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A Study on Development of A Concrete Brick Using Plastic PET Bottles as Fine Aggregates Using Solidworks Software

Syed Abdul Hafiz Wan Daud[1], Roslinda Ali[1]*, Noraini Marsi[2]

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

[2]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

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Abstract: Plastic is an organic polymer which usually made from synthetic. Plastic is a material that either cannot be totally decomposed or takes a long time to decompose. This study is interested to evaluate the mechanical and physical properties of PET bottles using different ratio of 20.00 %, 40.00 %, 60.00 %, and 80.00 % in producing a concrete brick. Different ratio of PET concrete bricks will undergo the mechanical and physical testings to determine the effectiveness of plastic waste by using Solidwork software simulation. The two tests conducted for the mechanical testing included compressive strength test and sound absorption test while for the physical testing, the tests conducted were density and porosity tests. From the test result recorded, the value from the comppresive strength test and density test carried out decreased when the percentage of PET increased. Meanwhile, the value of porosity test increase when the percentage of PET increase. It can be concluded that the optimum percentage for replacement fine aggregate with PET plastic waste for this study is 20.00 %.

Keywords: PET Bottles, Concrete Brick, Solidworks Software Simulation

1. Introduction

Over the years, the use of plastics is increasing worldwide in line with economic and industrial developments. A common feature of plastics is the process of making and forming or molding is not difficult and the cost required is low. This cause the plastic to become increasingly in demand especially in the packaging industry. Characteristic of plastics also make it difficult to decompose. One plastic takes billions of years to decompose. Due to that, plastic pollution begin to occur. Plastic pollution occurs in many form including but not limited to littering, marine debris, plastic particle water pollution, plastic netting and floaters [1]

Concrete is the most important material in the construction industry. Concrete is a building material consisting of cement, fine aggregates (sand) and coarse aggregates (gravel) mixed with water that

*Corresponding author:linda@uthm.edu.my

hardens with time. However, the use of concrete in construction pollutes the environment because cement one of the main producers of carbon dioxide, a potent greenhouse gas in addition the natural resource is widely used such as gravel and sand in concrete.

Over the past few decades, researchers from all over the world have conducted studies to find alternatives and produce concrete from waste material. Among the alternative materials used in the manufacturing of concrete include fly ash [2], gold mill tailing [3], wood sawdust [4], recycled paper mill waste [5]. The result of studies from previous researchers found that concrete produced from waste materials can highly fire insulation (fly ash), better tensile strength (polypropylene fiber).

The importance of the study is to produce concrete brick from the PET bottle waste which it is one of the plastic waste type that existed abundance in environment. The study covers the using of PET plastic waste as raw material to reduce the environmental problem, which then has ability to use as raw material to subtitute natural resource to produce the concrete brick. Therefore, this research is interested to investigate the properties of a concrete made from plastic waste. In this context, fine aggregates will be replaced with plastic PET bottles to produce concrete.

2. Literature Review

2.1 Compressive Strength

Compressive strength is the strength of hardened concrete measured by the compression test. The compression strength of concrete is a measure of the concrete's ability to resist loads which tend to compress it the major strength test conducted on concrete. Compressive testing typically provides an overall image of concrete consistency since it is directly related to the cement structure.

Table 1: Selected previous researches of compressive strength test using waste materials as a replacement in concrete

Waste material	Result	Source
Ceramics	32.6 to 57.2 N/mm^2	[6]
Tyres and rubber	25 to 33 MPa	[7]
PET	30.3 to 33.4 MPa	[8]
Glass	46.5 to 58.5 MPa	[9]

2.2 Sound Absorption

The sound absorption coefficient is ideally defined as the fraction of the randomly incident sound power absorbed by the material. The grather the coefficient, the grather the sound absorption. The sound absorption average (SAA) is a single number rating obtained by taking the arithmetic average of the one-third octave bands from 200 through 2500 Hz rounded to the nearest 0.01. As a result, the ratio of absorbed energy to total incident energy can be determined and it called as sound absorption coefficient.

