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A Study on The Characteristic of An Eco-Brick as A Replacement to The Conventional Brick

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Abstract: Plastic pollution is a global environmental concern. The increasing urbanization along with population growth rate contributes to an unaccountable amount of plastic waste. Eco-bricks have been identified as one of the measures to reduce the amount of plastic waste disposal at landfills. Eco-brick is a plastic bottle packed with solid non-biodegradable plastic waste. The aim of this study is to investigate the optimum strength of an eco-brick with different density ratios to replace a conventional brick. Five samples of eco-brick with different density ratios were prepared and tested using SolidWorks software version 2014. The tests include compressive test, drop test and failure analysis. From the test results, it can be concluded that density of an eco-brick plays an important role in determining its strength. In addition, the higher the density and the height of the bottle is dropped, the higher is the value of the impact force. The buckling and fracture of eco-bricks with high density ratio are less visible compared to eco-brick with low density ratio.

Keywords: Eco-brick, Density ratio, SolidWorks software version 2014

1. Introduction

Solid waste is one of the three main environmental problems in Malaysia. The waste generation rate in Malaysia has increased steadily throughout the years from 12.3 million tons in 2013 to 13.9 million tons in 2018 [1]. The increase of plastic waste generation in Malaysia and around the world can

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bring negative impact to the environment. Therefore, many creative solutions are needed to safe our mother earth. Eco-bricks have been identified as one of the measures to reduce the amount of plastic waste disposal at landfills. Eco-brick is a PET bottle filled with clean and dry plastic waste that can be used as a building block. Previous studies have shown that eco-bricks have several advantages and can be used to make modular units, furniture, landscape and structure. Furthermore, a wall made of eco-bricks is lighter and 20 times more load resistant compared to the conventional bricks. The wall is stable and cannot be damaged by earthquake [2]. In addition, eco-bricks can serve as a natural insulator due to tightly packed insulating plastic [3].

In Malaysia, several NGOs such as Trash Hero Malaysia, Malaysia Eco-brickers Community and Recycle Community Malaysia Lestari (RCOMM Lestari) are involved in eco-brick programs. They have been conducting programs in relation to plastic waste and eco-bricks to inculcate the public on plastic waste reduction. For example, Trash Hero Malaysia in collaboration with communities, volunteers and companies have organized eco-bricks projects at schools, community halls and companies to collect as many plastic wastes as possible for eco-bricks making. In addition, these NGOs have installed eco-bricks drop-off points across Malaysia for the public to deposit their completed eco-bricks. As a result, in July 2019, 8,765 eco-bricks were collected across Malaysia with a total of 4,282 kg of plastic waste. This amount is equal to 25,692 kg of carbon dioxide if they were released in landfill during degradation [4].

Therefore, this study is interested to investigate on the suitability of an eco-brick to be used as a replacement brick. In order to achieve the aim of this study, two objectives were formulated. The first objective is to determine the optimum strength of an eco-brick with different density ratios by using SolidWorks software version 2014. The second objective on the other hand, is to investigate the failure analysis of an eco-brick with different density ratios by using the same software. Three tests were conducted to achieve these objectives, namely the compressive test, drop test and failure analysis test.

1.1 Manufacturing of Eco-Brick

Plastics are the main material needed in order to make an eco-brick. Nevertheless, these plastics must be washed and dried beforehand. Plastic waste that can be used in eco-brick making include food wrapper, plastic bag, polystyrene and straws. After drying, it is best that these plastics are cut into smaller pieces to ensure the space inside the bottle can be fully filled.

After the materials were prepared, the bottle can be filled with plastics. However, for the first layer, colored soft plastic is inserted into the bottom of the bottle to give the bottom color. The plastic waste is squashed and compressed into the PET bottle using the wood stick. While compacting, the bottle must be rotated and pressed down to ensure that the plastic waste is evenly compacted in the bottle [5]. The process is repeated until the bottle is filled completely with plastics and the ideal weight is reached. The weight of an eco-brick is calculated by multiplying the volume of the bottle with density of eco-brick. According to [6], the best quality of eco-bricks has a range of density from 0.33 g/ml to 0.7 g/ml. During the compaction process, other than weighing the eco-brick, the density of the bottle can also be determined by squeezing the bottle from the outside. Once the bottle is fully compacted, it is ready to be used.

