THE EFFECTS OF ADDING WASTE PLASTIC FIBERS ON SOME MECHANICAL PROPERTIES OF GAP-GRADED CONCRETE CURING BY DRAINAGE WATER AND SEWAGE WATER

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Abstract: Developing countries like Iraq suffered from high quantities of solid waste such as empty beverage plastic bottles. This type of waste plastic formed one of the serious environmental pollution resources. In this study an attempt to benefit from non-biodegradable solid waste represented by beverage plastic bottles as useful material. This operation boils in enhancing some properties of concrete exposed to sewage water and drainage water by adding waste plastic resulting from cut plastic beverage Polyethylene Terephthalate (PET) bottles by electrical shredder machine (which is used to cutting paper) as fibers used to reinforce gap-graded concrete. Waste Plastic Fibers (WPF) were added with different volume ratios of fibers to concrete curing by drainage water or sewage water, which brings from different region in ANBAR district. These percentages were (0.5%, 1.0% and 1.5%). Reference mixtures were for a comparative reason.The following tests were made at room temperature to investigate the effects of adding WPF on the concrete properties as follows: compressive strength, tensile strength and density. All these tests conducted at ages of 28, 56 and 90 days. The plan of this research consist of two lines, the first includes the effects of adding WPF on concrete exposed to drainage water. The other line was, the study of concrete properties containing WPF in contact with sewage water.
Results proved that, the addition of waste plastic fibers leads to decrease in dry density of all mixtures curing by drainage water or sewage water according to references mixtures at all curing ages. For compressive strength there was an increasing in compressive strength comparing with reference mixtures up to waste plastic fiber percentage by volume of concrete equal to 1% , whereas the splitting tensile strength increased slightly with the increase in fiber volume of all ages for different types of concrete mixtures which cured by either drainage water or sewage water. One of the important results of this study is the possibility of using drainage water or gray water to curing of gap-graded concrete reinforced with WPF.

Keywords: mechanical properties, waste plastic, fiber reinforced concrete, waste plastic fiber reinforced concrete

INTRODUCTION

Solid waste management is an important challenge for the cities in developing countries due to big amounts of these wastes causing serious consumption in these countries budgets [1]. Waste plastic (WP) is an important kind of non-biodegradable solid waste in the world. Iraq is one of the countries which suffer from the environmental pollution by these solid materials [2]. In this study an attempt to benefit from non-biodegradable solid waste represented by beverage plastic bottles as useful material enhancing some properties of concrete exposed to sewage water and drainage water. Plastics will neither decay nor degenerate either in water or in soil. In turn it pollutes the water and soil. The plastic if burnt releases many toxic gases, which are very dangerous for the health [3]. Al-Nu'man et al [4] studied the possibility of manufacturing cheap, thermal insulation and environmentally friendly building elements from plastic waste. Experiments were achieved depends on the addition of plastic waste as aggregates to the mixes of concrete at different five percentages by weight to produce lightweight aggregate concrete that has the density (1760 - 1911) kg/m. The mechanical properties which had been tested include compressive strength, static modulus of elasticity, flexural strengths and density after (28) days of curing at 20 C^{o}. Results show that the increase in the amount of plastic waste decreases the density of concrete which leads significantly to improvement in thermal properties. Many trials were done to decrease the harm effects of WP by recycling these wastes. Some of these use the WP as fibers by cutting of PET bottles as fibers and adding to concrete mixtures. Al-Hadithi [5] studied the effect of adding the chips resulting from cutting the plastic beverage bottles, which is used in Iraqi markets, as fibres added to the concrete with very small percentages of concrete volumes. These percentages were (0.1%) and (0.2%). Results proved that adding of plastic fibres with these percentages lead to improvements in compressive strength and flexural strength of concretes containing plastic fibres, but the improvement in flexural strength appeared more clearly.
Al-Hadithi et al [6] investigates the impact resistance of concrete slabs with different volume percentages replacement ratios of waste plastic fibers (originally made from soft drink bottles). 0.5%, 1% and 1.5% the WPF

