Multidisciplinary Applied Research and Innovation Vol. 3 No. 5 (2022) 1-9

MARI

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/mari
e-ISSN:2773-4773

The Innovation of Brick from Plastic Waste

Norfateha Ayu Ahmad Sapuan, Nur Athirah Batrisyia Ramli, Nur Kahirinah Mustapa, Nor Baizura Hamid*

Department of Civil Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, 84600 Pagoh, Johor, Malaysia

DOI: https://doi.org/10.30880/mari.2022.03.05.001
Received 15 July 2022; Accepted 30 November 2022; Available online 31 December 2022

Abstract : The use of plastic waste, polyethylene terephthalate (PET) is the main material in producing environmentally friendly bricks. As much as 15% of plastic PET is used in producing this Eco-Brick. Control concrete brick was used as the control sample in this study to determine the workability of this Eco-Brick. The objective of this study is to develop an environmentally friendly structure as an innovation. Thus, Eco-Brick was designed using SketchUp software into Lego shapes as a new innovation in structural work. Furthermore, tests of density, water absorption, and compressive strength were conducted on control concrete brick and Eco-Brick. This experiment was conducted to compare the best results with previous research papers and the American Testing and Materials Association (ASTM). Eco-Bricks had been classified into two types, T and R, based on their differences in mixing method. For type T, the heated plastic liquid was poured directly into the concrete mixture, while for type R, the heated plastic liquid was set aside to harden into plastic clumps before being crushed into small pieces and mixed with the concrete mixture. The results for the density test for control concrete bricks were 2791.7 kg/m3, while type T was 2052.1 kg/m3 and type R was 1958.4 kg/m3, respectively. For the water absorption tests of control concrete bricks, type T and type R, the results were 2.83%, 3.23%, and 1.62%. The compressive strength values for control concrete bricks, type T, and type R bricks were 425.4 MPa, 440.4 MPa, and 356.4 MPa. Except for the density test results on type R bricks, all brick tests pass the American Society for Testing and Materials (ASTM C90, ASTM C129 and ASTM C55). This indicates that type T Eco-Bricks have effective workability.

Keywords: Plastic Waste, Polyethylene Terephthalate, Eco-Bricks, SketchUp, Polymer

1. Introduction

Plastic is made up of polymer compounds and plays a vital role in this period because of its flexibility, robustness, and rigidity [1]. The extensive use of plastic in practically every aspect of life, consisting of industrial packaging, electrical and electronics, food, construction, agriculture and more, has resulted in a massive amount of plastic waste. Despite its various uses, plastic is also a hazardous material to the environment since it cannot disintegrate naturally and will obstruct sustainability efforts

Corresponding author: norbaizura@uthm.edu.my

for more than a century [2]. Plastic waste can seep into soil and have an impact on fertility, while if it is dumped into the sea, aquatic life and the quality of seawater can be contaminated. It can release harmful and toxic gases if it is deposited through a burning technique. Reuse and recycle are applied to minimise the effect on human health, animals and the environment by utilising waste plastic in brick manufacturing. The use of plastic waste can improve environmental sustainability and is considered a reliable building material [3]. The application of bricks in the construction industry is in line with the current rate of urbanization. Urbanization denotes an increase in the population, which corresponds to a high demand for plastic materials [4]. An innovation in bricks made from plastic waste has been produced where natural coarse aggregate is replaced with crushed polyethylene terephthalate (PET) bottles in shredded form [5]. To facilitate construction and enhance a building's wall structure, Lego-shaped bricks have also been developed. It has grown in popularity in the construction industry, as evidenced by the work of well-known eastern and western architects who use prefabricated components and on-site assembly to reduce construction difficulty and increase construction efficiency and renewal [6].

The objective of this study is to develop an eco-friendly brick structure as an innovation using plastic waste with the type of polyethylene terephthalate (PET) as its main substance. The second objective is to demonstrate how to construct environmentally sustainable structures by making a simulation of Eco-Lego brick from plastic waste using SketchUp software. The outcome of this study is to encourage people to use eco-friendly bricks in construction to preserve our mother nature. Next, is to manifest environmentally sustainable structures to developers or builders through a simulation, so they may gain a better understanding of this new invention and better insights into the work of the system.