1.2 Compressive Strength Test

Compressive strength is the ability of material or structure to carry the load on its surface without any crack or deflection [7]. Before the test is conducted, the area of bottle is identified and used to calculate the compressive strength. Then, the load is applied on the eco-brick and maintained until the test material fails to achieve the maximum load. The equation for this test is shown in Equation 1 below:

$$Compressive\ strength = \frac{Maximum\ load\ carried\ by\ specimen\ (N)}{Area\ top\ surface\ of\ specimen\ (mm^2)} \quad \text{Eq. 1}$$

Table 1 summarizes several conclusions from selected past researches on compressive strengths that use different types of waste materials.

Table 1: Selected studies on compressive strength

Products:	Types of waste materials	Research findings	Sources
Bottle brick	Fine sand	When the size of plastic bottle increase, the compressive strength also increase.	[8]
Coal ash brick	Coal ash	When the amount of coal bottom ash increase, the compressive strength also increase.	[9]
Concrete cube	Cigarette butts	When the content of cigarette butts decrease, the compressive strength also decrease.	[10]

1.3 Drop test

Drop test is a test that measures the ability of the object to withstand a specific amount of physical impact by dropping it from a given height onto a standardized hard surface such as cement. However, impact resistance is often poorly referred to as impact strength. In fact, impact strength refers to a force and impact resistance of an energy that required to break the sample in two or more pieces. For example, elongation to break, impact resistance to any particles, voids or other inhomogeneities that act as flaws [11]. A summary of the selected past researches that have been carried out is shown in Table 2.

Table 2: Selected studies on drop test

Materials:	Research findings:	Sources
Plastic	When the height increase, the acceleration also increase.	[12]
Concrete	Shrinkage and expansion strain can reduce the level of stress during impact.	[13]
Plastic	The maximum impact force of 55N can cause damage to the test specimen.	[14]

1.4 Failure analysis

Failure analysis is a critical process in determining the physical root cause of problems. The process involves variety of observations, inspections and laboratory techniques. There are several techniques that can be used in performing failure analysis, namely: i) Failure Modes & Effects Analysis (FMEA); ii) Fault-Tree Analysis (FTA); and iii) Root Cause Failure Analysis (RCFA) [15].

In this study, RCFA technique is used because it is a simple process of identifying the root cause of a failure. By using the information from the RCFA analysis, corrective actions can be determined. Apart from that, it also can prevent future failure [16].

2. Materials and Methods

Five samples of eco-bricks, i.e. Sample A, Sample B, Sample C, Sample D and Sample E with different density ratios were prepared. The density ratio of every sample was 0.15 g/m3, 0.35 g/m3, 0.55 g/m3, 0.75 g/m3 and 0.95 g/m3 respectively. The physical and mechanical properties of an eco-brick were tested by using SolidWorks software version 2014. The SolidWorks 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 [17]. The tests involved are compressive test, drop test and failure analysis. The data obtained are recorded and analyzed by using Microsoft Excel. The flowchart of the research methodology is presented in Figure 1.

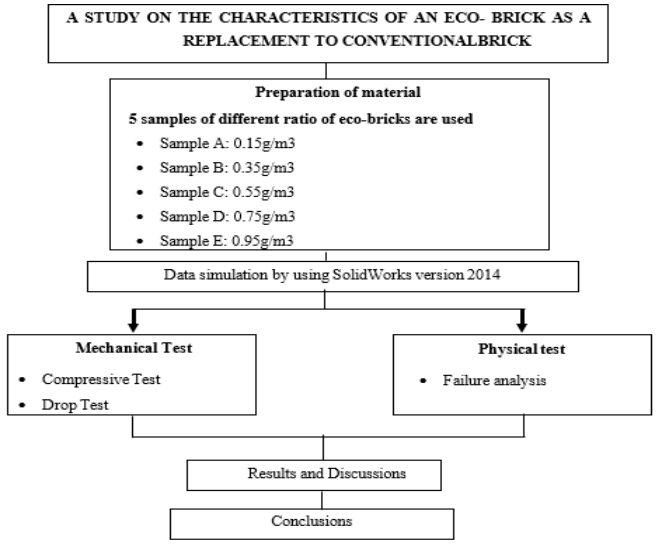

Figure 1: Flowchart of Research Methodology

3. Results and Discussion

3.1Compressive test

Table 3 shows the result of compressive test from the simulation analysis. The data indicated that samples with low density ratios have low value of compressive strength compared to samples with high density ratios. As the ratio of density increase, the value of compressive strength also increases.