Table 2: Selected previous researches on sound absorption test using waste materials as a replacement in concrete

Waste material	Result	Source
Rubber	0.13-0.18 α	[10]
Glass	10-50 db	[11]
PET	0.16-0.17 α	[12]
Industrial waste	0.9-1.0 α	[13]

2.3 Density

The main purpose of density concrete test is to measure the density of each sample of concrete cube. Density is depending on the cement concentration, size and amount of aggregates used and process of concrete mixing. The density of normal weight concrete lies within the range of 2,200 to 2,600 kg/m^3.

Table 3: Selected previous researches on density test using waste material as a replacement in concrete

Waste material	Result	Source
Tyre and rubber	1880 to 2380 kg/m^3	[7]
Glass	2285 to 2370 kg/m^3	[14]
Coconut shell	1975 to 2110 kg/m^3	[15]
PET	2010 to 2060 kg/m^3	[8]

2.4 Porosity

Porosity is an important characteristic of brick. Porosity of building material is an important factor to consider in respect its performance and applications. Porosity rate at 8.00 % is 10 times more durable in resisting salt attack than that with porosity rate at 20.00 %.

Table 4: Selected previous researches on porosity test using waste materials as a replacement in concrete

Waste material	Result	Source
Rice husk ash	14-16%	[16]
Glass	15-20%	[17]
PET	20.4-45%	[18]
Ceramics	50-60%	[19]

3. Methodology

3.1 Preparation of Sample

A total of 4 samples were prepared of which each sample consisted of a concrete composition and PET bottles used for fine aggregates as stated in Table 5. The purpose of preparing different samples is to view and compare the physical and mechanical properties of each sample and to determine its optimal ratio for producing concrete bricks.

Table 5: The different ratio of concrete and PET bottles

Sample	Concrete	PET (%)	Ratio
A	1	20	1 : 0.2
B	1	40	1 : 0.4
C	1	60	1 : 0.6
D	1	80	1 : 0.8

3.2 Solidwork Software

The Soldidwork software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. In this study, testing of cube concrete will be conducted by simulation process using solidwork software to get the mechanical and physical properties of the concrete cube. The flowchart of the research methodology for this study is illustrated in Figure 1.

