Comparative Evaluation on the MOE between EN, BS and ASTM of Concrete Containing PET

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Abstract. The wide use of plastic bottles has led to a drastic increase in the disposal of plastic bottles. Reusing waste plastic bottles in concrete may be beneficial to the environment and help ensure economic viability at the same time. Previous researchers had investigated the application of waste materials in the construction field by using polyethylene terephthalate as one of the solutions to address this environment threat. In this research, the aim of the study is to investigate the modulus of elasticity of concrete material incorporated with polyethylene terephthalate. To achieve the objective of the study, the modulus of elasticity test was conducted to determine the Modulus of Elasticity (MOE). A comparison of MOE between Eurocodes (EC), British Standard (BS) and American Society for Testing and Materials (ASTM) Standards was conducted. At the end of this study, the value of modulus of elasticity resulting from the plastic bottle concrete material was expected to be classified as the same category as common concrete. Besides, the plastic bottle concrete material was also expected to possess similar properties as other conventional materials. Optimistically, the results of this research resulting from the MOE concrete plastic bottles that are not classified as a similar category as conventional concrete recorded a difference of 4.26% to 59.29%. It can be concluded that shred plastic bottles have a lower feasibility and do not have the potential to be used in concrete mixes.

1. Introduction

In this era of modernization, the advancement of science and technology is increasingly vibrant with the emergence of new research. Polymer-based technology is increasing with recent researches resulting in the production of high quality plastic materials. Although the plastic-based products are increasingly on the market and widely used, the use of plastic materials has led to excessive plastic quantities and it still no effective solution to eliminating this waste material without polluting the environment. Therefore, there are several other alternatives to reuse this wasted material and to avoid further contaminating the environment.

Plastic bottles are used more commonly known as ‘Polyethylene terephthalate or PET bottles’ are increasingly used in construction work. PET bottles are also suitable for use with other beverages and durable [1]. Various waste materials can be recycled such as tires, plastic, waste residues and so on. Removal of plastic bottles using waste incinerators cause environmental pollution with the release of carbon gases derived from plastic bottle burning. In addition, there is the same process of pyrolysis, in
which plastic bottles or plastic materials are processed into re-oil. Both combustion and pyrolysis processes are more expensive than the recycling and uneconomical processes.

This report will focus on the use of plastic bottles to be recycled and used in concrete for the construction work. Reuse of waste plastic bottles in the concrete may have two environmental advantages and at the same time ensure economic viability. In this case, an attempt can be made to control environmental pollution and to save natural resources by using plastic bottles disposed in cement concrete [2]. Further testing and investigations are needed to determine the suitability used for concrete production in the construction industry. Therefore, this study relates to sustainable development due to the use of waste, plastic bottles to produce concrete in construction. Therefore, waste plastic bottles are recycled to replace the fine aggregate into the concrete. With this study, concrete plastic bottles can be compared with that of normal concrete in terms of strength and modulus of elasticity. As a result of the study, it is to decide that concrete plastic bottles are suitable for use in a construction.

2. Material and Procedure

2.1. Material preparation
In this research, the materials used included Ordinary Portland Cement Type 1 (OPC: Type 1) which was based on MS EN 197-1:2014 with a grade of 42.5 N, Fine Aggregates (FA) size of (0.075-5) mm, Coarse Aggregates (CA) size of (5-20) mm, Superplasticizers (SP), water and recycled PET fibers with 50 mm long and 5 mm width.

2.2. PET fiber preparation
Before being cut into fiber form, polyethylene terephthalate (PET) plastic bottles were collected and cleaned. The recycled PET plastic bottles were collected from areas around Universiti Tun Hussein Onn Malaysia and residential colleges located at Taman Universiti. The process of collecting the plastic bottles took around one month. After the bottles were collected, they were cleaned and dried to get rid of any impurities. Finally, the recycled PET pieces were cut into the desired size and shape which was 50 mm in length and 5 mm in width. On the Figure 1 (a) to Figure 1 (d) show the steps of cutting the PET bottles into desired fibers.

