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# Fabrication of Sand Brick with Additive of Waste Thermoplastic Composition

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**Abstract:** As Malaysia is overburdened with waste materials, plastic waste can be used as a replacement in the production of brick as brick is one of the most common important units as a building material. The main objective of this project is to develop a sand brick with an additive of thermoplastic composition waste which is PET. Using the property of mechanically recyclable, the PET bottles will be mixed with sand and cement in a different ratio in a range between 5% to 15%. The ratio of cement, sand and PET waste is 1: 5.7/5.4/5.1: 0.3/0.6/0.9 respectively. After that, the plastic sand brick will undergo a few tests such as bulk density, water absorption test and compressive strength test after 7 days of curing process. The comparison result between sand brick with PET and the conventional sand brick from the local hardware store was evaluated. From the result, it shows that brick with 10% of PET waste shows the highest average bulk density which is 2341.67 kg/mm<sup>3</sup>. The lowest average water absorption among the plastic sand brick was recorded by 10% of PET waste which is 9.68% but it is higher than the conventional sand brick which only had an average of 4.01%. The compressive strength decreases as the percentage of PET waste increases. The results obtained from this project are expected to help determine the appropriate mixing ratios of sand, cement and plastic in order to obtain a good brick.

**Keywords:** Thermoplastic, PET Waste, Bulk Density, Water Absorption, Compressive Strength

## 1. Introduction

Sand is a natural resource and an important substance that is used in manufactured brick. The sand prevents raw bricks from cracking, shrinking and warping. They also provide bulk and strength to construction materials. The higher the proportion of sand, the more and uniform in texture will be the brick. Sand mining had caused an environmental problem to occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate this material. According to [1], sand has been mined predominantly from land quarries and riverbeds, but, due to intensive exploitation, this practice has been banned in many regions and environmental regulations have become much stricter.

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Polyethylene Terephthalate (PET) is a long-chain polymer belonging to the generic group of polyesters, semi-crystalline and thermoplastic polyester. PET was also characterized as easy to handle, durable, strong, thermally with low glass transition temperature, and chemically stable with low gas permeability. PET is being used for beverage and food packages all over the world, but the issues with the disposal of these non-biodegradable hydrocarbon materials have been a major challenge to society. Most of the waste produced from this material has ended up in drains of water and ultimately into the ocean [1].

In sand replacement, PET waste will be used in the production of sand brick which is a type of brick made from a mixture of cement and sand. They were moulded under pressure and cured under steam. Cement sand brick has been used for decades, but its uses are still very limited [2]. The plastic sand brick will be tested in terms of density, water absorption test and compressive strength. The result obtained from the test will be recorded and compared with conventional sand brick.

## 2. Materials and Methods

The project's methodology is discussed to achieve the objectives of the project. It also describes the method, procedure and testing preparation that is applied into the project. Some of the methods and collected information from the literature review was referred in this section.

### 2.1 Materials

The materials used in manufacturing plastic sand bricks are PET waste which was rejected PET plastic bottles, Ordinary Portland Cement, sand and water. The preparation of the materials is done and handled with careful to make sure the bricks produced followed the research.



### 2.2 Methods

The PET waste was cleaned with tap water and then left to dry for about 24 hours. Then, the rejected bottles were cut into smaller pieces. The raw materials and PET waste were mixed and water was added. Then, the mixture was compactly moulded and was left to dry in atmospheric conditions. When the sample was dried enough, it was taken out of the mould. The sample was now cured for 7 days. The conventional brick ratio is 1:6 of cement to sand. In plastic-sand brick, the weight of sand will be removed by 5%, 10% and 15% as it will be replaced with PET waste. The ratio of cement, sand and PET waste is 1: 5.7/5.4/5.1: 0.3/0.6/0.9.