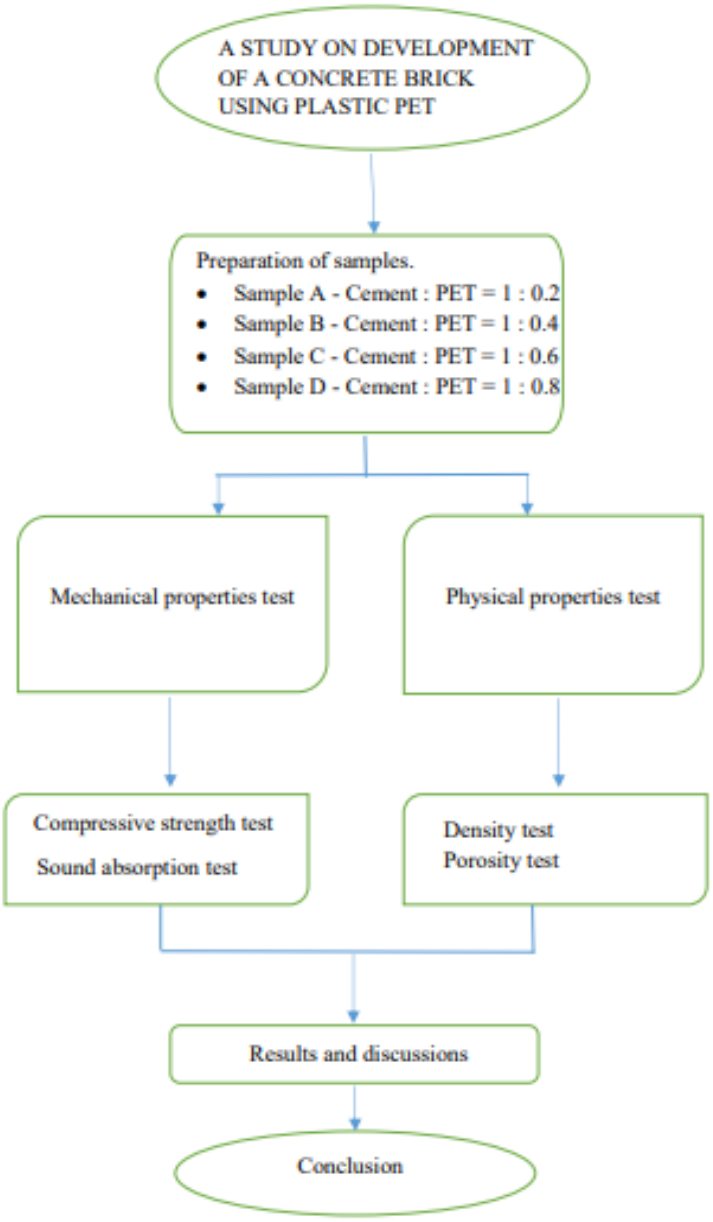

Figure 1: The flowchart of the research methodology

4. Results and Discussions

4.1 Commpresive Strength Test

The compressive strength test of concrete brick has been done by using Solidwork software simulation. The concrete cube size 100 x 100 x100 mm was used to carry out the compression strength test. The decided percentage of PET plastic waste 20%, 40%, 60% and 80% was use to carry out the test. The result of the compressive strength test is illustrated in Figure 2.

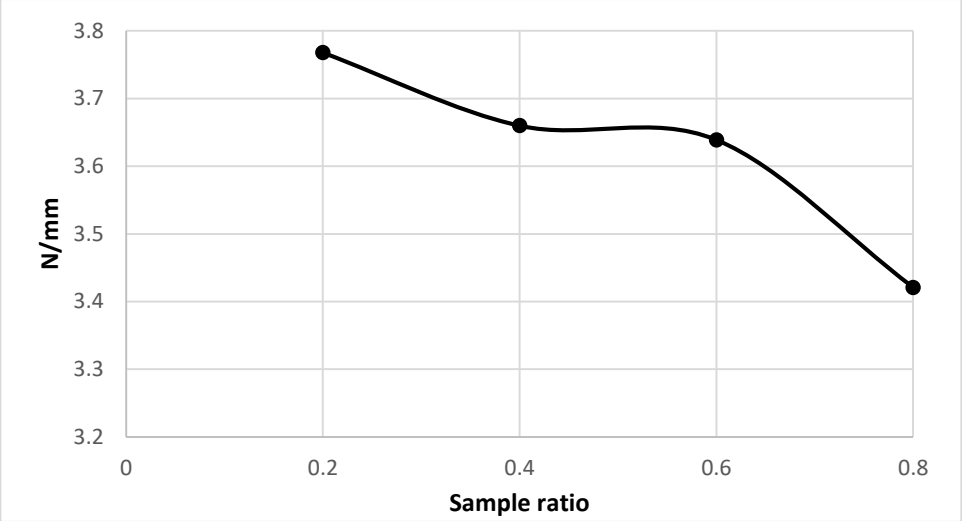

Figure 2: Commpresive strength test

From Figure 2 the result showed the decreasing linear graph with the increasing of composition of PET. The maximum load for 20.00 % composition was 3.760 N/mm which it was the highest maximum load compared to others three samples. For the 40.00 % composition, the maximum load was started to decrease to 3.660 N/mm while 3.639 Nmm was determined by the 60.00 % composition of PET plastic waste. The 80.00 % composition was displayed as the lowest maximum load which was 3.421 N/mm. Thus, it shown that the increasing of composition of PET plastic waste was influenced the performance of samples in impact properties especially in maximum load. The reduction in the compressive strength of concrete might be due to either a poor bond between the cement paste and the plastic wastes or to the low strength of this plastic wastes [20]

4.2 Sound Absorption test

Sound absorption test are the materials that in the sound energy emitted as the sound waves generated. A part of the released energy will be dissipated as heat energy. The test was conducted by Solidworks simulation and the selected frequencies is 2000hz-10000hz. The result are presented in Figure 3.