2. Materials and Methods

The methodology of this study presents the necessary flow of work that is required to achieve this study's objectives. It had been carried out according to the flowchart presented below in **Figure 1**.

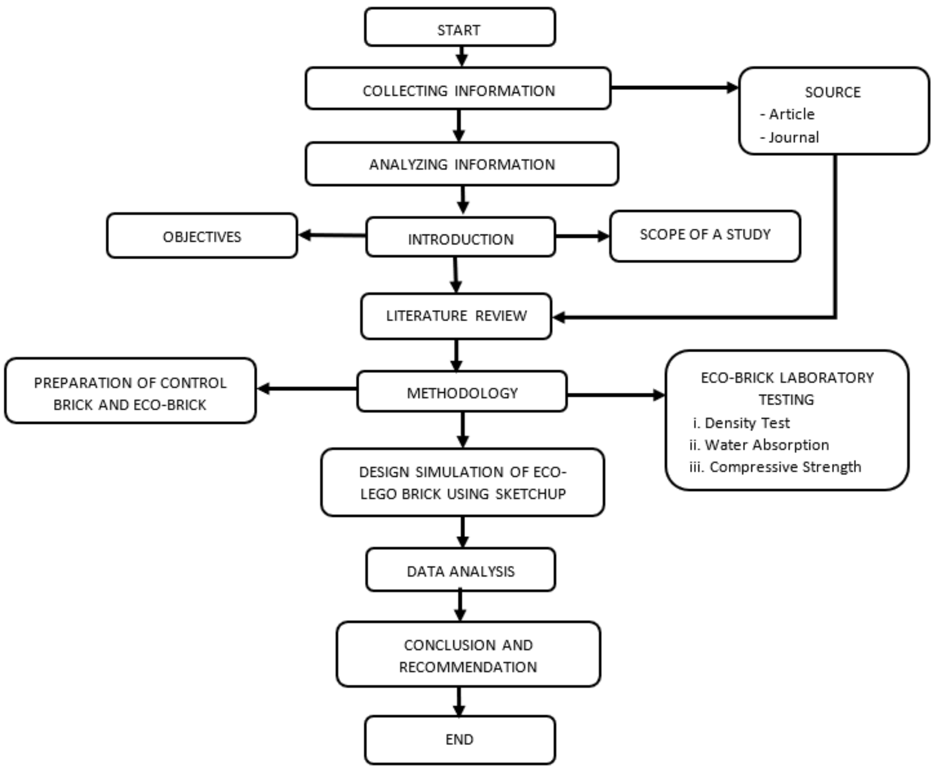

Figure 1: Flowchart of the study

2.1 Materials

The material used in this study to make the control bricks and Eco-Bricks consists of water, cement, aggregates, sand, and an additional substance, plastic waste. Ordinary Portland Cement (OPC) was utilised as the cement, and gravel that was retained on a screen size of 10 mm was employed as the aggregates. In this study, coarse sand was also used. A type of polyethylene terephthalate (PET) was chosen as the plastic waste from useable water bottles. Each of the produced bricks was 22 cm in length, 11 cm in width, and 6.5 cm in height. **Figure 2** shows the mould that was used to cast the bricks. With the concept of designing this Eco-brick into a Lego shape, a graphic software called "SketchUP" has been used to stimulate the design.

Figure 2: The mould used to cast control bricks and Eco-Bricks

2.2 Methods

This sub topic explain the methods carried out in this study. It consists of design mix testing, laboratory testing and design simulation of Eco-Lego Bricks.

2.2.1 Design Mix Testing for Control Bricks and Eco-Bricks

The concrete mixture for both control bricks and Eco-bricks were based on a ratio of 1: 2: 4, with 1 representing cement, 2 for fine aggregates (sand), and 4 for coarse aggregates. The mass of plastic added to the concrete mixture to create an Eco-brick was 15 % of the 0.67 kg of cement mass. Based on previous research [1], the percentage had been proven as the most suitable percentage in creating a strong Eco-brick. The produced control bricks were labelled as specimens 1, 2, and 3, whereas the produced Eco-Bricks had been classified into two types, T and R, based on their differences in mixing method. For type T, the heated plastic liquid was poured directly into the concrete mixture, while for type R, the heated plastic liquid was set aside to harden into plastic clumps before being crushed into small pieces and mixed with the concrete mixture.