Figure 1: The PET waste, sand and OPC were weighed



Figure 2: Mixing process

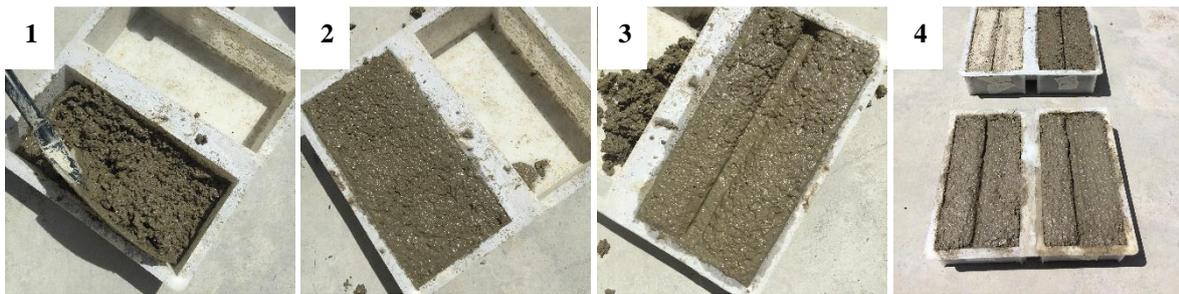


Figure 3: Moulding process



Figure 4: Curing process

Table 1: Quantity of material

Specimen	Cement (kg)	Sand (kg)	Material Plastic (kg)	Water (kg)	Total (kg)
5%	2	11.4	0.6	1	15
10%	2	10.8	1.2	1	15
15%	2	10.2	1.8	1	15

The bulk density of the bricks is determined by a density test. Density varies from country to country due to differences in conventional brick sizes, which are determined by the dimensions of the

bricks. [3]. For the bulk density test, we will be using Archimedes' principle. Before conducting this experiment, the weight of the specimens was measured. Next, a pail was filled with water to the brim and was placed in a big washbasin. Submerged the specimen into the water and some water will be displaced into the big washbasin. Lastly, collect and weigh the displaced water. The weight of the displaced water is equal to the volume of the specimen.



**Figure 5: The process of bulk density test**

For the water absorption test, the specimen was cooled to room temperature and obtain its dry weight. Immerse completely dried specimen in clean water for 24 hours. The specimens were removed from the water and wiped out of any traces of water with a cloth and the weight of wet brick was recorded.



**Figure 6: The process of water absorption test**

Compressive strength test was carried out to determine the load carrying capacity of the sand brick under compression with the help of compression testing machine. The compression testing machine (CTM) was used to test the compressive strength of the brick. The specimens are placed with flat and smooth faces horizontal and mortar filled faces facing upwards and carefully centered between plates of the testing machine. Apply load uniform rate of  $14 \text{ N/mm}^2$  per minute without shock till failure occurs and notes the maximum load at failure.



**Figure 7: Compression Testing Machine (CTM)**

### 2.3 Equations

The bulk density for the plastic sand was determined using the following equation

$$\text{Bulk density} = \frac{\text{Mass}}{\text{Volume}} \quad \text{Eq. 1}$$

The following equation was used to determine the percentage of water absorption by the plastic sand brick,

$$\% \text{ by wt.} = \frac{\text{Weight of wet brick} - \text{Weight of dry brick}}{\text{Weight of dry brick}} \times 100\% \quad \text{Eq. 2}$$

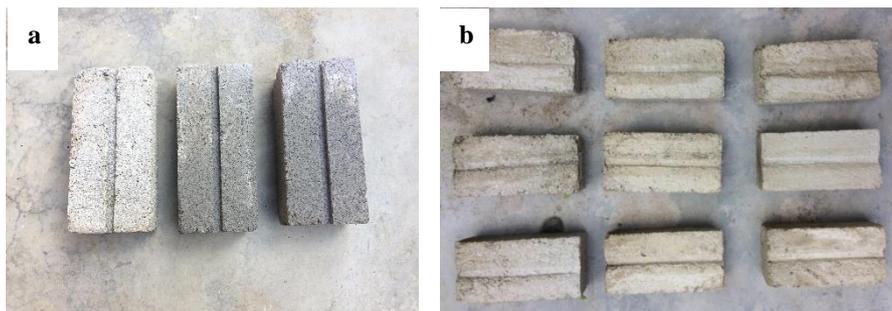
The compressive strength test was calculated after 7 days of curing process using the formula as follow,

$$\text{Compressive strength} = \frac{\text{Maximum load (kN)}}{\text{Area of specimen (mm}^2\text{)}} \quad \text{Eq. 3}$$

### 3. Results and Discussion

All collected data presented in the table and graph was to assure a better understanding of the results.

#### 3.1 Fabricated sand brick



**Figure 8: a) Conventional sand brick, b) Plastic sand brick**

Figure 8 shows the conventional sand brick and plastic sand brick with different ratios of PET waste. The standard size of the sand brick is 210 mm in length, 100 mm in width, 60 mm in depth and the tolerance limit is  $\pm 3$  mm.