Table 3: Results from compressive strength

No	Sample	Density	Load at failure (N/m^2)	Compressive strength (N/mm^2)
1	A	0.15	134.851	1.72
2	B	0.35	268.365	3.42
3	C	0.55	388.006	4.94
4	D	0.75	407.453	5.19
5	E	0.95	543.270	6.92

As shown in Figure 1, the higher the density ratio, the higher the compressive strength value. From the analysis, it can be concluded that eco-bricks with density ratio of 0.75 g/m^3 and 0.95 g/m^3 are suitable to be used as a replacement to the conventional brick. This is because based on JKR standard, the minimum permissible average compressive strength of sand brick is 5.2 N/mm2 [18]. A sample with high density is more durable and have better mechanical properties compared to the less dense sample. This is because sample with higher density ratio have less void [19].The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

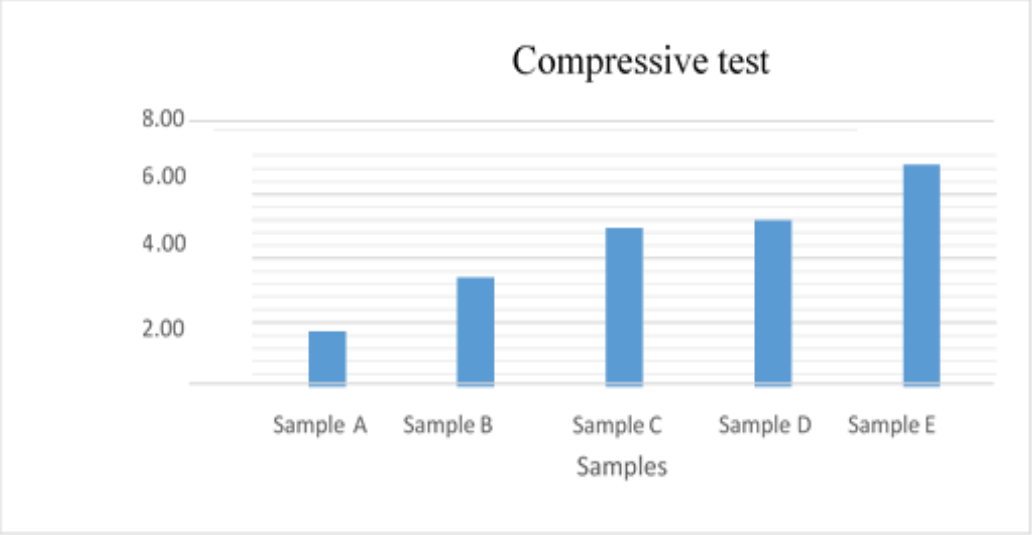

Figure 2: Compressive strength versus different density ratio of plastic bottle

In addition, results also revealed that the deformation value decreased when the density ratio of the sample increased (Figure 3). This is because when the value of stress increase, the value of strain also increases. The change of size is proportional to the force and depends on the substance from which the object is made. In a process deformation, a material can change its shape when a sufficient load is applied [20].