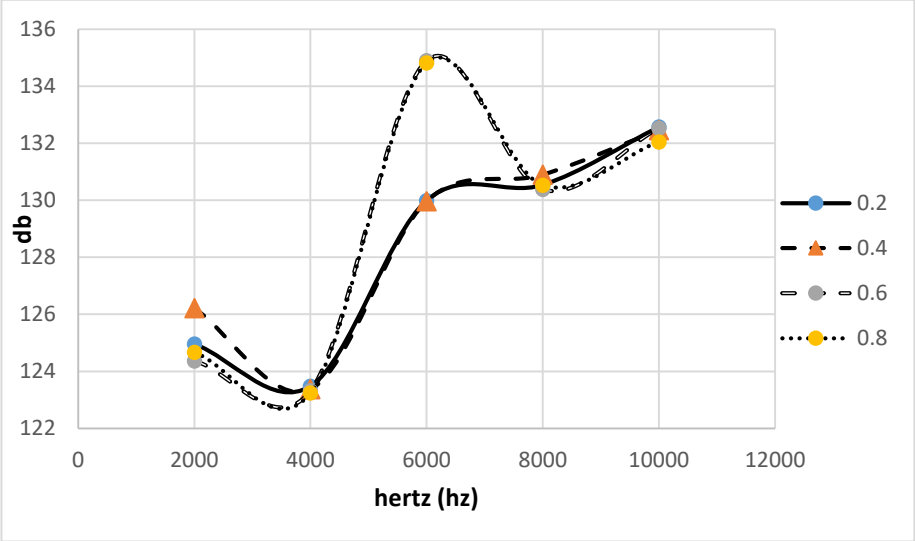

Figure 3: Rate of vibration test

Based on Figure 3, the graph shows the rate of vibration test. Based on the result obtained, the 60.00 % of PET plastic waste has highest vibration test which is at 6000 hz show 134.9 db and decrease at 10000 hz with value 132.53 db. For ratio 80.00 % the result show a bit similar at 6000 hz show 134.82 db. Sample 20.00 % and 40.00 % of PET waste plastic shows the similar value of vibration test which is higher at 10000 hz show 132.57 db and 132.46 db. As a conclusion, when the ratio of plastic waste increases, the absorbency of sound energy also increase, the thicker specimen has higher maximum sound absorption at higher frequencies [21]

4.3 Density test

The density of concrete is a measurement of concrete's solidity. The process of mixing concrete can be modified to form a higher or lower density of concrete end product. The mechanical properties of concrete are highly influenced by its density.The test was carry out to identify the density of the concrete cube with different PET ratio with is 20.00 %, 40.00 %, 60.00 % and 80.00 % partial replaced fine aggregate.

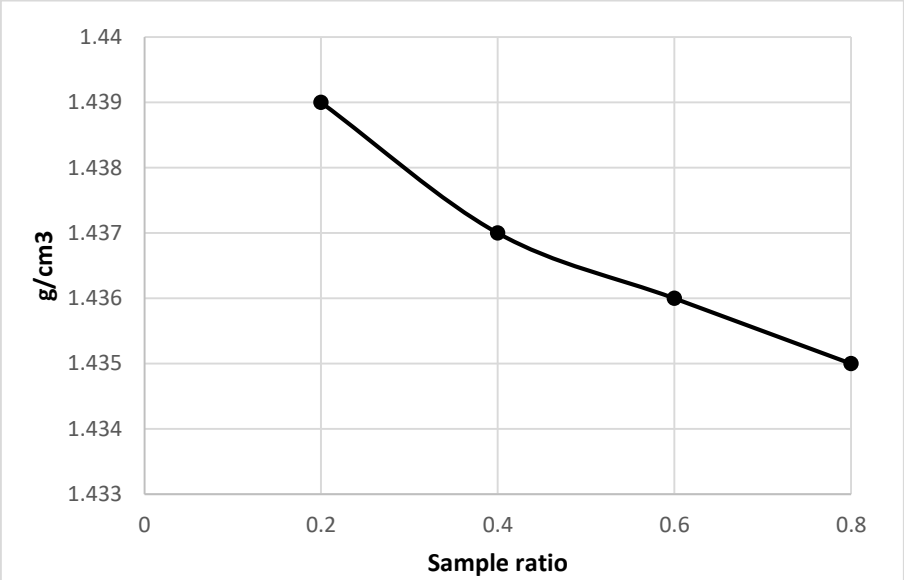

Figure 4: Density test

Based on the Figure 4, the 20.00 % composition was showed the highest density with 1.439 g/cm^3 while the 40.00 % with value 1.437 g/cm^3 and 60.00 % composition density value is 1.436 g/cm^3. Finally, the lowest density was the sample with 80.00 % composition with 1.435 g/cm^3. Thus, the increase in PET composition in concrete bricks is due to the decrease density and it is proven from previous research that states that, there is a reduction in the density of fresh concrete as the content of plastic aggregate increases, because the particle density of plastic aggregate is very low compared with natural aggregate [22].