**Table 2: Dimension for the sand brick**

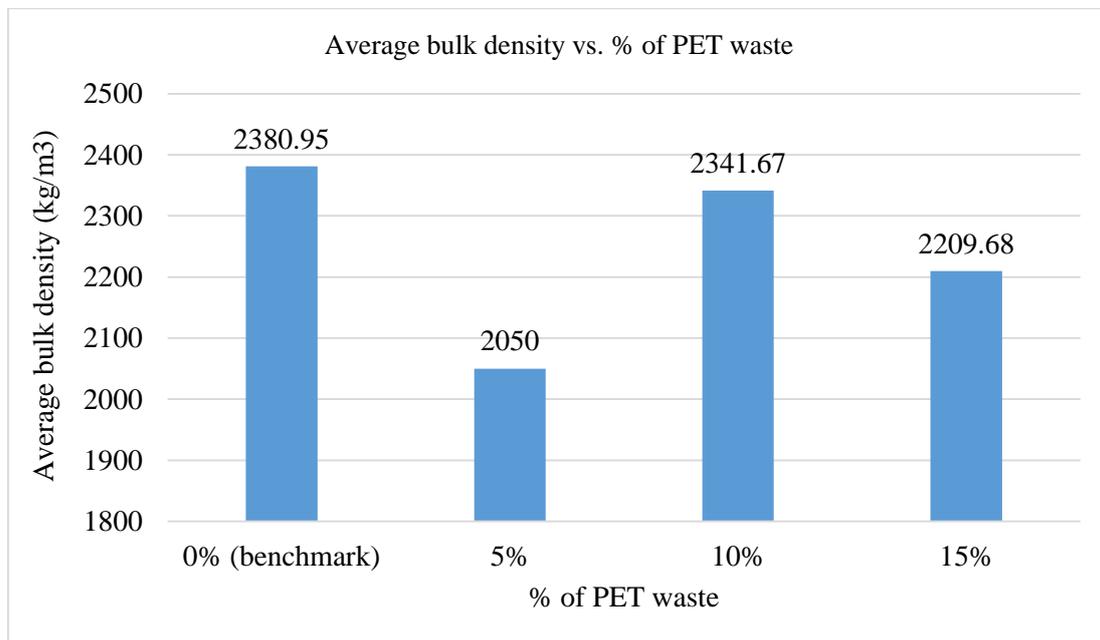
Specimen no.	% of PET waste	Dry weight (kg)	Length (mm)	Width (mm)	Height (mm)
1	0%	2.40	210	97	58
2		2.60	211	99	61
3		2.50	209	98	60
1	5%	1.80	210	100	58
2		1.90	208	98	58
3		1.80	208	98	58
1	10%	1.90	208	98	58
2		1.80	209	100	60
3		1.80	208	99	58
1	15%	1.75	208	99	57
2		1.75	207	98	58
3		1.76	207	99	59

Table 2 shows the weight and dimensions for the conventional (0% of PET waste) sand brick that was bought from a local hardware store and plastic sand brick. The conventional sand brick was the benchmark for this experiment. The measurement was taken using the measuring tape and the inaccuracy of this measurement may be due to the random error that occurred during taking the measurement. Even though the plastic sand brick has almost the same dimension as the conventional sand brick, the weight of plastic sand brick is less than the conventional sand brick.

### 3.2 Bulk density test

**Table 3: Result of bulk density test**

Specimen no.	% of PET waste	Dry weight (kg)	Volume of displaced water (m <sup>3</sup> )	Bulk density (kg/m <sup>3</sup> )	Average (kg/m <sup>3</sup> )
1	0%	2.40	0.00105	2285.71	2380.95
2		2.60	0.00105	2476.19	
3		2.50	0.00105	2380.95	
1	5%	1.80	0.0009	2000.00	2050.00
2		1.90	0.001	1900.00	
3		1.80	0.0008	2250.00	
1	10%	1.90	0.0008	2375.00	2341.67
2		1.80	0.0008	2250.00	
3		1.80	0.00075	2400.00	
1	15%	1.75	0.00075	2333.33	2209.68
2		1.75	0.00077	2272.73	
3		1.76	0.00087	2022.99	



