Investigating the Utilisation of Plastic Bottle as Aggregate Replacement for Concrete Block

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Abstract. Concrete block plays an important role in the construction industry. Concrete blocks have been used in the making of various buildings, retaining wall and others. In this modern era, various technologies have been presented and invented in order to upgrade the life quality of mankind. Unfortunately, there are some technologies that bring bad consequences to the environment. For instance, the production of cement will contribute to a high emission of bad gases such as carbon dioxide that may be harmful to human’s health. The manufacturing of cement is also emits hazardous fumes and dust that potentially can reduce the quality of air and lead to many respiratory problems. Therefore, the main objective of this paper is to search for a new alternative way to cope with this environmental problem. Plastic bottles such as Polyethylene terephthalate (PET) was used as the main component in construction of concrete blocks. After curing the blocks for 28 days, compression test and flexural test were prepared to test the ultimate strength of these concrete blocks. From both tests, it shows that bottle blocks were qualified to replace concrete blocks in walls as the maximum stress achieved by bottle blocks were higher than the minimum permissible compressive strength and flexural value. From these results, it can be concluded that plastic bottle has a potential to replace the current concrete blocks and further study about its other properties, such as lifespan and water cement ratio should be carried out.

1. Introduction

In this modern era, the innovation in science and technology are getting more competitive through new researches. As the result, the production of equipment in medical, industry, agriculture, information technology will be cost-saving and at the same quality or even better. Plus, the technology of polymer-based products are increased resulting from the new researches thus making the production of plastics more effective and good quality compared to the usual materials.

Nowadays, plastic-based products are getting more demand in many industries to produce their own products. Apart from that, the disposal of plastics is also getting serious and there are still no solutions yet to cope with this matter.

Therefore, it is essential for us to find and search for new alternatives to reuse plastics in a good way to prevent the environment from pollution. Plastic bottles need a large portion of area to undergo
decomposition which means a larger site or landfill is needed. However, the price for gaining a property is way too expensive and because of that, plastic bottles are recommended to be reuse rather than been thrown away or disposed.

Disposed plastic bottles can harm the environment and not to forget, humans’ health. Plus, plastic bottles disposed in the drain or small channels potentially can clog the channels thus resulting in flash floods that may cause loss of life and damaging valuable properties. Apart from that, the disposal of plastic bottles in rivers and sea can danger the natural ecosystem especially in the water.

The reuse and recycle programs in terms of plastic bottles have been actively organized by many societies as these are the most cost-saving and relatively effective. Besides that, recyclable materials can be used in many industries to produce something new with new and various functions as well as saving the energy. There are many materials that can be recycled for instance, old tires, rubber, waste products and others. This paper will prioritized the usage of plastic bottles for recycle and reuse in the production of concrete in construction.

2. Background of study
Polyethylene terephthalate (PET) is one of the most common thermoplastics resin of polyester used for various type of products mainly packaging. PET recycling consists in the transformation of bottles through two different kinds of processes which firstly is mechanical process which the most employed physical process to recycle PET. It consist three stages that include separation, washing, and grinding of containers. With this process, PET flakes produced can be directly employed without the need of being reprocessed as pellets in the creation of products by injection or extrusion.

Secondly, PET is recycled using chemical process consists of the separation of the basic components or monomers. The methanolysis, glycolysis, and hydrolysis are the elemental processes to achieve this transformation. Both ways are expensive and there are other alternative way to recycle PET materials which is using them as substitute of concrete aggregates. Due to demands of technological development in the construction area, the possibility for generating alternative materials that can be applied with increasing functionality, low costs, and better physical, chemical, and mechanical properties than conventional materials [1].

Concrete is a composite materials which mainly use in various type of construction. It made of cement, coarse and fine aggregate, sand and water. There are various type of admixture that can be use in concrete to increase its strength or to speed up productivity. The quality of concrete depends on type of materials use, mixture, transportation and compaction [2].

Generally blocks applied with PET, due to its lightweight structures compared to normal concrete blocks it will give less stress or load to the foundation thus engineer can designed more economical foundation due to less stress or load. Moreover, blocks applied with PET reduce volume of mixture which less labor needed because the mixture is lighter and also the cost of transportation can be reduce. Another feature for blocks applied with PET are good sound insulation and better shock absorption [3].

3. Materials and method
Firstly, 80 pieces of 500mL plastic bottles are filled with sand and compacted using iron rod. Formworks were cleaned and brushed with oil or grease to prevent the concrete from stick at the formwork surface during extraction. The mixture of concrete was poured into the formwork with three layers and compressed using a steel rod at 25 times. Cube and concrete cuboid was left for 24 hours before extraction from the formwork.

The size of concrete block was 440mm x 215mm x 100mm. Concrete blocks were tested for compression and deflection test after curing in water for 28 days. Figure 1 shows samples of concrete blocks after 28 days of curing period. There are 12 blocks produced for this study as shown in Table 1.
Curing is the process to avoid the water content in the concrete evaporate quickly by hot weather. The concrete should be put in a damp at least 14 days after it harden. Rather the purpose is to show that high-performance concrete has to be water cured as early as possible, late curing is of partially no value, but is still better than no curing at all, total shrinkage can be drastically reduced by appropriate early water curing and no water curing at all can be catastrophic [4].

