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Utilization of PTE and LDPE Plastic Waste and Building Material Waste as Bricks

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Abstract Plastic waste is becoming a problem in various countries because of the difficulty of natural decomposition. One type is PET plastic(Polyethylene Terephthalate), which is often used as a bottle for soft drink packaging, and LDPE(Low Density Polyethylene), which is also widely used as a food or beverage packaging material. The use of these two types of plastic continuously, without good recycling, will have a negative impact on the environment. Building material waste is also becoming a serious environmental problem. This study aims to provide a solution to the problem of the above plastic waste and building material waste by making them into a mixture to be used as bricks. Research is carried out by mixing both materials, namely plastic heated at a temperature of 180-220°C and building material waste that had been crushed and sized to 30-40 mesh with homogeneous stirring. The ratios of PET and LDPE plastic to building material waste are 9 : 1, 8 : 2, 7 : 3, 6 : 4 and 5 : 5. After heating and printing, density, water absorption and compressive strength tests are carried out. Addition of PET and LDPE plastic can increase compressive strength, and reduce water absorption, porosity and density. A maximum compressive strength of 10.5 MPa is obtained at the ratio of 6 : 4.

Key words plastic waste, building material waste, bricks.

1. Introduction

Many big City in Indonesia having residential area increasingly congested in line with the increasing construction of new housing and settlements. On the other hand the growth of formal and informal trade areas and population growth is increasing. This condition affects the volume of household waste every year. Based on data from one of the big city with population of 1 million people, the volume of waste in 2006 was 259,832 m^3/day. Three years later in 2009 the volume increased to 343,266 m^3/day.[1)] Every day the garbage is transported from 43 polling stations scattered in various regions in City. Today there are around 400 tons of wet and dry garbage mixed goes to the landfill.[1)]

Based on data from the big city Sanitation and Landscaping Office 2013, the composition of waste is 61.5 % organic waste, and 38.5 % inorganic waste with the largest composition being plastic waste which is 17.50 %.[1)] This percentage is very large, if the mass is calculated from the total mass of waste available every day around 106 tons/day, with a large amount of plastic waste amounting to 18,555 kg/day.

In this study, the aim is to make bricks from a mixture of plastic and building material waste. There are two types of plastic waste used, the PET (Polyethylene Terephthalate) and LDPE (Low Polyethylene Density). The results is to determine the type of plastic that has a high compressive strength product, and small density, porosity, water absorption.[2)]

Recyclable plastics are coded in numbers based on their nature and to make it easier to identify the type of plastic used. The types of plastic as follows.[3)]

1.1 PET – Polyethylene Terephthalate

At the bottom of the plastic bottle packaging, there is a recycled logo with the number 1 in the middle and the writing PETE or PET under the triangle. In textile PET is usually called polyester and also used as mineral water bottles, juice bottles, and almost all other drink bottles. Not for warm or even hot water.

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1.2 LDPE — Low Polyethylene Density

Recycled logo is printed with the number 4 in the middle, as well as writing LDPE which is brown type plastic (thermoplastic/made from petroleum). Usually used as food packaging and plastic bag.

2. Research Methodology

This research was done by making bricks from materials plastic raw material with a mixture of building waste material powder uses a heating process by melting the plastic. The purpose of this study is to determine the effect of the mass ratio between plastic and a mixture of building material waste, the influence of the type of PET and LDPE on the quality of plastic bricks. The step of making brick from PET and LDPE with building material waste.