**Figure 9: Result of bulk density test**

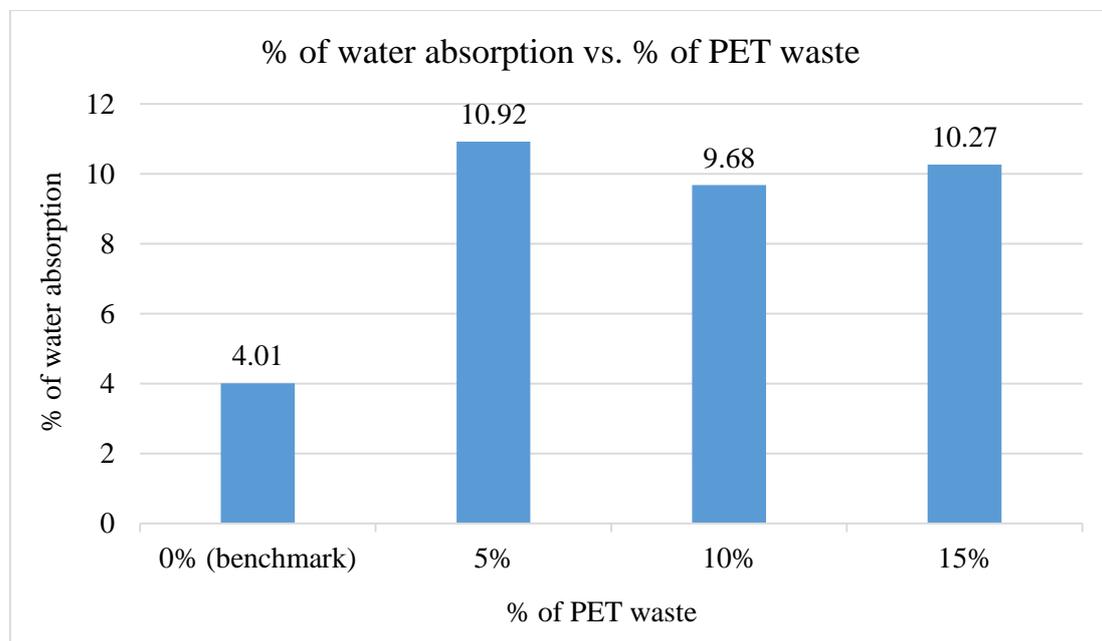
Table 3 and Figure 9 show the result of the bulk density test for conventional and plastic sand brick. Each of the bricks has a different value of density. The values range for the bulk density was from 1900.00 to 2476.19 kg/m<sup>3</sup>. From the graph obtained, the average density of bricks with 0% of PET waste which was the benchmark for the experiment was 2380.95 kg/m<sup>3</sup>. The brick that consists of 10% of PET waste recorded the highest density within the plastic sand brick with the value of 2341.67 kg/m<sup>3</sup> while 5% of PET waste recorded the lowest average density which is 2050.00 kg/m<sup>3</sup>.

When a comparison was made, there was no noticeable difference between the conventional sand brick with the brick that contains 10% of PET waste. Based on the graph obtained, all the plastic sand brick samples have a lower density than the conventional sand brick. This is because of the properties of the PET material which is lightweight. Other than that, this is most likely due to the PET particles have a lower density ( $1370 \text{ kg/m}^3$ ) as compared to sand ( $1602 \text{ kg/m}^3$ ).

### 3.3 Water absorption test

**Table 4: Result of water absorption test**

Specimen no.	% of PET waste	Weight (kg)		Percentage of water absorption (%)	Average ( $\text{kg/m}^3$ )
		Dry brick	Wet brick		
1	0%	2.40	2.50	4.17	4.01
2		2.60	2.70	3.85	
3		2.50	2.60	4.00	
1	5%	1.80	1.95	8.33	10.92
2		1.90	2.10	10.53	
3		1.80	2.05	13.89	
1	10%	1.90	2.10	10.53	9.68
2		1.80	2.10	7.69	
3		1.80	2.05	10.81	
1	15%	1.75	1.90	8.57	10.27
2		1.75	1.95	11.43	
3		1.76	1.95	10.80	



**Figure 10: Result of water absorption test**

Table 4 and Figure 10 shows the result of the average percentage of water absorption test of sand brick. The values range for the percentage of water absorption test was from 3.85% to 13.89%. The average percentage of water absorption for the benchmark specimen (0% of PET waste) is 4.01%. Among the plastic sand brick, the specimen with 10% of PET waste showed the lowest reading which

is 9.68% followed by the brick specimen with 15% of PET waste, 10.27%. Meanwhile, the specimen with 5% of PET waste recorded the highest reading which is 10.92%.

Based on Figure 4.3, all of the plastic sand bricks had a higher percentage of water absorption compared to the conventional sand brick. Although PET significantly affected the increased water absorption characteristic of sand bricks, they were still considered good bricks because the percentage of water absorbed by all the bricks is less than 20% as a good quality of brick should not absorb water more than 20%. As PET material is resistant to water, we can see that the percentage of water absorption for plastic sand bricks was in acceptance criteria. In conclusion, the water absorption performance of PET waste was found to be average and satisfactory.