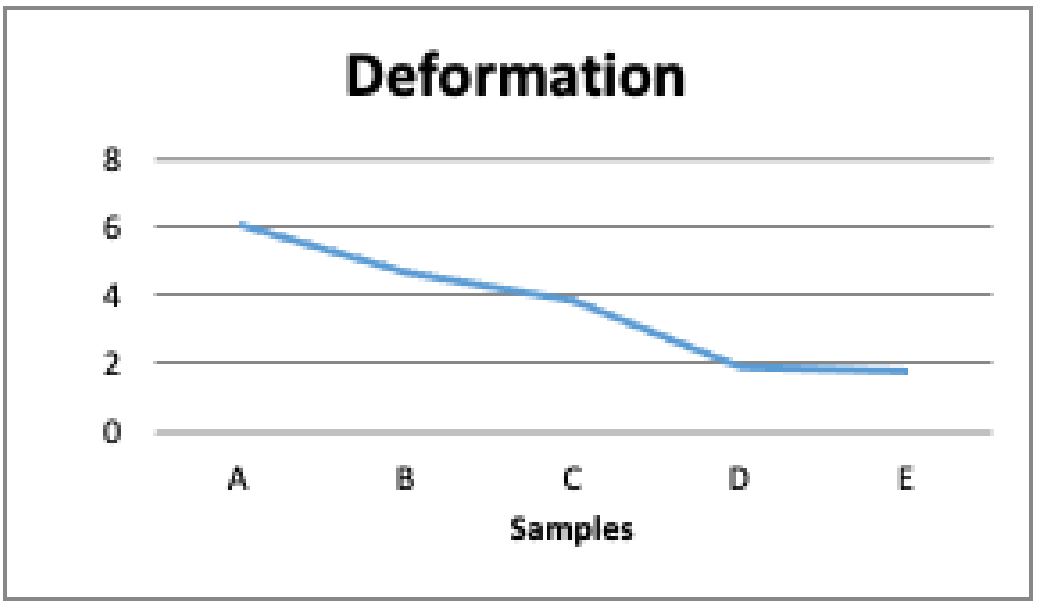

Figure 3: Different density ratio of samples versus deformation

3.1 Drop Test

Table 4 shows the data of eco-bricks with the lowest density ratio (sample A) to the highest density ratio (sample E). The samples were dropped from four different heights, i.e. 0.5 m, 1.0 m, 1.5 m and 2.0 m. The results revealed that the impact for all samples increase when the height increases. Sample A with the lowest density ratio had the lowest impact while sample E with the highest density ratio had the highest impact. This is because the density of sample can increase the impact. Other than that, the higher the drop height, the more damage it caused to the sample.

Table 4: Results from Drop Test

SAMPLES	DENSITY	DROP HEIGHT (m)	RESULT (N/ m²)
A	0.15	0.5	2.06256e+006
		1.0	3.06839e+006
		1.5	3.82186e+006
		2.0	4.45249e+006
B	0.35	0.5	5.91576e+006
		1.0	8.80976e+006
		1.5	1.09808e+007
		2.0	1.27988e+007
C	0.55	0.5	6.81469e+006
		1.0	1.01084e+007
		1.5	1.25741e+007
		2.0	1.46285e+007
D	0.75	0.5	1.5181e+007
		1.0	1.7211e+007
		1.5	2.13859e+007
		2.0	2.48593e+007
E	0.95	0.5	1.2353e+007
		1.0	1.83398e+007
		1.5	2.28102e+007
		2.0	2.65401e+007

3.2 Failure Analysis for Compressive Strength and Drop Test

After the compressive strength and drop test were conducted, the failure analysis was carried out. In this context, the failure analysis was carried out by observing the end-product of the samples from both the compressive strength and drop tests. From the compressive strength test results, in terms of failure analysis, it can be concluded that the lower the density ratio of an eco-brick, the higher is the damage made to the bottle. In addition, facture and buckling were more visible in eco-brick with low density ratio samples compared to the higher density ratio samples. This is because low density ratio samples cannot withstand the given load. Apart from that, due to less filler, low-density of eco-brick samples have more void compared to high-density eco-brick samples [21].

From the drop test results, in terms of failure analysis, from observation, it can be said that the stress wave moved from bottom to top before reflected back from the top surface to the bottom [22]. It was observed that eco-brick with higher density ratio samples were more ruptured compared to eco-brick with lower density ratio samples. This is because the impact made to the eco-brick depends on the density and drop height of a sample [23]. Therefore, it can be concluded that Sample E with the highest density ratio and at the highest drop height was the most ruptured compared to the other samples.

4. Conclusion

Overall, there are few conclusions that can be made from this study. Firstly, in terms of compressive strength test results, it can be concluded that the compressive strength value will be increased when the density ratio of eco-brick increase. In addition, the failure analysis indicated that as the density ratio of the sample is increased, the buckling and fracture made to the eco-brick were less visible.

Secondly, in terms of drop test results, it can be concluded that the higher the sample is dropped, the higher is the impact made to the eco-brick. Therefore, Sample E with the highest density ratio and at the highest drop height was the most ruptured compared to Samples A, B, C and D.

From the tests conducted, it can be concluded that samples D and E with density ratio of 0.75 g/m3 and 0.95 g/m3 respectively are suitable to be used as a replacement to the conventional bricks.

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