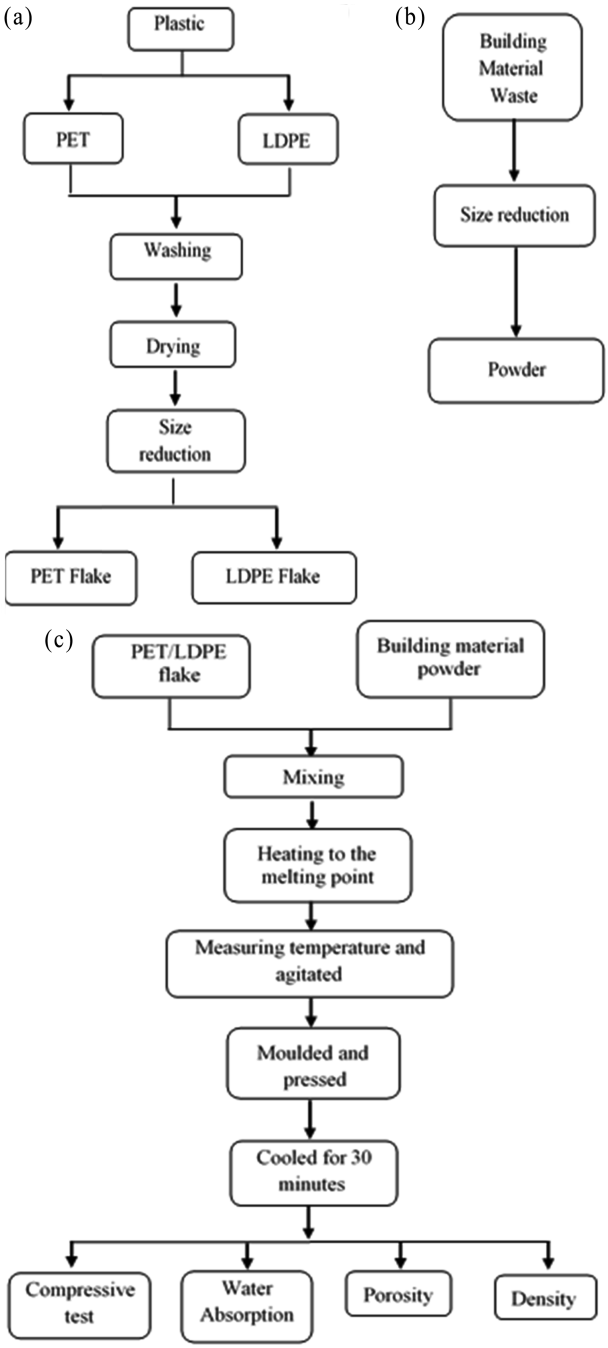

Fig. 1. (a) Plastic preparation, (b) Building Material Waste preparation, and (c) Making Bricks and some tests.

3. Results and Discussions

The density value of bricks in this research ranged from 1.15 to 1.59 g/cm^3 for mixture of building material

Table 1. Density of brick (mixture of building material waste with PET).

PET	m (g)	v (cm^3)	ρ (g/cm^3)
9:1	35.64	31	1.15
8:2	69.84	49	1.43
7:3	78.28	55	1.42
6:4	41.72	29	1.44
5:5	110.99	70	1.59

Table 2. Density of brick (mixture of building material waste with LDPE).

LDPE	m (g)	v (cm^3)	p (g/cm^3)
9:1	80.09	70	1.14
8:2	108.53	90	1.21
7:3	53.33	41	1.30
6:4	67.73	50	1.35
5:5	51.93	29	1.79

Table 3. Water absorption of brick (mixture of building material waste with PET).

PET	wm (g)	dm (g)	Water absorption (%)
9:1	35.98	35.94	0.11
8:2	66.48	66.39	0.13
7:3	78.55	78.42	0.16
6:4	42.06	41.86	0.48
5:5	74.40	73.70	0.95

Table 4. Water absorption of brick (mixture of building material waste with LDPE).

LDPE	wm (g)	dm (g)	Water absorption (%)
9:1	80.40	80.24	0.19
8:2	65.08	64.90	0.27
7:3	54.85	54.62	0.41
6:4	79.25	78.86	0.49
5:5	97.53	97.01	0.53

waste with PET, higher than brick which has a mixture of building material waste and LDPE.

