Use of Waste Plastic in Concrete Mixture as Aggregate Replacement

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ABSTRACT

Concrete is the most extensively used man-made construction material in the world and it is second only to water as the most consumed substance on the planet. Seek in aggregates for concrete and to dispose of the waste materials from numerous commodities is the present concern. In the present study, the waste plastics were used as partial replacement of aggregates by this means providing a sustainable option to deal with the waste plastic. Over the world, there are many recycling plants, due to the high volume of the plastic bottles. The purpose of this experimental study was to investigate the possibility of using Polyethylene Terephthalate (PET) waste in concrete mixes as an aggregate replacement to diminish the environmental effects of waste plastic disposal. (PET) bottle was used in concrete as a partial replacement for fine and coarse aggregate. Various tests carried out on coarse and fine aggregates like sieve analysis, fineness modulus, specific gravity.

Fresh and hardened concrete tests like slump, compressive and splitting tensile tests are performed, to understand their behavior and usefulness as a replacement. In this study 2.5%, 5%, 7.5% and 10% of waste plastic replacement were considered in addition to a control mix. However, the result showed that in the fresh state, workability decreased with an increase in replacement percentage of a shredded plastic bottle. In Hardened concrete, the compressive strength and tensile strength decreased with introduction of shredded plastic bottle except concrete mix with 2.5% waste plastic replacement in tensile strength.

Keywords: Waste plastic, Aggregate, compressive strength, tensile strength.

1.Introduction

The concrete is one of the most significant structural elements on the earth in the modern era. Its high quality and reasonable cost compared to its high specifications and the role it plays in construction. As the world's population grows and the demand for residential accommodations increases as well as the economic growing in the world, the demand for concrete increased considerably and dramatically interestingly. Concrete consists of three essential materials include cement, water and aggregates, the aggregate normally accounts about 75% of the concrete volume and plays an important role in concrete properties such as workability, strength, stability and durability, that means increased natural resource consumption. It follows that increased pollutant emissions.

There is developing interest in using waste material as alternative aggregate materials as aggregate substitutes such as slag, waste plastic and waste rubber. The development of concrete with unconventional aggregate, such as high-density polyethylene HDPE, polyethylene terephthalate (PET), and other plastic materials has been investigated for concrete.

The objective of this investigation is to provide alternative materials to fine and coarse aggregates in concrete to reduce the consumption of natural aggregates sources and reduce the emission of energy residues such as carbon dioxide and other harmful gases from pollutants and the final disposal of waste plastic. However, most of the previous studies used concrete mix contains waste plastic (PET) as partial replacement of fine or coarse natural aggregate. Therefore, this study was conducted to investigate the effect of partial replacement of both fine and coarse aggregate together in the concrete mix. On these investigations focus on the consequences of waste plastic on the workability of the fresh concrete and on the mechanical strength of the hardened concrete properties.

However, Hashmath and Meraj concluded that the waste Plastics can be used to replace some of the aggregates in a concrete mixture, which it contributes to reducing the unit weight of the concrete and then it could be useful in some applications requiring nonbearing lightweight concrete, such as concrete panels used in facades [1].

Akcaozoglu et al. reported that the use of shredded waste PET granules in concrete or mortar has a potential to reduce the dead weight of concrete, thus, it can reduce the earthquake risk of a building, and it could be helpful in the design of an earthquake-resistant building [2]. Arivalagan et al. had conducted an investigation on using waste PET bottles as fine aggregate in concrete and found that the concrete workability increases as the percentage of plastic increases because the waste plastic which is used as aggregate is smooth. As well as water absorption capacity of plastic is also low [3].

Harini and Ramana had conducted experiments on strength properties of M30 grade concrete are studied different plastic percentage proportions. The various plastic proportions are 5%, 6%, 8%, 10%, 15% and 20% by volume. There is a decrease in compressive strength when the ratio of plastic to aggregate was increased. For which compressive strength was least and to that mix have partially replaced cement with silica fume of 5%, 10% and 15% by weight. The strength properties were again studied, it was noticed that when cement was partially replaced by 10 and 15% of silica fume was higher than the reference mix. Also, it is reported that the tensile strength increases when fine aggregate is partially replaced by 6% of plastic however replacing plastic more than 6% to the fine aggregate will lead to a decrement in tensile strength [4].