percentages by volume of concrete which were used. Reference mix produced in order to compare the results. The low-velocity impact test was conducted by the method of repeated falling mass where 1400gm steel ball was used. The ball falling freely from height of 2400mm on concrete panels of (500×500×50 mm) having a mesh of waste plastic fiber. The number of blows that caused first crack and final crack (failure) were determined, according to the former obtained results, the total energy was calculated. Results showed an improvement in compressive strength and flexural strength of concrete containing waste plastic fiber over reference mixture. Another significant improvement in low-velocity impact resistance of all mixes containing waste plastic over reference mix. Results illustrated that mix with (1.5%) waste plastic: concrete give the higher impact resistance than others, this increase at failure over reference mixture was (340%). The possibility of using fibers from PET bottles to increase the ductility of the concrete was studied by Foti [7]. Tests showed that PET fibers in a concrete mix are likely to increase the ductility of concrete. Adding the chips resulting from cutting PET plastic beverage bottles by hand to gap-graded concrete as small fibers is an attempt was done by Al-Hadithi [8] to improve impact and mechanical properties of this kind of concrete. These fibres were added with different percentages of concrete volumes. These percentages were (0.5%), (1%) and (1.5%). Results proved that, adding of waste plastic fibres with these percentages leads to improvements in mechanical properties of gap-graded concretes containing plastic fibres. There is significant improvement in low-velocity impact resistance of all waste plastic fibres reinforced concrete (WPFRC) mixes over reference mix. Results illustrated that waste plastic fibres reinforced mix of (1.5%) give the higher impact resistance than others, the increase of its impact resistance at failure over reference mix was (328.6%) while, for waste plastic fibres reinforced mix of (0.5%) was (128.6%) and it was (200%) for fiber reinforced mix of (1%). Behavior of ferro-cement reinforced with waste plastic fibers slabs under high and low velocity impact loadings investigated by Al-Obaidi [3]. For low velocity impact tests were at age of (56) days, the results showed that the addition of waste plastic fibers increased the number of blows which were required to make the first crack and failure, with the increase of number of wire mesh layers. For high velocity impact tests were at age of (180) days. The results showed that the area of scabbing and area of spalling decreased with the increase in waste plastic fiber volumes and number of wire mesh layers compared with the reference mixes. Some tests performed on concrete specimens and beams reinforced with WPF made from PET bottles [9]. The results that had been obtained from this study were interesting, especially regarding the adherence between PET and concrete, suggesting a possible use of this material in the form of flat or round bars, or networks for structural reinforcement.

EXPERIMENTAL

The experimental program was planned to investigate the effect of using WPF on the mechanical properties and density of concrete cured by drainages and, or sewages.

MATERIALS:

Cement: The cement used through this work was Ordinary Portland Cement type I and it is conforming to the Iraqi specification No. 5/1999[10]. **Fine aggregate:** The fine aggregate used is natural sand brought from Ramadi region. It was clean, free of organic impurities and deleterious substances and relatively free of clay. The grading of sand is conformed to the requirements of the (B.S.882/1992) [11]. **Coarse aggregate:** Gap-graded natural coarse aggregate brought from the Iraqi West Desert, this aggregate conforms to the requirements of the (B.S.882/1992 – Zone 3) in all sieve numbers but sieve with opining equal to 10 mm. **Waste plastic fibers:** Rectangular shape of waste plastic fiber with dimension (61 × 3.8 mm) and thickness of (0.3) mm was used to this research .The waste fibers made from shredded beverage bottles made of (PET) into a regular shapes and dimensions using the shredder machine. Fibers were added to the mixes as a ratio by volume of mixture of 0.5%, 1.0% and 1.5% respectively. Fig.1 shows the WPF which is used in this research.

Figure 1. Waste plastic fibers mixed with other mixture components before mixing operation

Mixing and Curing Water: Ordinary drinking water was used for mixing and it tested according to Iraqi Specification No. 1703/1992[12]. Table 1 shows the results of this test. Two types of water were used for curing of specimens the first was gray water which was taken from Ramdi City sewage water, the other kind of water was taken from some drainages in Faloja city. The analysis of both types of water is shown in Table 1.