PET plastic with linear chain structure has higher density than LDPE plastic. This is because[6] A linear chain structure makes it easier to approach other chains so that they form solid bonds and produce high density plastic. The branched chain structure in LDPE plastic causes the main chain to be far apart and it will be difficult to form bonds so that it reduces density.

Table 5. Brick porosity of brick (mixture of building material waste with PET).

Type	wm (g)	dm (g)	im (g)	Porosity (%)
9:1	35.98	35.94	9	0.11
8:2	66.48	66.39	12	0.15
7:3	78.55	78.42	28	0.24
6:4	42.06	41.86	15	0.58
5:5	74.40	73.70	30	1.56

Table 6. Brick porosity of brick (mixture of building material waste with LDPE).

Type	wm (g)	dm (g)	im (g)	Porosity (%)
9:1	80.40	80.24	10	0.21
8:2	65.08	64.90	12	0.33
7:3	54.85	54.62	13	0.51
6:4	79.25	78.86	22	0.66
5:5	97.53	97.01	40	0.89

Table 7. Compression test of brick (mixture of building material waste with PET).

Type	Gauge Reading	F(KN)	p (mm)	L (mm)	Stress Compression (MPa)
9:1	1,340	31.83	35	35	8.27
7:3	1,696	40.14	35	35	10.43
6:4	1,710	40.4	35	35	10.5
5:5	280	6.8	35	35	1.76

Table 8. Compression test of brick (mixture of building material waste with LDPE).

Type	Gauge Reading	F(KN)	P (mm)	L (mm)	Stress Compression (MPa)
9:1	1,170	27.84	35	35	7.23
8:2	1,350	32.06	35	35	8.33
7:3	1,240	29.49	35	35	7.66
6:4	1,285	30.54	35	35	7.93
5:5	1,385	32.88	35	35	8.54

3.1 Effect of mass ratio and type of PET and LDPE plastic

In Fig. 2 it is shown that the density increases with the addition of building material waste mass and reduction of plastic mass. Comparison of 9 : 1 PET plastic building material waste obtained value of 1.15 g/cm^3 and 5 : 5 obtained value of 1.59 g/cm^3. This is because the density of building waste material powder is greater than PET plastic. Thus the greater the building waste material powder added causes the density of the brick increases.[4]

Likewise the density of bricks using a mixture of LDPE plastic and building material waste is greater than the plastic itself. Based on Fig. 1, it shown that at the same mass ratio, the density of bricks mixed with PET plastic is greater than LDPE plastic.[5] This is because PET plastic binds building waste material powder more than LDPE so that its density is greater and the pore volume is smaller. At a ratio of 5 : 5 the value of the density of brick mixed with PET plastic is smaller than that of LDPE plastic. The same mass ratio or ratio of 5 : 5 PET plastic will make it more difficult to bind brick powder so that pores are formed in plastic mixed bricks. The difference in the ratio of 5 : 5 LDPE plastic is more binding on building material waste powder so that the density value is large. PET plastic with linear chain structure has higher density than LDPE plastic. This is because[5] a linear chain structure makes it easier to approach other chains so that they form solid bonds and produce high density plastic. The branched chain structure in LDPE plastic causes the main chain to be far apart and it will be difficult to form bonds so that it reduces density. In the article[6] described branched chain structure decreases the density level so that the molecular chain structure affects the density of plastic mixed bricks with building material waste powder. The molecular weight of PET plastic is greater than LDPE. The greater the molecular weight, the greater the density. In the study[8] it was mentioned that the molecular weight of LDPE plastic was 15,000 and the plastic molecular weight of PET was 27,000. The density of PET and LDPE plastic is 1.29-1.4 g/cm^3, 0.91-0.93 g/cm^3 respectively.

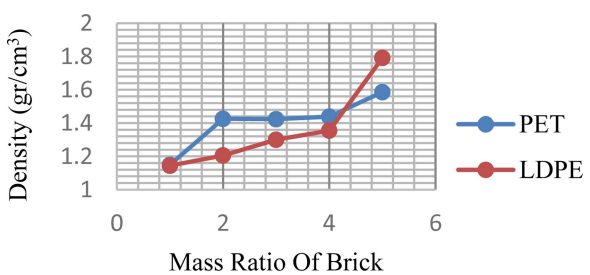

Fig. 2. Comparison of the density of building material waste powder with PET and LDPE.