Hannawi et al. investigated the effect of using polyethylene Terephthalate (PET) and polycarbonate (PC) aggregates on the physical and mechanical properties of mortars and concrete and found out that the compressive strengths values decreased for both mixtures with an increase in the amount of the two types of plastic aggregates for each mixture type. The replacement levels adopted for both mixtures were 3%, 10%, 20% and 50% for both types of plastic aggregates and the reduction in compressive strengths were observed to be 9.8%, 30.5%, 47.1% and 69% for PET aggregates and 6.8%, 27.2%, 46.1% and 63.9% for PC aggregates as per the replacement levels respectively [5].

Bandodkar et al. concluded that various plastic wastes can be used as a replacement for natural sand to the extent of 10% without much appreciable reduction in 28 days compressive strength. When 10% of plastic is added, reduction in strength to the tune of 10.5% to 13.5% was observed for pulverized blow and injection moulded plastic and PET bottles, whereas in the case of polythene bags the reduction in strength is only 3.5% [6].

2. Materials Used

Different materials used in the present study include cement, aggregates and waste plastic. All materials used throughout this study were from the same source. Also, the properties of material for making concrete mix are tested in the laboratory were in accordance with relevant BS standards and considered suitable for the scope of this study. The description of various materials which were used in this study is given below.

2.1 Cement

Portland cement (type 42.5 N) was used throughout the study. The cement was obtained from a local factory (Al-borj for cement -Zliten).

2.2 Water

The concrete mixing water should not contain undesirable organic substances or inorganic constituents in excessive proportion.Therefore; tap water was used throughout the mixing and curing and curing procedure of concrete in this study.

2.3 Coarse Aggregate

Several tests were done on coarse aggregate to ensure that they have good grading according to specifications BS 882:1992 [7]. Whereas two sizes of coarse aggregate have been tasted. Figures 1 and 2 show the grading curve for coarse aggregate with 10 and 20 mm size. The specific gravity was 2.56 and 2.58 for coarse aggregate sizes 10 and 20 mm respectively.

2.4 Fine Aggregate

Figure 3 shows the grading curve of the sand, which complies with BS as fine sand; this type of sand is the most locally available one in Sirte city. The specific gravity for fine aggregate was 2.61