4.4 Porosity test

Porosity test can be defined as the mass per volume and was performed by means of Archimedes principle (buoyancy method). It is stated that a body immersed in fluid apparently loses weight by an amount equal to the weight of the fluid it displaces. This method determines of the porosity of solids, viscous and pasty substance as well as liquids. The results of the porosity test is illustrated in Figure 5.

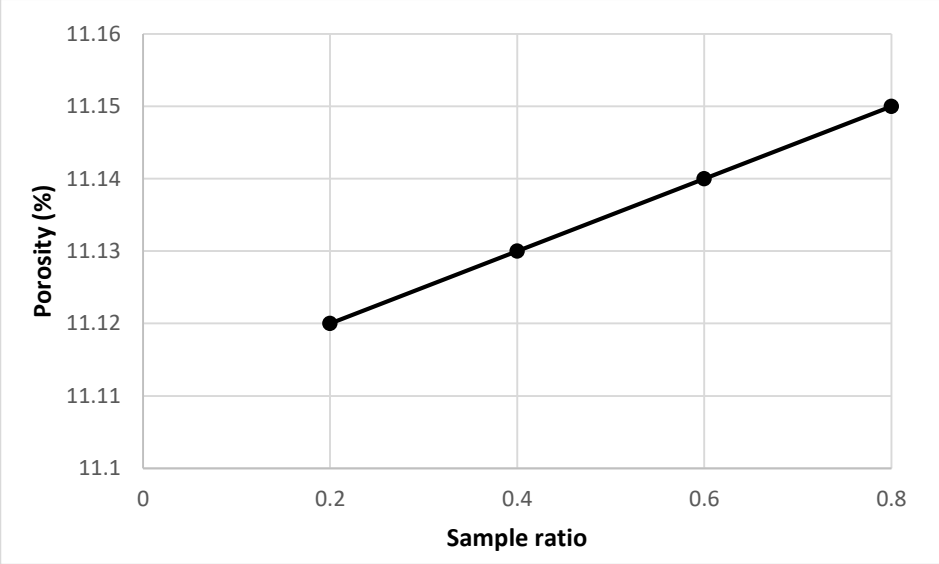

Figure 5: Porosity test

Based on Figure 5, the average porosity of the sample with a 20.00 % composition of PET plastic waste was about 11.12 % which showed the lowest reading and the sample with a composition of 40.00 % is 11.13 % was determined. Meanwhile, the third sample of 60.00 % PET plastic waste composition showed a increase with an average porosity of 11.14 % while the 80.00 % PET plastic waste composition sample showed an 11.15 % reading as shown in Figure 5. According (Albano, et al 2009) porosity increase caused aggregates can influence in shape is plane and elongated. The increasing of porosity with increasing of plastic composition is due to the filing which effect of voids in the cementations matrix and porous material of the plastic waste [23]

5. Conclusion

In conclusion, the objectives of this study are achieved. The optimum composition percentage of 20.00 % of PET plastic waste with mixture of gravel and cement is possible to be applied for concrete bricks application. The mechanical and physical tests based on different percentage of PET plastic waste for concrete brick application had been conducted and evaluated. However, due to budget and time constraint, few limitations occurred in carrying out this research which is preparation of sample took a long time as PET bottle were manually cut into small pieces and due to pandemic Covid-19, physical and mechanical tests were conducted simulatively using Solidworks software vision 2019. To ensure this study improve in the future, recommendation can be taken to improve this research are to obtain a more accurate results, conduct physical and mechanical test in laboratory and compare the result obtained from using Solidworks software. Based on this study, by using simulation software such as Solidwork can investigate the mechanical properties and analysis before proceed to a real production process.

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