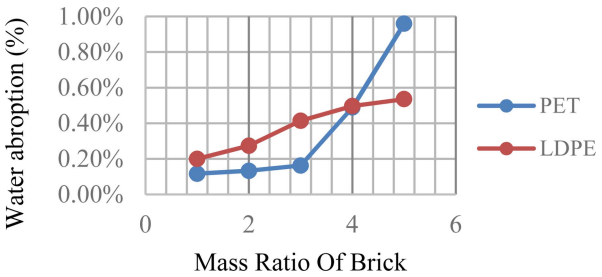

Fig. 3. Comparison graph of the water absorption on a mixture of building material waste with PET and LDPE.

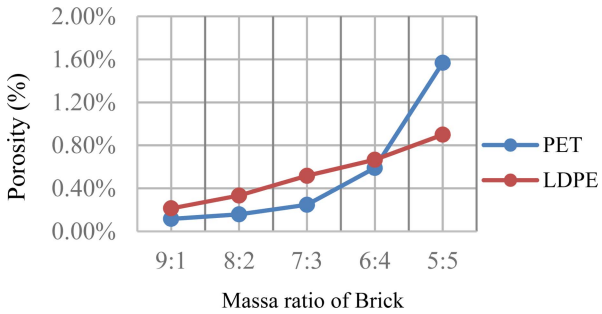

Fig. 4. Graph Comparison of porosity of bricks mixed with building material waste powder with PET and LDPE.

3.2 Effect of mass ratio and water absorption on PET and LDPE plastic

In Fig. 3 the absorbency of brick water from PET type shows that there is a significant increase along with the addition of fine powder mass of building material waste. Comparison of 9 : 1 PET plastic water absorption value of 0.11 % and 5 : 5 the value is 0.95 %. This is due to the building material waste powder that is hydroscopic. The greater the building material waste powder that is added causes the percentage of absorption of water from the brick mixture of PET plastic with building material waste increases.[7)]

Water absorption is shown in Fig. 2 with the LDPE plastic mixture increasing steadily. A ratio of 9 : 1 is obtained by the percentage of water absorbency of 0.19 % and 5 : 5 percentage of 0.53 %. The water absorption of bricks using LDPE plastic shows that the addition of masses of brick powder is the percentage of absorption of brick water increases. Figure 2 shows a comparison of the water absorption capacity of PET plastic smaller than LDPE plastic. The comparison of brick water absorption type of PET plastic water absorption capacity is smaller than LDPE. The factors that influence the absorbency of brick water mixed with smaller types of PET plastic are PET plastic which binds the building material waste powder so that its density is greater and smaller pores are formed compared to the mixture of LDPE plastic types. Greater density and smaller pore pores cause the bricks from the plastic surface to be difficult to absorb water. Water absorption at a ratio of 5 : 5 PET plastic is greater than LDPE. Comparison of types of PET and LDPE plastic with a mass ratio of 5 : 5, PET plastic is less binding on brick powder so that its absorption capacity is greater than LDPE plastic.