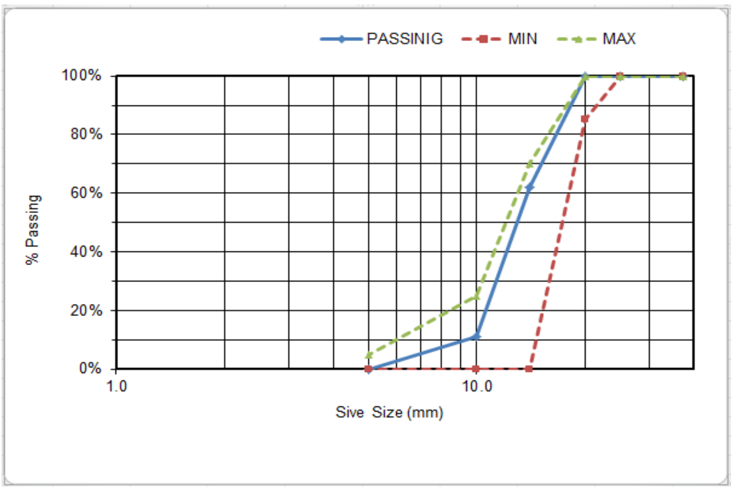

Figure 1. Grading curve of 20mm coarse aggregate

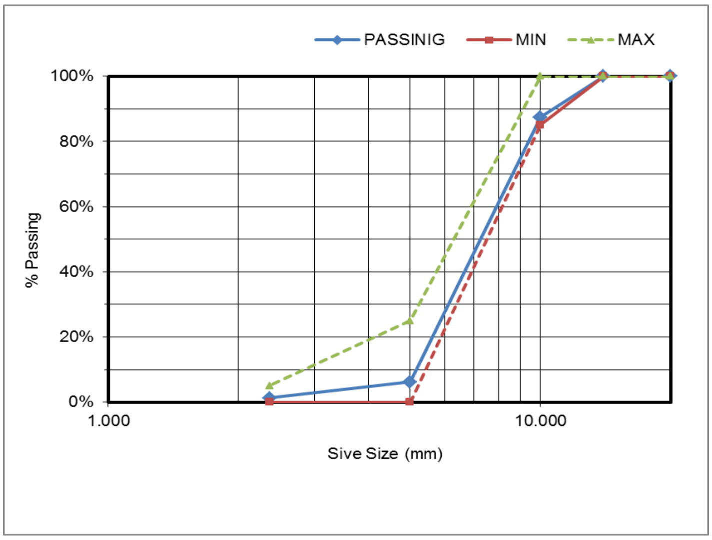

Figure 2.Grading curve of 10mm coarse aggregate

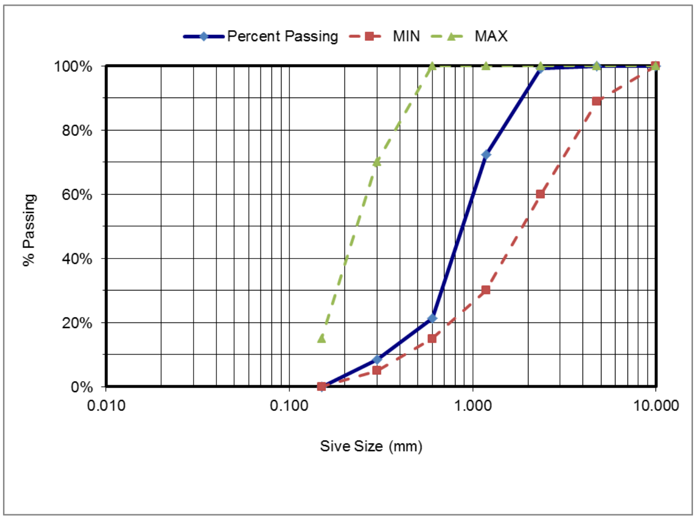

Figure.3. Grading curve of fine aggregate

2.5 Plastic

In this study, polyethylene terephthalate (PET) waste plastic bottles collected from a disposal area in Misurata city. It was shredded in a plastic recycled plant to a small fraction between (1 mm to 10 mm). Figure 4 illustrates a sample of shredded waste plastic after shredding. The specific gravity of PET waste plastic =1.3

Figure 4. Shredded waste Plastic

3. Mix Design and calculation

Design of the normal concrete mix in this study was done by building research establishment (BRE), where the mix proportions were prepared according to British standard[8]. Five concrete mixes were prepared in this study, where the control mixes with specific characteristic strength M30. One concrete mix contains only natural aggregate as a control mix and four concrete mixes contain 2.5%, 5%, 7.5% and 10% waste plastic aggregate as partial replacement of natural aggregate by volume, the results are given in the following table 1. The quantities of fine and coarse aggregates required were calculated for each case based on the mass of waste plastic that was calculated using respective specific gravities. Eq (1) and (2) were used to calculate the amounts of aggregate and PET waste plastic.

$$m_{\alpha,plastic} = m_{agg} \times \alpha \times \left(\frac{SG_{plstic}}{SG_{agg}}\right) \qquad (1)$$

$$m_{\alpha,agg} = (1 - \alpha)m_{agg} \qquad (2)$$

Where: $\alpha =$ fractional replacement of aggregate considered (2.5%, 5%, 7.5%and 10% or); $m_{\alpha,plastic}$ is mass of waste plastic to be used with 'α' replacement; $m_{agg}=$ total mass of aggregate in the control mix;$m_{\alpha,agg}=$ aggregate in the mix with 'α' replacement; $SG_{plstic}=$ specific gravity of plastic; SG_{agg} = specific gravity of aggregate.