There were a total of nine specimens, three of control bricks, three of type T and three of type R, which are presented in **Table 1**. The total material and mass for control bricks and Eco-Bricks types T and R is shown in **Table 2**. **Figure 3** shows the produced specimens of Eco-bricks.

Table 1: Mix design for control, Eco-Bricks Type T and Type R

Specimen	Water to cement ratio (w/c)	Water (mL)	Cement (kg)	Coarse Aggregate: (10 mm) (kg)	Fine Aggregate Sand (kg)	Plastic Waste (PET) (kg)
1	0.5	0.33	0.67	2.67	1.33	0
2	0.5	0.33	0.67	2.67	1.33	0
3	0.5	0.33	0.67	2.67	1.33	0
T1	0.5	0.33	0.67	2.67	1.33	0.1
T2	0.5	0.33	0.67	2.67	1.33	0.1
T3	0.5	0.33	0.67	2.67	1.33	0.1
R1	0.5	0.33	0.67	2.67	1.33	0.1
R2	0.5	0.33	0.67	2.67	1.33	0.1
R3	0.5	0.33	0.67	2.67	1.33	0.1
Total	4.5	2.97	6.03	24.03	11.97	0.6

Table 2: Total material and mass for control bricks and Eco-Bricks of type T and R

Material	Mass
Water (mL)	2.97
Cement (kg)	6.03
Aggregates 10 mm (kg)	24.03
Sand (kg)	11.97
Plastic waste (PET) (kg)	0.6

Figure 3: Produced specimen of Eco-Bricks

2.2.2 Laboratory Testing

Laboratory testing consists of Water Absorption test and Compressive Strength test, which have been conducted to prove the quality, strength, and effectiveness of control bricks and Eco-Bricks. The density and water absorption tests were carried out by soaking the bricks in water for 28 days, following which they were weighed and measured for length, width, and height. The density test acted as a parameter to obtain the mass and volume for each specimen. In a water absorption test, the dry mass of the specimen and the mass after it was cured were taken to determine its water absorption percentage. The compressive strength test was performed using a Universal Testing Machine (UTM), with the cross-sectional area of the brick in indirect plane contact with the load, and the area of the applied load divided by its maximum load. Compressive strength is one of the parameters used to assess a material's strength and capacity to withstand a force until it cracks or breaks [7].

2.2.3 Design Simulation of Eco-Lego Brick using 'SketchUp'

A software called "SketchUp" has been utilised to design the Eco-brick into a Lego shape, which was inspired by a Lego. A three-dimensional Lego shaped brick has been designed and stimulated successfully using this software due to its easy handling tools, movement capabilities, and variation of colours and textures.

3. Results and Discussion

All of the necessary data and results were obtained through laboratory testing, which included density, water absorption, and compressive strength tests. In order to facilitate understanding of this study, the results were illustrated in tables.

3.1 Density

According to **Table 3**, the average density for control concrete bricks is 2791.7 kg/ m³. The average density value for Eco-Brick, on the other hand, is classified into two types: T and R. Type T has an average density of 2052.1 kg/ m³, whereas type R has a density of 1958.4 kg/ m³. The average density of the control concrete brick was the highest of all the values obtained.

Table 3: Density for control concrete brick

Specimen	Density (kg/m³)
1	2875.0
2	2718.8
3	2781.3
Average	2791.7

The proportion of Eco-Bricks types T and R after curing is shown in **Table 4**. According to the data, the average density of type T is greater than that of type R. The density of common weight concrete is between 2,000 kg/m³ and greater, according to ASTM C90. The average density value of type T Eco-Brick exceeds the concrete brick's minimum density value.

