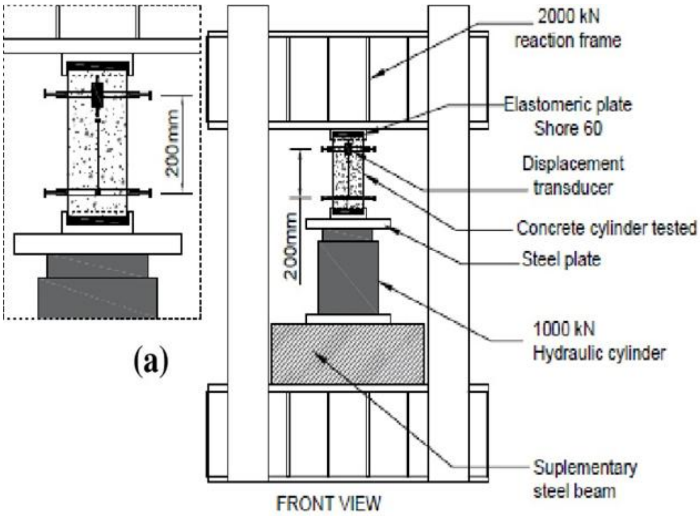

Figure 2. Compression Testing Machine

Testing Water Absorption of Bricks, the amount of water absorption by bricks is greatly influenced by the pores or cavities in the bricks. The more pores contained in the bricks, the greater the water absorption will be so that its resistance will decrease. Cavities (pores) in bricks occur due to the inaccurate quality and composition of the constituent materials. The effect of a ratio that is too large can cause cavities because there is water that does not react and then evaporates and leaves cavities [15], [16]. Bricks with PET plastic additives are tested for absorption to determine the extent of the test object's ability to absorb water through its pores. In this water absorption test, several test objects are used to obtain well-validated results, and using cement and sand-based bricks that are >28 days old as a comparison [17], [18].

RESULTS AND DISCUSSION

Sand Zone Inspection Results

Fine aggregate is a filler in the form of sand. Good fine aggregate must be free from organic materials and clay. The sand used in mixing concrete, when viewed from its source, can come from rivers or from mining excavations.

The sand zone test is carried out to determine the distribution of variations in the size of sand grains expressed as a percentage of the total weight. The results of the sand zone test calculation are shown in Table 1.

Table 1. Sand Zone Calculation Results

Sieve Aperture (mm)	Zone 1		Cumulative Weight %	Cumulative Weight Passing Through Sieve %
	gr	%		
4.75	37	3.70	3.70	96.30
2.36	152	15.20	18.90	81.10
1.18	107	10.70	29.60	70.40
0.6	381	38.10	67.70	32.30
0.3	265	26.50	94.20	5.80
0.15	52	5.20	99.40	0.60
0,075	6	0.60	100.00	0.00
Total	1000	100	313.50	286.50

From Table 1, it is the calculation result of:

1. Calculation of retained weight (%) = ((Remaining weight on the sieve/total remaining) x 100%)
2. Calculation of cumulative weight (%) = Remaining weight of sieve + Cumulative weight above it

3. Cumulative calculation through the sieve (%) = 100% - Cumulative weight of the sieve

Table 2. Sand Zone Test Results

Sieve Aperture (mm)	Zone 1		Zone 2		Zone 3		Zone 4		Test results
4.75	10	0	10	0	10	0	15	0	3,90
2.36	20	5	30	8	40	12	50	15	20,80
1.18	34	15	59	35	79	60	100	80	44,10
0.6	70	30	90	55	100	75	100	90	73,40
0.3	95	60	100	75	100	85	100	96	91,10
0.15	100	90	100	90	100	90	100	95	98,30
0,075	100	100	100	100	100	100	100	100	100

Table 2, is the result of sand zone test from zone 1 to zone 4 using sieve with holes of 4.75mm to 0.075mm. From the data obtained, a sand zone graph is then made as shown in Figure 3 below.