Table 1: Concrete mix design

Material Weight (Kg/m^3)					
% of PET	0	2.5	5	7.5	10
Cement	395	395	395	395	395
Coarse Aggregate (10mm)	450.2	438.95	427.69	416.44	405.18
Coarse Aggregate (20mm)	675.3	658.42	641.54	624.65	607.77
Fine Aggregate	579.8	565.31	550.81	536.32	521.82
Plastic	0	21.4	42.8	64.3	85.7
Water	210	210	210	210	210

4. Results and Discussion

4.1 Consistency

Figure 5 shows the slump tests of the fresh concrete, the influence of the PET waste plastic on the workability of concrete mix can be seen clearly. It is observed that the fluidity of concrete decreased with the increasing amount of waste plastic compared with workability of reference concrete (RC). Also, it is noted that there is a difficulty to compact the concrete mixes start with 5% waste plastic replacement and the difficulty increases extremely with 10% due to irregularity and roughness shape of the waste plastic.

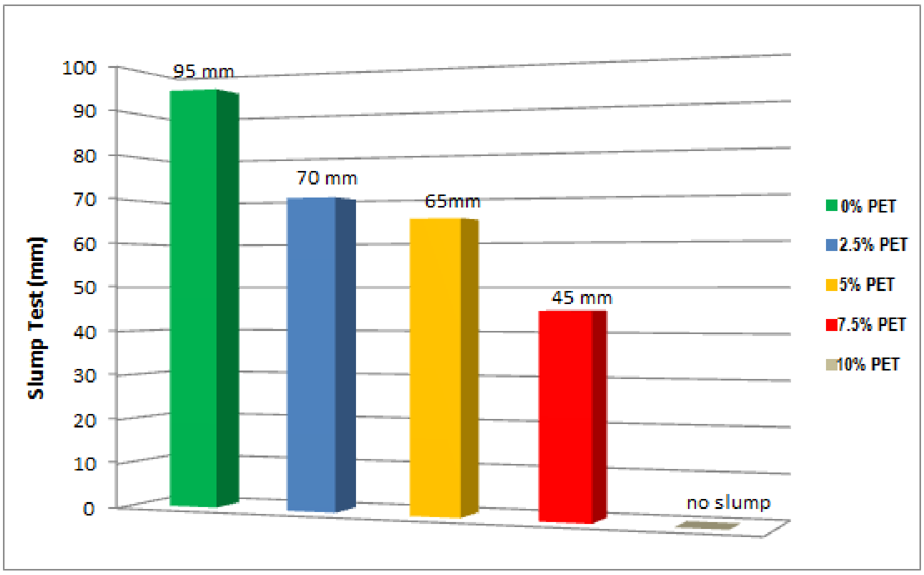

Figure 5. Slump values of concrete containing plastic wastes in different percentages

4.2 Density

Table 2 illustrates the density of reference concrete and other mixes containing waste plastic. It is clear that the density of concrete decreased with the increase of plastic waste aggregates content also, reduction in density was directly proportional to the plastic aggregates content; and density of concrete was reduced by 2.5%, 3,4% and 4.5% for concrete containing 2.5%, 5%, 7.5% and 10% waste plastic aggregates at 28 days, respectively. Reduction in density was attributed to the lower unit weight of the plastics.

Table 2: Concrete Density (Kg/m^3)

% of PET	0	2.5	5	7.5	10
Density (Kg/m^3)	2346.66	2288.33	2275	2256.66	2243.33

4.3 Compressive strength

Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. In this study, three cubes were tested in each age to each percentage of the concrete mixes, and then the average has been taken. Table 3 summarizes the values of compressive strength at 7, 14 and 28 days.

Table 3: Compressive strength at 7, 14 and 28 days.