Table 4: Density for Eco-Bricks Type T and Type R

Specimen	Density (kg/m³)
T1	2125.0
T2	1812.5
T3	2218.8
Average	2052.1
R1	1968.8
R2	1968.8
R3	1937.5
Average	1958.4

3.2 Water Absorption

Table 5 explains how to use the specific formula to calculate water absorption for control concrete brick. With a value of 1.83%, specimen 1 had the highest water absorption, while specimen 3 had the lowest. The average water absorption rate of a control concrete block is 2.83%. The average water absorption value of the control concrete brick met the ASTM standard value.

Table 5: Formula used to calculate the water absorption for control concrete brick

Specimen	Water Absorption (%)
1	4.55
2	2.11
3	1.83
Average	2.83

The water absorption values for Eco-Bricks Type T and R are shown in **Table 6.** The formula for calculating water absorption was presented in the table. Type T has an average value of 3.23%, whereas Type R has an average value of 1.62%. Both types of findings, however, are acceptable because they absorb less than 12% of the water. According to ASTM C90-11 and ASTM C129-11, water absorption in brick should be less than 12%.

Table 6: Formula used to calculate the water absorption for Eco-Bricks type T and R

Specimen	Water Absorption (%)
T1	3.03
T2	3.57
T3	2.90
Average	3.23
R1	1.61
R2	1.61
R3	1.64
Average	1.62

3.3 Compressive Strength

Table 7 displays the control concrete brick's compressive strength. The control concrete brick has an average compressive strength of 425.4 MPa, which is higher than the required minimum value.

Table 7: Compressive strength for control concrete brick

Specimen	Compressive Strength (MPa)
1	906.7
2	107.3
3	262.3
Average	425.4

The average compressive strength value for each kind of Eco-Bricks, types T and R, is determined using **Table 8**, in which each type contains three samples. The average value for type T and type R both surpassed the minimum compressive strength. According to ASTM C55-11, the minimum compressive strength value for a three-unit sample is 17.2 MPa. Type T has the highest compressive strength. This shows that Eco-Bricks are made to support heavier loads than standard concrete bricks. Referring to Ikechukwu and Shabangu [8], the value of compressive strength is directly related to the percentage of plastic in the block. The higher the percentage of plastic, the higher the compressive strength of the block. This statement is proven based on the results in **Table 4**.

Table 8: Compressive strength for Eco-Bricks type T and R

Specimen	Compressive Strength (MPa)
T1	314.2
T2	607.0
T3	400.1
Average	440.4
R1	67.0
R2	553.1
R3	450.5
Average	356.9

According to previous research [9], the compressive strength of concrete mixed with plastic would be reduced due to the low binding strength between cement and plastic. In contrast, the results improved because the plastic bottles (PET) were heated after being shattered into flakes, as compared to previous studies in which the plastic flakes were simply thrown into the concrete mixture without being heated. The melted plastic flakes will make it simpler for the cement and plastic elements to combine and produce a strong bond.

3.4 Simulation of Eco-Lego Brick using SketchUp

Initially, Lego was mainly used as a child's play that might stimulate mental creativity and intelligence. Building Lego creations is a popular activity among children of all ages all across the world. The amount of ways a set of distinct Lego bricks may be combined into a Lego creation is enormous, allowing for a lot of creativity [10].

SketchUp is a 3D modelling software used for architecture, interior design, industrial and product design, landscape architecture, civil and mechanical engineering, and more. This application was used to simulate the research of 'Simulation of Eco-Lego Bricks from Plastic Waste' to demonstrate drawings for the Lego forms that were developed. This software can display and explain an image of a brick listing from one brick to a wall. The bricks are rectangular in shape, measuring 25 cm in length, 12 cm in width, and 6.5 cm in height. The round shape used to connect the bricks measures 4 cm in diameter and 2 cm in height. **Figure 4** shows the shape of a Lego brick from the front view and the bottom view.