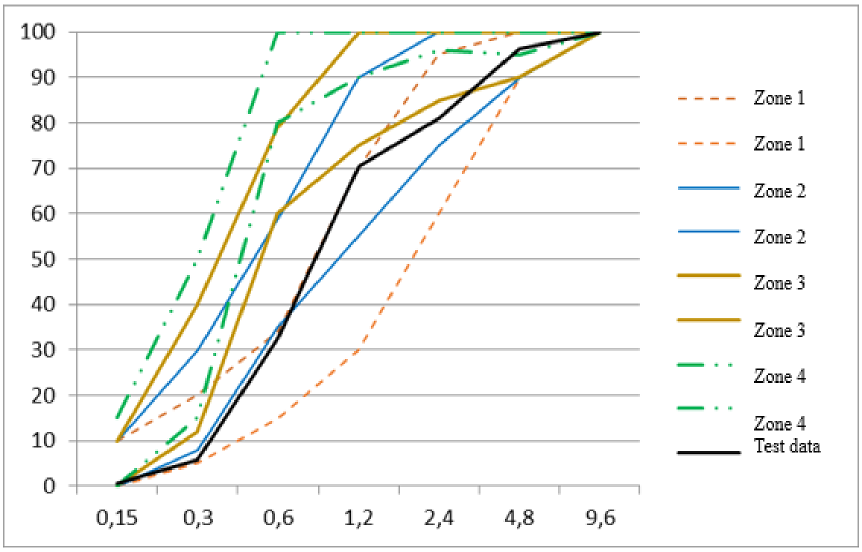

Figure 3. Sand Zone Graph

Results of Mud Content Test

This mud content test aims to determine the mud content in the sand to be used. This mud content test is carried out by dissolving sand into a 1000 ml measuring cup by mixing fine aggregate with water and shaking it 60 times then leaving it for 1x24 hours to determine the mud content in the sand. Figure 4 shows that the mud content test obtained 4.28% which is based on PUBI article 11 concrete sand.

Figure 4. Mud Content Examination

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Mix Plan Calculation

This study uses a ratio of 1: 6 in making bricks. This study uses PET plastic as a partial substitute for fine aggregate.

Rectangular brick shape
P = 30 cm = 0,3 m
L = 10 cm = 0,1 m
T = 15 cm = 0,15 m
Volume of one brick
V = P x L x T
= 0,3 x 0,1 x 0,15
= 0,0045 m^2
=1,2 kg/m^2

Weight of 1 brick = 0.0045 x 1.2 = 0.0054 m

So in one test object, the sand and plastic pieces (PET) requirements are:

a. Cement 250 kg/m x 0.0054 m = 1.35 Kg

b. Sand 6 x 1.35 Kg = 8.1 Kg

c. Plastic pieces (PET) = 12.15 Kg

d. Water requirements = 0.7 liters

So the material requirements for 5 bricks can be seen in Table 3 of the following Mixed Plan.

Table 3. Mixed Plan

No	Mixing Percentage (%)	Cement (Kg)	Sand (Kg)	Plastic PET (Kg)
1	0	6,75	40,5	0
2	5	6,75	38,475	2,025
3	10	6,75	36,45	4,05
4	15	6,75	34,425	6,075

After planning the composition of the mixture, the next step is to make 5 samples of bricks for each variation.

Water Absorption Results

The test was carried out on 7-day and 28-day old bricks, each sample consisted of 5, then the average water absorption capacity was taken for each sample. The test method is to soak the bricks for 1 x 24 hours. This test was carried out in the Civil Engineering Study Program Laboratory, Faculty of Engineering, Veteran Bangun Nusantara University, Sukoharjo.

The percentage of water absorption in bricks is expressed by the equation:

Water absorption = (A-B)/B x 100%

Where: A = Wet Brick Weight

B = Dry Brick Weight

Table 4. Results of solid brick water absorption capacity at 7 days

Variation	Percentage (%)	Age of Test Specimen	Dry Weight (Kg)	Wet Weight (Kg)	Absorption Capacity (%)
Solid Brick	0%	7	8,700	9,055	4,08 %
	5%	7	7.945	8.365	5,3 %
	10%	7	7.500	8.046	7,3 %
	15%	7	6.865	7.505	9,3 %

From Table 4, the calculation of the water absorption capacity of solid bricks shows that the higher the percentage of PET content, the higher the water absorption value of the bricks, this is because

PET plastic waste affects the adhesion between materials so that there are cavities that can cause higher water absorption.