% of PET		0	2.5	5	7.5	10
Compressive Strength (MPa)	7 day	28.6	30.8	26.2	27.5	25.0
	14 day	35.1	35.5	34.9	32.5	28.2
	28 day	37.6	36.0	35.2	34.1	32.7

To study the percentage of decreasing or increasing the value of compressive strength for concrete with waste plastic relatively with the control mix, see figure 6. It can be seen that the maximum decrease in compressive strength at 28 days age was about 13% when10% waste plastic replacement. Also, it is clear that the compressive strength at an early age (7 days) with 2.5% waste plastic replacement reaches 8% more comparing with the reference concrete mix. While in the age 14 days ,the increase in compressive strength more than1% when the waste plastic 2.5% and then tend to decrease to 20% when the waste plastic 10%.finally, the compressive strength at age 28 days tend to decrease in compressive strength gradually about 4% from control mix to 10% waste plastic replacement.

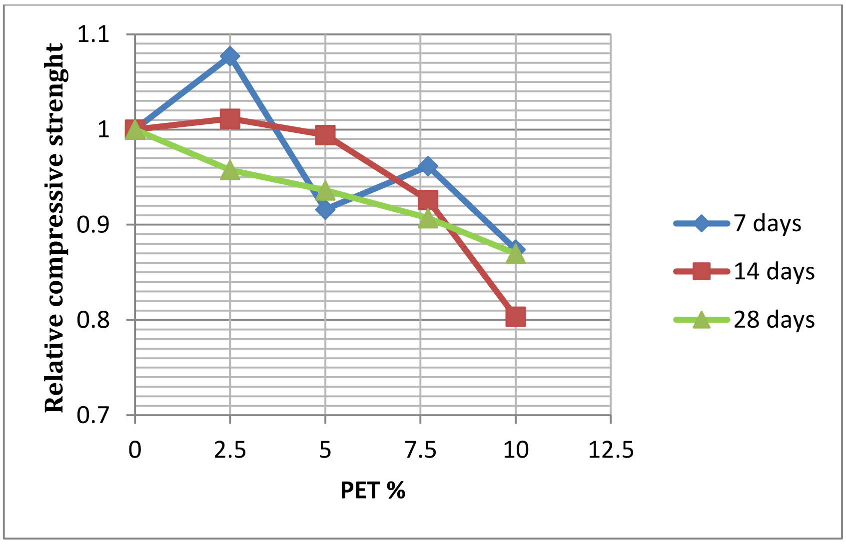

Figure 6.Relative Compressive strength of concrete

4.4 Splitting Tensile strength

From figure 7, it was observed that the maximum splitting tensile strength at 28 days of the concrete prepared with 2.5% plastic waste was noticed as 3.00 MPa, which is increased about 6% more when it compared with the control mix. Also, it reduced to 2.26 MPa when the waste plastic was added in concrete up to 5% by volume of the mix. Moreover, it was recognized that the value of splitting tensile strength was decreased slightly between additions of waste plastic from 7.5% to 10% in the concrete. Throughout testing of cylinder specimen. It is important to report that the specimen does not split directly when the failure load occurred, specially at 10% waste plastic, because the waste plastic contributes to concrete ductility.