Table 1: Analysis of dranage and sewage curing water

Curing water from drainages			Curing water from sewage		
Test	Test Result	Limits of I.Q.S 1703 / 1992	Test	Test Result	Limits of I.Q.S 1703 / 1992
T.D.S	3320 PPM	≤ 3000 PPM	T.D.S	3020 PPM	≤ 3000 PPM
CO_3	Nil	≤ 1000 PPM	CO_3	Nil	≤ 1000 PPM
Cl	1155.996 PPM	≤1000 PPM	Cl	971.604 PPM	≤1000 PPM
SO_3	1215.76 PPM	≤ 500 PPM	SO_3	1245.76 PPM	≤ 500 PPM
HCO_3	683.257 PPM	≤ 1000 PPM	HCO_3	561.292 PPM	≤ 1000 PPM
pH	7.5	6.5-8.5	pH	6.8	6.5-8.5

Mixture proportions

Two groups of mixes were used in this research; each group contains reference mix and other three mixes containing WPF with different volume ratios of fibers to concrete. These ratios were 0.5%, 1% and 1.5%. Table (2) shows the mix proportions of materials used in this work.

Table 2 :Mixes proportion to produce one cubic meter of concrete

Group	Symbol	C (Kg)	S (Kg)	G (Kg)	WPF (Vf%)	WPF (Kg)	W (Kg)
1	RD	389.1	713.2	1167.3	0	0	175.1
	WFD0.5	387.16	708.5	1161.5	0.5	6	174.22
	WFD1	385.2	706.2	1155.6	1	12	173.35
	WFD1.5	383.3	702.5	1149.8	1.5	18	172.47
2	RS	389.1	713.2	1167.3	0	0	175.1
	WFS0.5	387.16	708.5	1161.5	0.5	6	174.22
	WFS1	385.2	706.2	1155.6	1	12	173.35
	WFS1.5	383.3	702.5	1149.8	1.5	18	172.47

C: cement S: fine aggregate G: coarse aggregate WPF: waste plastic fiber W: water
Group 1 cured by drainage water and Group 2 cured by sewage water.
R-reference mix, D-drainage water curing, S-sewage or gray water,
WF-waste plastic fiber, Numbers- 0.5, 1 and 1.5 refer to volume of waste plastic fibers percentage by volume.

Concrete specimens preparing and tests : Casting, compaction and curing was done according to ASTM C192-88[13]. **Dry density test** was done according to ASTM C642-97[14]. **Compressive strength** test was done according to B.S.1881[15], while **splitting tensile strength** was done according to ASTM C496-86 [16].

FINDINGS AND ARGUMENT

Dry density test: As seen in Fig. 2. and Fig. 3., results showed that, increasing of all dry densities with time for all concrete mixtures for the two groups. The first group which cured by drainage water, and the other which cured by sewage water. Adding WPF to concrete leads to decrease in concrete mixture density, because the density of plastic lower than that of other concrete composites, i.e. cement, fine aggregate and coarse aggregate. The amount of decreasing in density increased according to WPF volume. Concrete mixes curing with gray water had densities slightly greater with these curing by drainage water. No concrete mix in both groups reached the value of lightweight structural concrete. These results are similar with the previous results approved by researchers like Ismail and Al-Hashmi [2].

Compressive strength tests: The relationship between compressive strength at different ages and volume of fiber for both groups are is shown in Fig. 4. and Fig. 5. From these figures it can be seen that, the compressive strength of all concrete mixtures increases with time as a result of development in hydration of cement paste, but the percentage of increasing in compressive strength differs between the reference mixture and the fiber reinforced concrete. From Fig. 6. and Fig. 7. it can clearly noticed that there is a tendency to for compressive strength values of WPF concrete mixtures, with fiber content by concrete volume over than 0.5%, to decrease below plain mixture at each curing ages for both groups. The improvement of the compressive strength for the mixtures contains WPF with Vf=0.5% is due to the ability of the mechanical blocking action of the fiber, whereas the decreasing in compressive strength of other mixture containing WPF may be attributed to the decrease in adhesive strength between the surface of WPF and the cement paste.