Compressive strength test was carried out to obtain the strength of the concrete sample. This test is performed by BS 5628: Part 1: 1992 [5]. Sample used are concrete sample that had reached the age of 28 days. The main factors affecting the strength of concrete is the number of honeycomb are left in the concrete, the strength will reduced if the concrete more compressible. Therefore, it is imperative that concrete is made as dense as possible. Concrete strength also increases with age, but the rate increases is greatly affected by proper curing methods. Ideally concrete stored in humid conditions to allow the cement hydration occurs properly. Compressive strength is a more highly utilized parameter in the cement and concrete industries than are elastic modulus. [4].

Table 1. Type of block concrete produced

| Type of block | Description           | Diagram (mm) |
|---------------|-----------------------|--------------|
| A             | Single vertical       | ![Diagram](image) |
| B             | Double vertical       | ![Diagram](image) |
| C             | Horizontal            | ![Diagram](image) |
| S             | Standard              | ![Diagram](image) |
4. Results and discussion
Table 2 showed the results from compression and deflection tests. The ordinary concrete block is acted as control sample to be compared with the bottle concrete blocks. From the compression strength test, the maximum stress that can be achieved by control sample, single vertical bond, double vertical bond and horizontal bond were 12.2 N/mm², 6.4 N/mm², 9.4 N/mm² and 4.3 N/mm² respectively. Among the three bottle blocks, the double vertical bond have the highest value of stress that can be achieved.

According to BS EN 771-3 [6], the minimum permissible average compressive strength shall be 7.3 N/mm² for 440mm x 215mm x 100mm solid concrete blocks. Therefore, this can prove that bottle blocks are qualified as wall materials to replace standard masonry as its compressive strength exceed the minimum permissible compressive strength. This prove that bottle concrete blocks are potentially in replacing standard blocks or masonry in wall.

Besides that, according to ASTM C293 [7], the standard flexural strength of concrete block is 5.5 N/mm². The single vertical bond, double vertical bond and horizontal bond can exert 5.02 N/mm², 4.21 N/mm² and 5.7 N/mm² of flexural strength respectively. In terms of flexural strength, only horizontal bond has exceed the standard value. Therefore, this can prove that bottle blocks are qualified as wall materials to replace standard masonry as its compressive strength exceed the minimum permissible compressive strength.

Table 2. Results from compression and deflection tests

| Types | Compressive Strength (N/mm²) | Flexural Strength (N/mm²) |
|-------|-----------------------------|--------------------------|
| A     | 6.4                         | 5.02                     |
| B     | 9.4                         | 4.21                     |
| C     | 4.3                         | 5.7                      |
| S     | 12.2                        | 5.5                      |

5. Conclusions
In a nutshell, the application of plastic bottles filled with sand as retaining wall or other wall structures to replace bricks and concrete blocks in the construction industry is acceptable as the strength is over the minimum permissible strength of British Standard and the flexural strength was according to ASTM C293. In terms of compressive strength, the double vertical bond have the highest value of strength. In the terms of flexural strength, the horizontal bond have the highest value of flexural strength. On the other hand, the plastic bottle have the ability to replace standard concrete blocks in Malaysia’s buildings in the terms of saving budget and conserve the natural environment. The water cement ratio was 0.50 and the moisture content was 0.30. Besides that, the ratio of concrete mixture is 1:2:4 and the results are obtained. Hence, a research on the optimum ratio of the mixture should be carried out to obtain the strongest concrete.
Acknowledgements
The author would like to thank the Office of Research, Innovation, Commercialization and Consultancy (ORICC), UTHM, for supporting this research.

References
[1] L. Á. Córdoba, G. M. Barrera, C. B. Díaz, F. U. Nuñez, and A. L. Yañez 2013 Effects on Mechanical Properties of Recycled PET in Cement-Based Composites (International Journal of Polymer Science)
[2] N. A. Abdulla 2014 Effect of Recycled Coarse Aggregate Type on Concrete (J. Mater. Civ. Eng.)
[3] S. Chowdhury, A. T. Maniar and O. Suganya 2013 Polyethylene Terephthalate (PET) Waste as Building Solution (International Journal of Chemical, Environmental & Biological Sciences (IJCEBS)), vol 1
[4] P. Klieger and J. F. Lamond 1994 Significance of tests and properties of concrete and concrete-making materials (American Society For Testing And Materials (ASTM): Philadelphia)
[5] British Standard Institution 2003 BS 5628 Part 1, Structural use of unreinforced masonry (London-BSI)
[6] British Standard Institution 2003 BS EN 771-3, Specification for masonry units: Aggregate concrete masonry units (UK-BSI London)
[7] ASTM 2007 ASTM C293/C293M–10: Standard Test Method for Flexural Strength of Concrete (American Society for Testing and Materials)