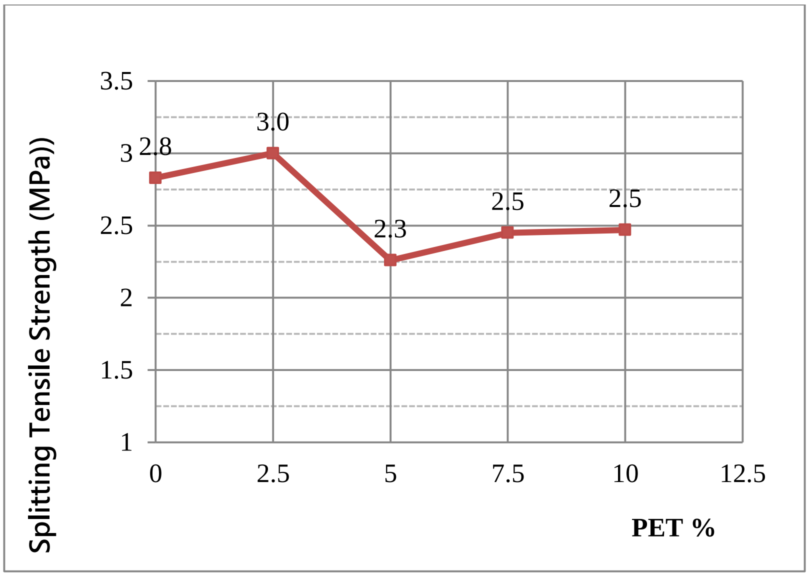

Figure 7.splitting tensile strength of the concrete(28 days)

5. Conclusions

The study found that waste plastic has a good possibility of replacing aggregate in a concrete mixture in some construction applications. Based on the laboratory works on fresh and hardened state. In the fresh state, they show that. The workability of concrete could decrease as the amount of fine waste plastic aggregate increases also depending on the particle shape, size, water-cementt ratio and amount of cement paste.

In the hardened state, a gradual decrease in the compressive strength development occurs at 28 days age with an increase in the content of waste plastic aggregate (both fine and course). This occurs as a result of a weak bond between the plastic and the surrounding matrix. Also, at early ages, it is noted that an improvement in compressive strength with 2.5% waste plastic. On the other hand , the splitting tensile strength was determined at 28 days and it was observed that there was increase with 2.5% replacement of the natural aggregate with a waste plastic bottle and then decreased with an increase in the replacement of the waste plastic aggregate.

Moreover, Concrete containing waste plastic aggregates exhibited more ductile behavior than concrete made with conventional aggregates. This ductile behavior could be of significant advantage in reducing crack formation and propagation before failure. However, from the results, it could be use waste plastic as aggregates in civil engineering applications, such as pavement, producing concrete bricks and non-structural concrete panels, can be an alternative to disposing of them in landfill sites and helpful to produce green sustainable concrete.

6. Acknowledgment

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References

[1] MdHashmath,MdMeraj, "*Experimental Study on Utilization of waste Plastic As Aggregate*," *InternationalJournal of Engineering Science and Research Technology*, vol. 4, no. 8, pp. 207-214, August, 2015. www.ijesrt.com

[2] S.Akçaözog ,C.D.Atis,K.Akçaözog˘, "*An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete*,"Waste Management,vol. 30, no. 2, pp. 285-290, issn 0956-053x. Month, 2010.www.elsevier.com/locate/wasman

[3] Arivalagan.S,M.G.R, "*Experimental Investigation On Partial Replacement Of Waste Plastic In Concrete*," *International Journal of Engineering Science and Research Technology*,vol. 5, no. 11, pp. 443-449, IJESRT. November,2016. doi: 10.5281/zenodo.167190

[4] Harini B ,.Ramana K.V., ",*Use of Recycled Plastic Waste as Partial Replacement for Fine Aggregate in Concrete*," *International Journal of Innovative Research in Science*, *Engineering and Technology*,vol. 4, no. 9, pp. 8596-8603, IJIRSET. September, 2015.

[5] Hannawi, K., S. Kamali-Bernard, and W. Prince, "*Physical and mechanical properties of mortars containing PET and PC waste aggregates*," *Waste management*, vol. 30, no. 11, pp. 2312-2320, November, 2010. https://doi.org/10.1016/j.wasman.2010.03.028

[6] L. Bandodkar, A.Gaonkar, N.Gaonkar, S.Aldonkar,P. Savoikar&Y.Gauns, "*Pulverised PET Bottles as Partial Replacement for Sand*,"*International Journal of Earth Sciences and Engineering*"vol. 4, no. 6, pp1009-1012, SPL. October, 2012

[7]BSI, BS 882:1992 specification foraggregate from natural sources forconcrete 1992, BSI-British StandardsInstitution.

[8]Teychenné, R Franklin, H Erntro. *Design of normal concrete Mixes*. Second Edition.Watford : Building ResearchEstablishment Ltd, 1997.