3.3 Effect of mass ratio and porosity on PET and LDPE plastic

The porosity of bricks shown in Fig. 4 using PET plastic type has increased with the addition of building material waste. In the ratio of 9 : 1 the value is 0.11 % and in the ratio 5 : 5 the value is 1.56 %. The increase in the percentage of porosity is due to the addition of building material waste powder to form an air cavity in a mixture of PET plastic bricks. The greater the mass of brick powder added, the greater the percentage of porosity so that the air cavity in the plastic bricks is getting bigger. In Fig. 3 shows the percentage of porosity of LDPE mixed plastic bricks increases. The bigger the powder of building material waste added, the greater porosity because the porosity of the building material waste is greater. The porosity of the building material waste is greater than the porosity of the plastic bricks. The porosity of the bricks is 39.59 % (Forest, 2017) while the porosity of the brick is a mixture of PET plastic at a ratio of 9 : 1 of 0.11 % so that the porosity of the plastic bricks is smaller. Small porosity gives advantages to building bricks because small air cavities are stronger and not brittle. In Fig. 3 the comparison of porosity of a mixture of PET plastic bricks is smaller than LDPE. This is because PET plastic binds the building material waste powder so that the air cavity formed is smaller than LDPE. LDPE plastic bricks formed more air cavity so the percentage of porosity is greater. In a ratio of 5 : 5, a mixture of PET plastic, the percentage of porosity is greater than LDPE because in this comparison the type of PET plastic is difficult to bind to building material waste powder. A large percentage of porosity indicates that larger pores are formed so that it is easily passed by the fluid.

3.4 Effect of mass ratio and compressive on PET and LDPE plastic

In Fig. 5 the compressive strength of a mixture of PET plastic shows the highest compressive strength test value obtained in a ratio of 6 : 4. Plastic brick ratio 5 : 5 compressive strength test value is smaller than the other mass ratio. This is because in this variable the type of PET plastic cannot bind the building material waste powder properly so the compressive strength is small.[8)] In Fig. 4 shows the compressive strength of a stable LDPE plastic mixed brick. This is due to the elastic

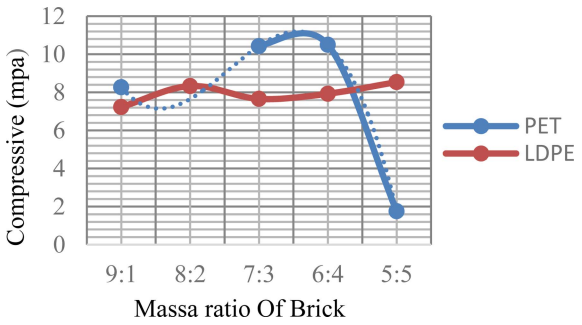

Fig. 5. Comparison of the compressive of bricks mixed of building material waste powder with types of PET and LDPE.

characteristics of LDPE so that it has a small effect on compressive strength. The addition of building material waste powder will cause breakage easily because there is no flexibility between the plastic and the building material waste powder. The increase in compressive strength of the plastic mixture with other materials is caused by the strength between plastic surfaces with aggregates that increase with the addition of thermoplastic binders.[7] The function of polymers to fill pores can increase mechanical strength in the mixture.[9] The compressive strength of the bricks getting higher with the addition of polymers. In Fig. 5 shows a comparison of compressive strength of bricks with a mixture of PET and LDPE plastic. The highest comparison of compressive strength of plastic bricks in PET plastic and LDPE plastic in the ratio of 5 : 5. In a ratio of 5 : 5 PET plastic mixed bricks the compressive strength is small compared to the others. This is because the comparison has more air cavities so it is the beginning of cracks or easily broken. The molecular chain structure has an influence on compressive strength. The linear chain structure in PET plastic will produce strong and rigid characteristics. Branched chain structure in LDPE plastic is more difficult to form bonds so that compressive strength is smaller than linear structures.[5] The molecular weight of PET plastic is greater than that of LDPE so that PET plastic bricks are stronger than LDPE. Polymers with a higher molecular weight are stronger.[10] In the study[11] it was mentioned that the molecular weight of LDPE plastic was 15,000 and the plastic molecular weight of PET was 27,000. Compressive strength is influenced by molecular weight, also influenced by bonds between molecules. The intermolecular forces in the structure of the LDPE plastic molecular chain occur rejecting. This is because the same charged intermolecular hydrogen bonds. The chain structure of the PET plastic molecule occurs between the molecular tensile forces that occur between hydrogen atoms that are bound to oxygen atoms so that the mixture of PET plastic bricks is stronger than LDPE plastic. According to[12] the tensile force between molecules in a large polymer chain increases its strength. The compressive strength of conventional building material wastes according to class 1[13] SNI (Indonesian National Standard) is 8-10 MPa. Comparison of plastic mixed bricks with conventional building material wastes is a compressive strength of a mixture of brick types of plastic larger than conventional building material wastes. Making bricks with a plastic mixture is more beneficial because of the compressive strength greater than conventional bricks.