Splitting tensile strength: This type of strength was determined like compressive strength at ages of 28, 56 and 90 days for moist curing by either derange water, or sewage water. The results indicated that splitting tensile strength increased with development of curing ages. It is clearly appear from Fig. 8. and Fig. 9. that, the splitting tensile strength increased slightly with the increase in fibers volume of all ages for different types of concrete mixtures cured by drainage water and by sewage water. This increase in splitting tensile strength can be attributing to the fact that the waste plastic fibers arrest cracks progression. Also, the addition of waste plastic fibers contributed to strengthen the interior tensile stresses [17]. In contrast, the increase of splitting tensile strength of specimens reinforced with waste plastic fibers is due to the fiber bridging effect, which prevented cracks from opening widely.

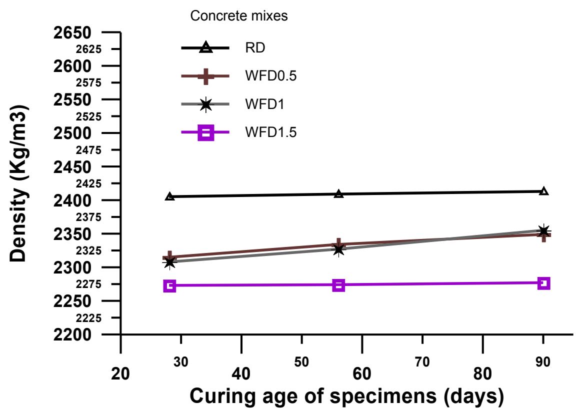

Figure 2. The relationship between dry density and curing ages for concrete mixtures cured by drainage water

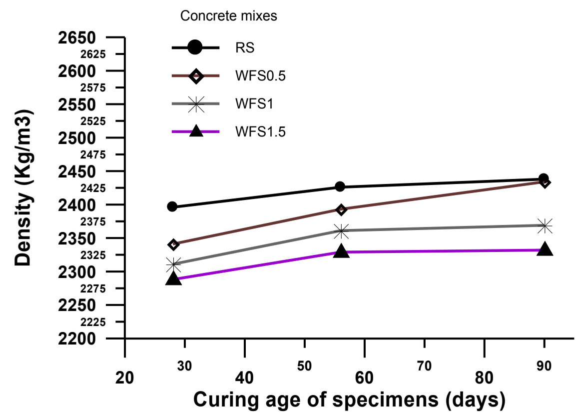

Figure 4. The relationship between dry density and curing ages for concrete mixtures cured by sewage water

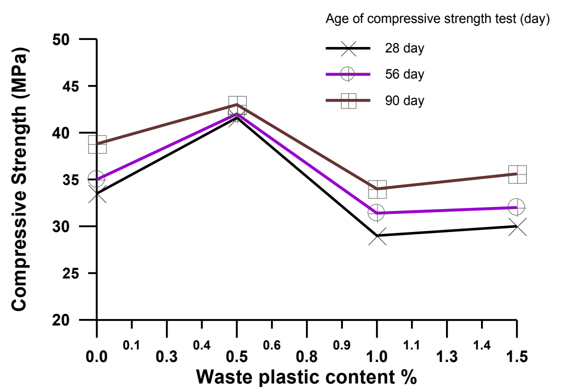

Figure 4. The relationship between compressive strength and volume of WPF during different ages of curing by derange water.

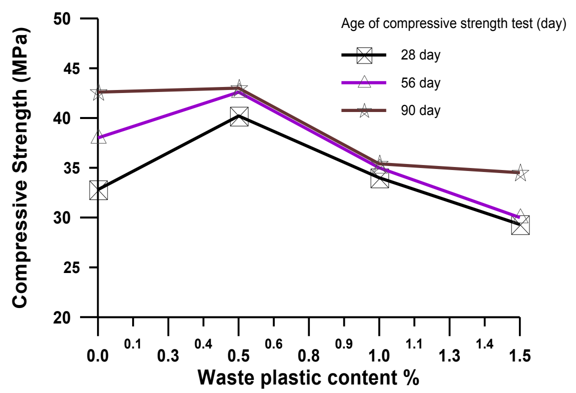

Figure 5. The Relationship between compressive strength and volume of WPF during different ages of curing by sewage water