Table 5. Results of water absorption capacity of solid and perforated bricks at 28 days

Variation	Percentage (%)	Age of Test Specimen	Dry Weight (Kg)	Wet Weight (Kg)	Absorption Capacity (%)
Solid Brick	0%	28	8.785	8.990	4%
	5%	28	8.315	8.675	4,3 %
	10%	28	8.085	8.465	4,7 %
	15%	28	6.695	7.170	7 %
Hollow Brick	0%	28	6.970	7.580	8%
	5%	28	6.805	7.600	11 %
	10%	28	6.790	7.505	10,8 %
	15%	28	6.695	7.525	12 %

Table 5 shows the results of the calculation of water absorption capacity on solid and hollow bricks, the same as on 7-day bricks where 28-day bricks experience an increase in water absorption value for each percentage of PET waste used, this proves that the adhesion between materials on the bricks is less than optimal due to the increasing amount of PET waste, so that there are cavities that allow more water to seep in.

Compressive Strength Results

Compressive strength is defined as the ability of the brick cross-section to receive a unit area of compression force. The compressive strength of this brick is usually used as a criterion for determining the quality of the brick. The compressive strength test refers to the SNI Standard. The compressive strength of bricks in kg/cm^2 is expressed by the equation:

Brick compressive strength = P/A

Where: P = crushing load (Kgf)

A = area of the compressed brick cross-section (cm^2)

Table 6. Results Brick Compressive Strength of 7 day

Test specimen	Variation (%)	Surface area (mm²)	Test Object Age	Compressive strength (KN)	Compressive strength (Kg/cm³)
Solid Brick	0	30000	7	88	29,87
	5	30000	7	119	40,38
	10	30000	7	101	34,26
	15	30000	7	92	31,30

Table 6 shows the results of the compressive strength test of solid bricks aged 7 days, with the highest compressive strength value in bricks with a variation of 5% PET waste of 119 KN and the lowest compressive strength value at a variation of 0% PET waste with a value of 88 KN. The compressive strength value decreases as the PET waste content increases.

Table 7. Results of Compressive Strength of 28-Day-Old Bricks

Test specimen	Variation (%)	Surface area (mm²)	Test Object Age	Compressive strength (KN)	Compressive strength (Kg/cm³)
Solid Brick	0	30000	28	225	76,47
	5	30000	28	191	65,27
	10	30000	28	186	63,22
	15	30000	28	172	58,12
Hollow Brick	0	30000	28	114	38,74
	5	30000	28	80	27,22

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Test specimen	Variation (%)	Surface area (mm²)	Test Object Age	Compressive strength (KN)	Compressive strength (Kg/cm³)
	10	30000	28	70	23,45
	15	30000	28	66	22,43

Table 7 shows the results of the compressive strength of solid and perforated bricks aged 28 days with the highest compressive strength values each found in bricks with a variation of 0% PET waste and the lowest compressive strength value in bricks with a variation of 15% PET waste, which means the compressive strength value decreases with increasing percentage of PET waste content. This shows that the addition of PET waste as a mixture of fine aggregate affects the compressive strength value of bricks.

CONCLUSION

Based on the results of the compressive strength test of bricks that have been carried out with the addition of PET waste, the values are around 58-65 kg/cm^2 for solid bricks and 22-27 kg/cm^2 for perforated bricks, where the value is still low compared to bricks without the addition of PET waste. However, the range of compressive strength values of solid bricks still meets SNI requirements, especially for non-structural wall concrete bricks, while in perforated bricks only at 5% PET waste content meets SNI standards. Based on the results of the water absorption test of bricks with the addition of PET waste that has been carried out on solid bricks, the value ranges from 4-7% and on hollow bricks it ranges from 11-12%. The results of this water absorption meet the SNI requirements, because water absorption occurs less than 25%.

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