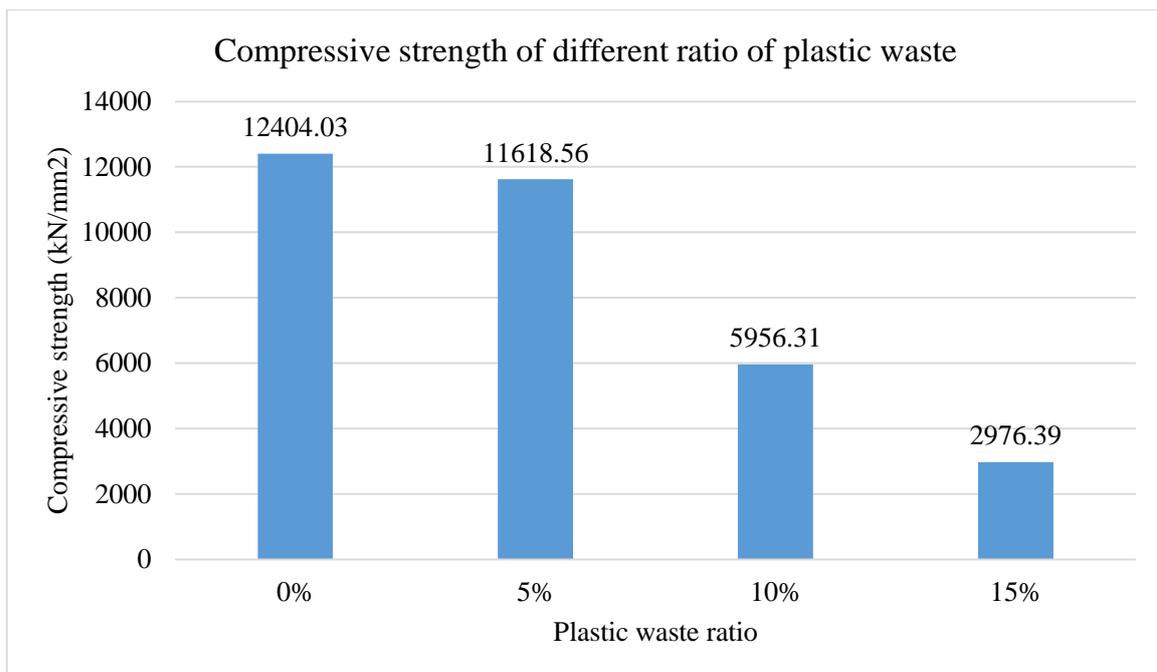
### 3.4 Compressive strength test – A review

Due to the Covid-19 pandemic, students were not allowed to use the laboratory. So, a review from the previous research will be done for the compressive strength test.

According to previous research conducted by [4], the flawed bottles that were rejected were gathered and crushed into little pieces. The plastics were then sieved to obtain the smallest size. The proportion of sand, sand dust, cement and water with the ratio of 9:9:4:2 respectively were put into the mixer. After that, the plastics materials were divided into ratios and mixed with the raw components. The mixture was then poured into the mould to produce bricks. The compression test was conducted as per BS 5628: Part 1: 1992.

**Table 5: Compressive strength of different ratio of plastic waste [4]**

Sample	Weight (kg)	Density (kg/m <sup>3</sup> )	Max load at crushing (kN)	Compressive strength (kN/mm <sup>2</sup> )
0%	2.60	1994.4	252.67	12404.03
5%	2.42	1856.3	236.67	11618.56
10%	2.40	1840.9	121.33	5956.31
15%	2.10	1610.8	60.67	2978.39



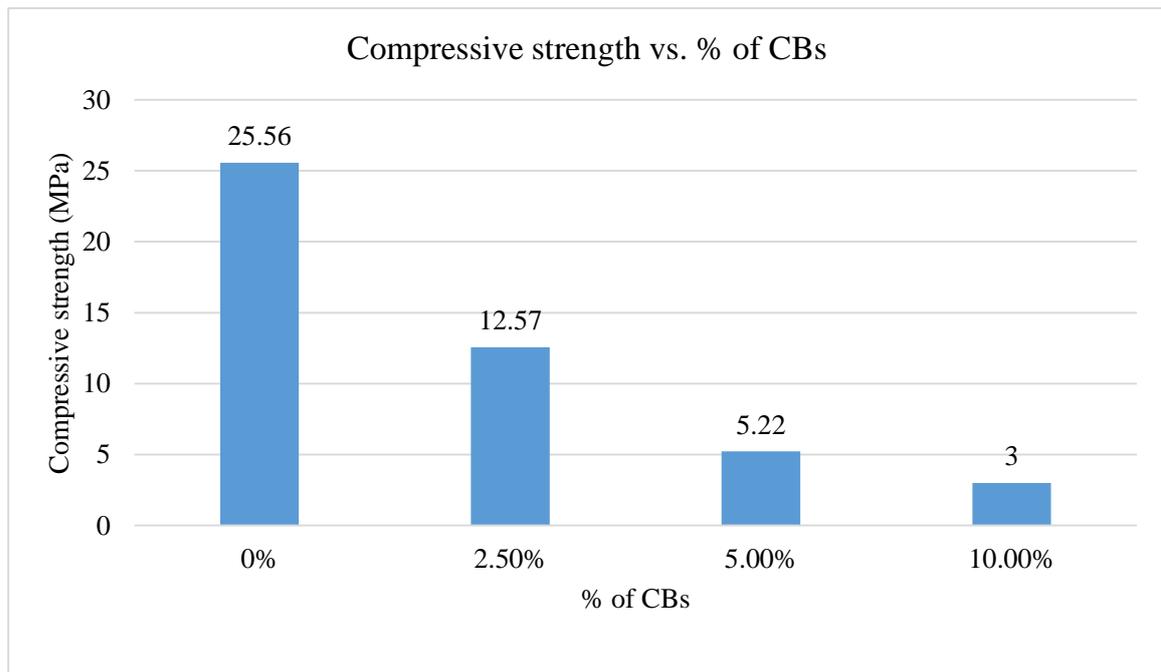
**Figure 11: Graph of compressive strength versus plastic waste ratio**