![Figure 1. The preparation of recycled PET fibers: (a) Collecting the recycled PET plastic bottles, (b) Cleaning and drying the recycled PET plastic bottles, (c) Cut recycled PET bottles into smaller pieces, (d) Cut the recycled PET pieces into desired size and shape.](image)

2.3. Mix Design
The process that conducted to selected the most suitable ingredients of concrete and to determine their relative quantities to achieve the desired strength is mix design. In this study, the concrete proportioning was designed using the Concrete Mix Design Form Table 1 and Trial Mix Table 2 shows the proportion of the materials needed in this study based on DOE method.
Table 1. Concrete Mix Design Form

| Stage | Item                              | Value                          |
|-------|-----------------------------------|-------------------------------|
| 1     | 1.1 Characteristic Strength       | 30 MPa at 28 days             |
|       | 1.2 Standard Deviation            | Proportion defective 5%       |
|       | 1.3 Margin (k = 1.64)             | 8 MPa                         |
|       | 1.4 Target Mean Strength          | 1.64 x 8 = 13.12 Mpa         |
|       | 1.5 Cement Type                   | 30 + 14 = 44 Mpa             |
|       | 1.6 Aggregate Type: Coarse        | OPC                           |
|       | Aggregate Type: Fine              | Un crusher                    |
|       | 1.7 Free Water/Cement Ratio       | 0.48                          |
| 2     | 2.1 Slump or Veb Time             | Slump 50 -100 mm              |
|       | 2.2 Maximum Aggregate Size        | 20 mm                         |
|       | 2.3 Free Water/Cement Ratio       | 195 kg/m                      |
| 3     | 3.1 Cement Content                | 195/0.48 = 406.25 kg/m$^3$    |
| 4     | 4.1 Relative Density of Aggregate (SSD) | -                           |
|       | 4.2 Concrete Density              | 2400 kg/m$^3$                 |
|       | 4.3 Total Aggregate Content       | 2400 - 410 – 195 = 1795 kg/m$^3$ |
| 5     | 5.1 Grading of Fine Aggregate     | 70%                           |
|       | 5.2 Properties of Fine Aggregate  | 30%                           |
|       | 5.3 Fine Aggregate Content        | 1795 x 0.30 = 539 kg/m$^3$    |
|       | 5.4 Coarse Aggregate Content      | 1795 x 539 = 1255 kg/m$^3$    |

Table 2. Mix design of concrete

| Quantities | Cement (kg) | Water (kg) | Fine aggregates (kg) | Coarse aggregates (kg) | PET fibers (kg) |
|------------|-------------|------------|----------------------|------------------------|-----------------|
| Per m$^3$  | 410.00      | 195.00     | 540.00               | 1255.00                | 420.00          |
| 0.014 m$^3$| 5.74        | 2.73       | 7.56                 | 17.57                  | 5.88            |
| Normal     | 5.74        | 2.73       | 7.56                 | 17.57                  | 0.00            |
| 0.5% PET   | 5.74        | 2.73       | 7.56                 | 17.57                  | 0.21            |
| 1.0% PET   | 5.74        | 2.73       | 7.56                 | 17.57                  | 0.43            |
| 1.5% PET   | 5.74        | 2.73       | 7.56                 | 17.57                  | 0.64            |
| 2.0% PET   | 5.74        | 2.73       | 7.56                 | 17.57                  | 0.85            |
| TOTAL      | 28.70       | 13.65      | 37.80                | 87.85                  | 2.13            |

2.4. Specimens and Test
In this research, the total of 30 specimen were prepared are cylinder mould with size (100 x 200) mm. Five types of mixes were prepared where the control specimens prepared with 0% volume of fibres followed by 0.5%, 1.0%, 1.5% and 2.0% of recycled PET fibres added into the mix. The concrete properties were tested after a curing period of 7 days and 28 days respectively. Compressive test was conducted as specified in the test method BS 1881-116:1983, Part 116: Method for the determination of...
compressive strength and modulus of elasticity of concrete cylinder [3] and ASTM C469: Standard Test Method for Static Modulus of Elasticity and Poisson’s Ratio of Concrete in Compression [4].