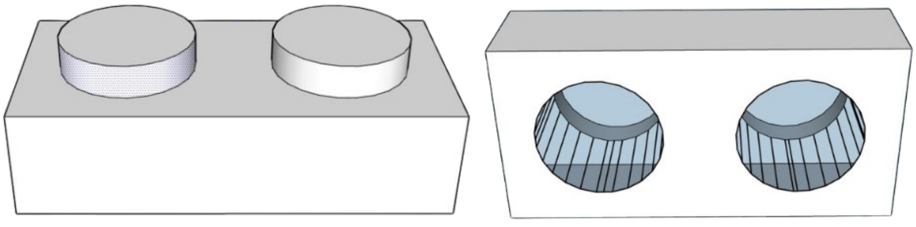

Figure 4: The shape of a Lego brick

As seen in the figure above, there are two circles that connect one brick to another. These bricks are designed in the shape of a Lego brick to simplify and save employees time when building the bricks into a wall. This Lego brick is not only more appealing than conventional bricks, but it is also stronger due to the value of the junction between one brick and another. The joints between the bricks become stronger as a result of their Lego form, as they are characterised as gripping one other. To connect one Lego brick to another, cement is still required as adhesive. **Figure 5** represent an overview of the brick arrangement meanwhile **Figure 6** shows the combination of one brick with other bricks.

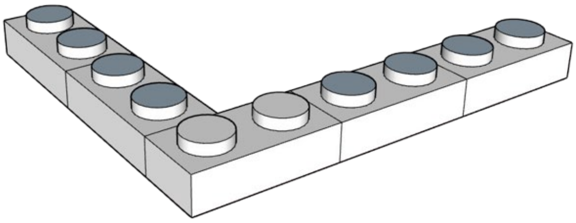

Figure 5: Overview of the arrangement of the brick

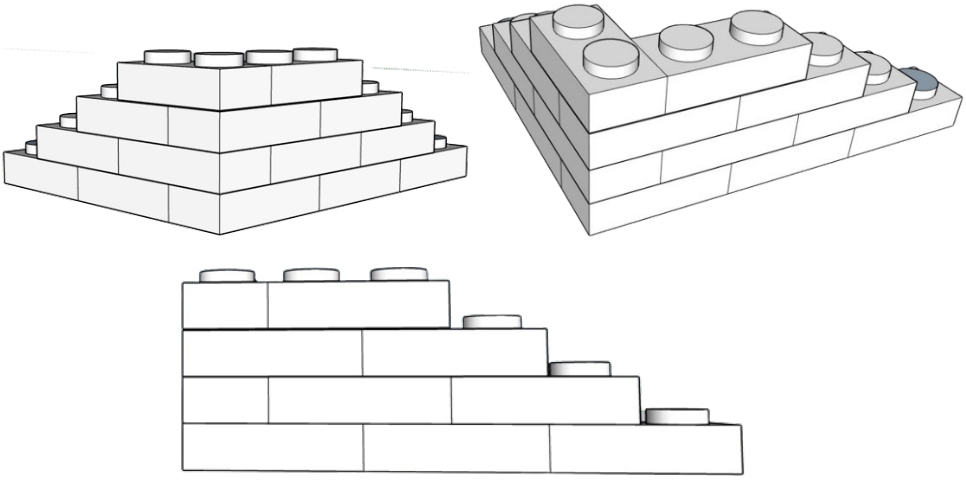

Figure 6: Combination of one brick with other bricks

Last but not least, the major benefit of this Eco-Brick in the shape of a Lego is that it simplifies masonry work. This can be attributed to a decrease in the quantity of energy and manpower required for masonry work. As a result, the number of employees needed to complete a construction job will be lowered. Therefore, the Eco-brick in a Lego shape was an affordable alternative for construction as it was less expensive than conventional bricks and could lower the cost of hiring construction workers and it also has an attractive and beautiful aesthetic value. This will make a building look stately and aesthetically pleasing.