Based on Table 5, it shows that the value of the compressive strength decreases when the ratio of PET waste increase. The original sand brick has the highest value of compressive strength, 12404.03 kN/mm<sup>2</sup> while the 5%, 10% and 15% plastic sand brick have a compressive strength of 11618.56 kN/mm<sup>2</sup>, 5956.31 kN/mm<sup>2</sup> and 11618.56 kN/mm<sup>2</sup> respectively. This could be due to the fact that plastic waste lacks cementitious properties as plastic does not mix up well with the cement which resulted in the reduction of strength [4].

Based on the experiment conducted by [5] who presents and discusses some of the results from a study on recycling CBs into fire clay bricks, four different mixes were used to make the fired brick samples. The brick samples which contain 2.5, 5 and 10% of CBs by weight, 10-30% by volume were mixed with the experimental soil and fired to produce brick. The fired samples were tested for compressive strength, flexural strength, density, water absorption and initial rate of absorption according to the Australian Standard. The provided findings are the average of three different values.

**Table 6: Experimental results for the mixes containing CBs [5]**

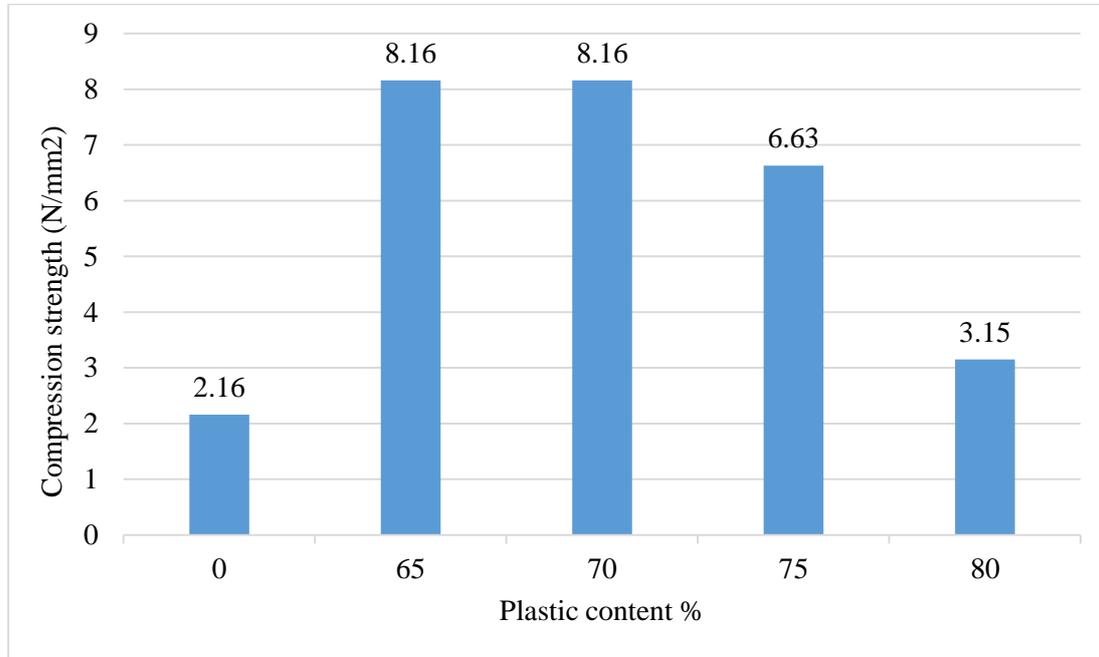
Mixture identification	Compressive strength (MPa)	Flexural strength (MPa)	Water absorption (%)	Initial rate of absorption (IRA) (kg/m <sup>2</sup> /min)	Average density (kg/m <sup>3</sup> )
CB (0.0)	25.65	1.97	5	0.2	2118
CB (2.5)	12.57	2.48	9	1.4	1941
CB (5.0)	5.22	2.40	15	2.3	1611
CB (10.0)	3.00	1.24	18	4.9	1482