In making plastic mixed bricks according to the SNI (Indonesian National Standard) size of building material wastes for walls with a comparison of plastic and brick powder red at 6 : 4. Comparison of 6 : 4 is the optimum variable and the right ratio because it has a large compressive strength. Data from the Malang City Sanitation and Landscaping Office in 2013 had a mass of 18,555 kg. In the ratio of 6 : 4 with a mixture of plastic masses with red stone powder obtained a mass of plastic mixed brick of 1.4 kg. Bricks that can be produced every day are 15,462. Compressive strength test with size according to SNI (Indonesian National Standard) obtained results of 13.58 MPa.[13] Plastic mixed bricks with building material waste powder will increase the value of compressive strength.

4. Conclusions

The conclusion of the study is as the following :

1. Adding plastic has an influence on the characteristics of plastic bricks. The effect of adding plastics is density, porosity, reduced water absorption and greater compressive strength. The compressive strength of mixed plastic bricks is greater than the standard 6-8 MPa bricks.
2. Comparison of types of PET and LDPE plastic has an influence on the quality of bricks. Water absorption, PET plastic porosity is smaller than LDPE plastic and density, PET plastic compressive strength is greater than LDPE plastic.
3. Potential plastic waste in Big City with a plastic mass of 185,550 kg can be made in the amount of 15,462 kg/ day plastic bricks using a mass plastic ratio with building material waste powder 6 : 4.

References

1. S. Arief, J. Humanity., **9**, 195 (2013).
2. M. Gauthier, Engineered Materials Handbook, p.1, ASM, America (1995).
3. S. Koswara, The danger behind Plastic Packaging (Bahaya dibalik Kemasan Plastik) On the Web. Retrieved February 15, 2018 from www.ebookpangan.com.
4. A. Rakhmawati and Y. Arnandha, Semnas Teknologi dan Informatika, **5**, 535 (2018).

5. M. Sepe, Density and Molecular Weight in Polyethylene On the Web. Retrieved 2012 from www.ptonline.com.
6. R. Ady, Paper Polymer Material On the Web. Retrieved 30 July 2018 from https://www.academia.edu/7490581/PaperPolimermaterial.
7. K. K. Asthana and R. Lakhani, J. Contruct Build Mater., **18**, 639 (2004).
8. A. J. Babafemi, B. Savija, S. C. Paul, V. Anggraini, J. Sustainability, **10**, 3875 (2018).
9. M. Frigione, Concr. with polym., p. 1, University of Talento, Italy (2010).
10. S. Umoren and M. M. Solomon, Polymer science: research advances, practical applications and educational aspects, p. 412, Ed. A. Méndez-Vilas, A. Solano (2016).
11. J. Greene, Classes of Polymeric Materials On the Web. Retrieved 2 July 2018 from www.csuchico.edu.
12. J. D. Robert and M. C. Caserio, Basic Principles Of Organic Chemistry : Forces Between Polymer Chains. Chemistry LibreTexts On the Web. Retrieved 30 July 2018 from https://chem.libretexts.org/Bookshelves/Organic_Chemistry/Book%3A_Basic_Principles_of_Organic_Chemistry_(Roberts_and_Caserio)/29%3A_Polymers/29.3%3A_Forces_Between_Polymer_Chains.
13. SNI, (Indonesian National Stadard) 15-2094-2000. Solid Red Brick For Wall (Bata Merah Pejal Untuk Pasangan Dinding). Jakarta : Pekerjaan Umum, 2000.