4. Conclusion

Overall, the conclusion that can be drawn is that the objective was successfully achieved. Three types of testing were performed for control concrete bricks and Eco-Bricks according to the percentage that had been selected. Each type of brick consists of three samples. The tests are evaluated using the average results. The first test is a density test. The result for control concrete brick is 2791.7 kg/ m^3, while type T is 2052.1 kg/m^3 and type R is 1958.4 kg/ m^3, respectively. The results show that control concrete bricks and type T brick exceed the minimum value of density for concrete bricks. Next is the water absorption test. For control concrete bricks, types T and R, the results were 2.83%, 3.23%, and 1.62%. All the values for the bricks have passed the water absorption level test, with the proportion of the water absorption not exceeding 12%. The compressive strength of the produced bricks is the last test. The values for control concrete bricks, type T and type R bricks were 425.4 MPa, 440.4 Mpa, and 356.4 Mpa. The results show that all three bricks have passed the minimum compressive strength level. An observation that can be made from the whole experiment is that type T are suitable Eco-Bricks to be used as examples of effective Eco-Bricks. The utilization of SketchUp software to stimulate the Eco-Lego Brick had been redeemed as successful. The design of Lego shape enables the bricks to grip into each other more firmly and this new innovation of bricks in conserving and protecting the environment had proven that all project goals had been achieved.

Acknowledgement

The authors would like to thank the Centre for Diploma Studies (CeDS), Universiti Tun Hussein Onn Malaysia for their support. In addition, a heartfelt thank you to all team members for their dedication to the project and mutual support in making it a success.

References

[1] Journal, I., Bhushaiah, R., Mohammad, S., & Rao, D. S. (2008). IRJET-Study of Plastic Bricks Made From Waste Plastic Study of Plastic Bricks Made From Waste Plastic. International Research Journal of Engineering and Technology, 1122. www.irjet.net

[2] Vigneshwar, P. V., Anuradha, B., Guna, K., & Ashok Kumar, R. (2021). Sustainable eco-friendly fly ash brick using soil filled plastic bottles. Materials Today: Proceedings, xxxx, 7–9. https://doi.org/10.1016/j.matpr.2021.03.573

[3] Tempa, K., Chettri, N., Thapa, G., Phurba, Gyeltshen, C., Norbu, D., Gurung, D., & Wangchuk, U. (2021). An experimental study and sustainability assessment of plastic waste as a binding material for producing economical cement-less paver blocks. Engineering Science and Technology, an International Journal, xxxx. https://doi.org/10.1016/j.jestch.2021.05.012

[4] Kognole, R. S., Shipkule, K., & Survase, K. S. | M. P. | L. P. | U. (2019). Utilization of Plastic waste for Making Plastic Bricks. International Journal of Trend in Scientific Research and Development, Volume-3(Issue-4), 878–880. https://doi.org/10.31142/ijtsrd23938

[5] Shakir, A. A., Wan Ibrahim, M. H., Othman, N. H., Ahmed Mohammed, A., & Burhanudin, M. K. (2020). Production of eco-friendly hybrid blocks. Construction and Building Materials, 257, 119536. https://doi.org/10.1016/j.conbuildmat.2020.119536

[6] Chen, D., Wang, G., & Chen, G. (2021). Lego architecture: Research on a temporary building design method for post-disaster emergency. Frontiers of Architectural Research, 10(4), 758–770. https://doi.org/10.1016/j.foar.2021.08.001

[7] Indra, A., Edison, E., & Nofrianto, H. (2018). Optimization of compaction pressure on brick. MATEC Web of Conferences, 215, 1–5. https://doi.org/10.1051/matecconf/201821501025

[8] Ikechukwu, A. F., & Shabangu, C. (2021). Strength and durability performance of masonry bricks produced with crushed glass and melted PET plastics. Case Studies in Construction Materials, 14, e00542. https://doi.org/10.1016/j.cscm.2021.e00542

[9] Jaivignesh, B., & Sofi, A. (2017). Study on Mechanical Properties of Concrete Using Plastic Waste as an Aggregate. IOP Conference Series: Earth and Environmental Science, 80(1). https://doi.org/10.1088/1755-1315/80/1/012016

[10] Kollsker, T., & Stidsen, T. J. R. (2021). Optimisation and Static Equilibrium of Three-Dimensional LEGO Constructions. In Operations Research Forum (Vol. 2, Issue 2). Springer International Publishing. https://doi.org/10.1007/s43069-021-00062-3