**Figure 12: Result of compressive strength test**

Based on the result in Table 6 and figure 12, the compressive strength of the bricks reduced from 25.65 MPa for 0% CBs (control) to 12.57, 5.22 and 3.00 MPa for 2.5%, 5% and 10% of CBs respectively. The most recommended compressive strength for non-load-bearing solid fired clay bricks is 3MPa to 5 MPa and for load-bearing solid fired clay bricks is 5 MPa to 10 MPa. Mixing at a faster speed and for a longer period of time can result in finer mixtures with better compressive strength [5].

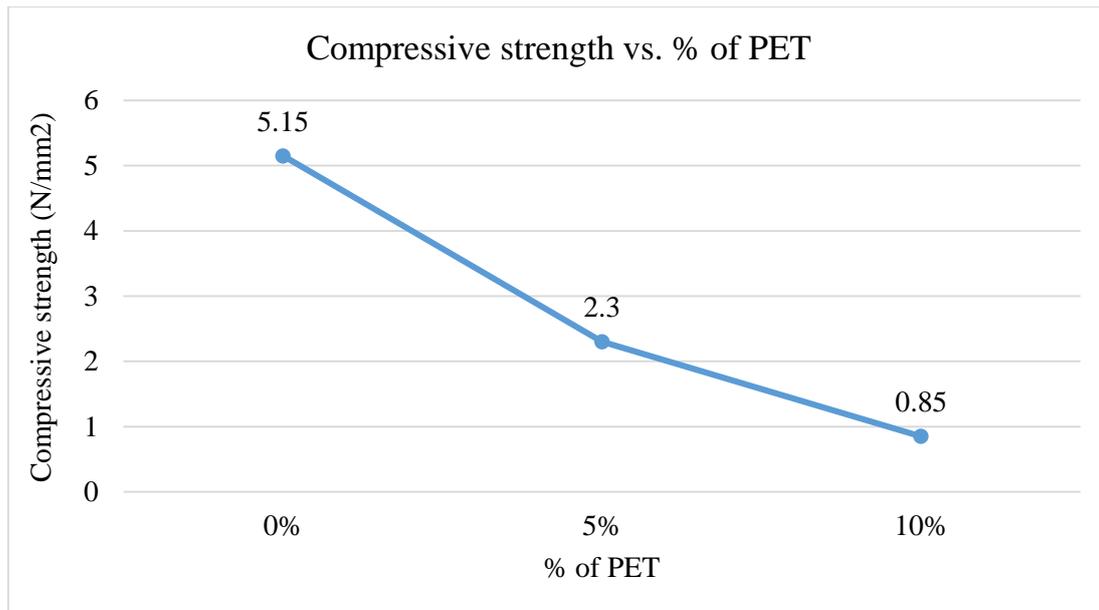
From a previous study, the main objective of the research conducted by [6] is to develop an efficient way to effectively utilize waste plastic. Bricks with different mix proportions were made, with 3kg of laterite soil added for each brick, with varying bitumen content of 2, 5, and 10%, as well as varying percentages of plastic. 70% of PET by weight of soil is cleaned and heated to a molten state. Then, at intervals, sieved soil is applied with proper mixing. 2% bitumen by weight of soil is added and stirred for uniform distribution to prepare 3 bricks. The hot mixture was poured into the moulds. After 30 minutes, the bricks are demoulded and air dried for 24 hours to ensure optimum heat dissipation.



**Figure 13: Compression strength of plastic soil bricks [6]**

According to Figure 13, as the percentage of plastic increased, the compressive strength of the brick decreased. Based on the figure, 65% and 70% plastic by weight of soil with a constant binder content of 2% by weight of soil give the same compressive strength which is 8.16 N/mm<sup>2</sup>, but 70% plastic by weight of soil is considered the optimum in terms of workability criteria during manufacture [6]. This is because both have the same compression strength but different plastic content. So, it will be better to choose higher plastic content because the brick will be lighter and eco-friendlier. The brick with 0% plastic has the lowest compressive strength which is 2.16 N/mm<sup>2</sup>.