3. Result and Discussion
The analysis of the results obtained from the data collected from the laboratory tests. An analysis was done according to the parameters used in controlling the effect of the percentage of recycled PET fibres in concrete under curing conditions of 7 days and 28 days respectively. In this part, it consists of result for slump test, compressive strength test and modulus of elasticity.

3.1 Slump Test
Figure 1 showed a decrease of workability was recorded when adding PET to the mix. Based on the concrete mix design by using the DOE (Department of Environmental) method, the slump range target of this mixture was between 50 mm to 100 mm. The normal concrete in the experiment showed that the slump of concrete was 75 mm which lied between the target range of 50 mm and 100 mm and the slump kept decreasing with the addition of fibre into concrete mixture. The reason behind this decrease is due to present of PET fibres in concrete causes more friction between the particles and this leads to less workability in the mixtures. Besides, the high content and large surface area of the fibres can easily absorb the cement paste thereby increasing the viscosity of the concrete mixture. As the PET content increases, the plasticity and consistency of fresh concrete will decrease. The effects of recycled PET fibres on the slump test between a normal concrete mixture and a mixture with PET fibres are shown in Figure 2.

3.2 Compressive Strength
According to the test results from Figure 3 the compressive strength of plastic bottles concrete decreased when there was an increase in the percentage of shredded plastic bottles in the concrete mix. The compressive strength values for normal concrete at 7 days and 28 days were 19.13N/mm² and 20.9N/mm², respectively. The highest compressive strength value of 10N/mm² was obtained by the concrete sample containing 0.5% of shredded plastic bottles at 7 days whereas the concrete sample containing 1.0% of shredded plastic bottles achieved the highest compressive strength value of 15.73N/mm² at 28 days. These findings also concurred with the results reported by previous researchers. It was evident that the long fibres reduced the compressive strength more than the short fibres at a given fraction. Short fibres get mixed thoroughly with the other constituents and therefore a mesh-like structure was not formed as in the case of long fibres [5]. In general, the rate of reduction in strength was found to decrease with the increase in the percentage of recycled PET fibres and also the length of PET fibres.
Figure 3. Compressive strength of shredded plastic bottles in concrete

3.3 Modulus of Elasticity between EC, BS and ASTM

According to the findings presented on Figure 4, the findings clearly show that the modulus of elasticity of the concrete specimens containing varying percentages of shredded plastic bottles was the highest for all curing ages according to the Eurocode. Overall, at the curing age of 7 days, the MOE value based on the Eurocode was higher than the British Standard and the ASTM standard in the range of 6.73% to 18.21% and 46.02% to 86.3%, respectively. Besides, the MOE value based on the Eurocode was also higher than the British Standard and the ASTM standard in the range of 0.81% to 11.91% and 30.02% to 64.87% respectively at the curing age of 28 days. This finding indicated that during the structural analysis for buildings, the assumption on the modulus of elasticity of concrete is vital. It is known that the standard equations are established based on experimental results obtained for normal strength concrete and the standards generally propose empirical equations for predicting the modulus of elasticity depending on the compressive strength of concrete [6]. The comparison of MOE suggested by the standards indicated that the uses of the existing equations are appropriate for plastic bottle concrete. It also suggests that the MOE value for each standard depends on safety factors, cost effectiveness and sustainability.
Figure 4. Comparison of modulus of elasticity of plastic bottles concrete between Eurocode, British Standard and ASTM at (a) 0%; (b) 0.5%; (c) 1.0%; (d) 1.5%; (e) 2.0%

4. Conclusions
In this research, the conclusion of investigate the potential applications of the shred plastic bottles as concrete material in this study were achieved. The following recommendations are on the physical properties and chemical properties of shred plastic bottles need further investigation especially the interconnection between fine and coarse aggregates and cement paste which may affect the concrete’s modulus of elasticity.

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