Akinyele et al. [7] has been carried out an experiment to investigate the use of PET in burnt bricks with a view to improve its properties and usage as a building material. The manufacture of bricks began with control samples and then progressed to bricks using waste plastics. The percentage of laterite replaced by crushed PET was 0, 5, 10, 15, and 20%, and the samples were labeled M<sub>0</sub>, M<sub>5</sub>, M<sub>10</sub>, M<sub>15</sub>, and M<sub>20</sub>, respectively. M<sub>0</sub> bricks were used as a control for the various brick mix percentages. For the experiment, thirty bricks were produced, each with three replicate samples for compressive and flexural strength tests.



**Figure 14: Compressive strength results [7]**

Based on Figure 14, the amount of compaction, burning, and lack of impurities all play a role in the compressive strength of bricks. The compressive strength of clay bricks decreased as the quantity of plastic waste was increased. Based on the findings of this project, the highest compressive strength was 5.15 N/mm<sup>2</sup> and the lowest was 0.85 N/mm<sup>2</sup>. It indicates that the addition of PET waste considerably contributed to the reduction in strength. According to [7], if the furnace temperature can be controlled so that the PET particles do not melt, the compressive strength can be improved. The sample with 5% of PET waste demonstrated that burnt bricks containing less than 5% PET can have compressive strengths that fall into the third-class brick category which is mostly used in ordinary construction.

Based on the review provided, we can conclude that when the percentage of plastic content increase, the compressive strength of the brick decrease. When compared to conventional sand bricks, the plastic sand bricks had lower compressive strength. This can be attributed to the decrease in adhesive strength between the surface of the waste plastic and the cement paste. Other than that, the size of PET material would also affect the compressive strength. The PET material should be in a really small size to increase the compressive strength. A larger sand particle size also reduces the compressive strength by increasing the porosity. The compressive strength of construction material is the most essential criterion for determining its engineering excellence, as a higher compressive strength implies a good quality and strong material.

#### 4. Conclusion

In conclusion, sand bricks with an additive of PET waste were fabricated. There were 9 plastic sand bricks produced with 3 different groups and the dimensions are 210 mm in length, 100 mm in width and 60 mm in height. Each 3 of the bricks contain 5%, 10% and 15% of PET waste. The mechanical properties such as bulk density, water absorption and compressive strength of the plastic sand brick were studied. The density of the sand brick was obtained by using Archimedes' Principle and the result shows that the range for average density of plastic sand brick is between 2050.00 to 2341.67 kg/m<sup>3</sup>. The value range for the percentage of water absorption for the plastic sand brick was from 9.68 to 10.92%. Based on the review made, the compressive strength decreases when the plastic content increase. The decrease in adhesive strength between the PET waste and the cement paste might be the reason. Lastly, the performance of fabricated sand brick and conventional sand brick were compared. The average bulk density for all the sand brick with PET waste was lower than the conventional sand brick which is 2380.95 kg/m<sup>3</sup> as it was influenced by the addition of PET because PET was lighter than

sand. The average percentage of water absorption for fabricated sand brick, 9.68% were higher than the conventional brick, 4.01%. As for the compressive strength, the conventional sand brick has higher compressive strength compared to the plastic sand brick.

**Table 7: Comparison between conventional and plastic sand brick**

<b>Characteristics</b>	<b>Higher value</b>	<b>Lower value</b>
<b>Bulk density</b>	Conventional sand brick	Plastic sand brick
<b>Water absorption</b>	Plastic sand brick	Conventional sand brick
<b>Compressive strength</b>	Conventional sand brick	Plastic sand brick
<b>Weight</b>	Conventional sand brick	Plastic sand brick
<b>Cost</b>	Conventional sand brick	Plastic sand brick

Based on the comparison above, PET waste may be used as an addition in sand brick. Lastly, the use of PET waste as a replacement to the sand in the mixture would solve the problem of safe disposal of plastic waste in an eco-friendly way. This simple method has the potential to clean up the environment, develop new construction materials, and drastically reduce the amount of PET waste by converting plastic wastes into a useful resource.

Recommendation for future work, the curing process of the plastic sand brick should be longer to achieve a better quality of brick. In this project, the curing process was only for 7 days. For future work, the curing process should be 14 and 28 days so that we can compare the result between 7,14 and 28 days. Next, the sieving process. In order to get a fineness size particle, the PET waste and the sand should be sieved before conducting the project. By sieving the raw materials, a maximum packing density can be achieved and can increase the compressive strength. Lastly, mix the raw materials using a mixer at a faster speed can result in finer mixtures with better compressive strength.

### **Acknowledgement**

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