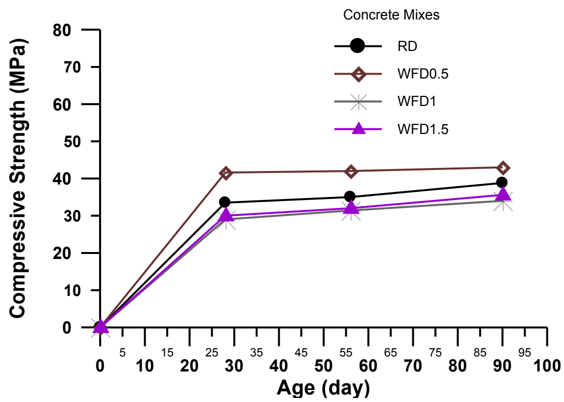

Figure 6. The development of compressive strength with increasing of volume WPF during different ages of curing by derange water

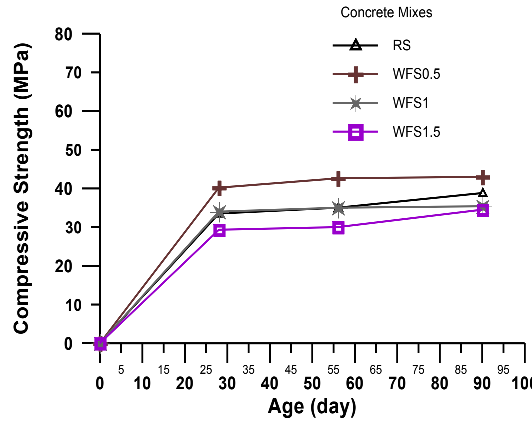

Figure 7. The development of compressive strength with increasing of volume WPF during different ages of curing by sewage water

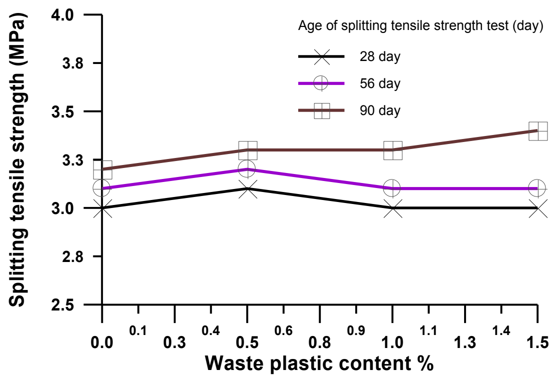

Figure 8. The relationship between splitting tensile strength and volume of WPF during different ages of curing by derange water

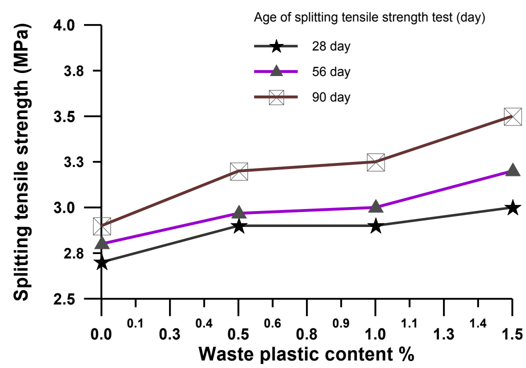

Figure 9. The relationship between splitting tensile strength and volume of WPF during different ages of curing by sewage water

CONCLUSIONS

Conclusions should include (1) the principles and generalisations inferred from the results, (2) any exceptions to, or problems with these principles and generalisations, (3) theoretical and/or practical implications of the work, and (5) conclusions drawn and recommendations.

Based on the extensive research works the following conclusions can be drawn:-

- Adding of waste plastic fibers leads to decrease in dry density of all mixtures curing by drainage water or sewage water according to references mixtures at all curing ages. Concrete mixtures curing with gray water had densities slightly greater with these curing by drainage water
- The best waste plastic fiber percentage by volume of concrete which gives an increasing in compressive strength over references mixtures was equal to 0.5%. The other percentages gave compressive strength values less than that of references mixtures. The decreasing in compressive strength of other mixture containing WPF may be attributed to the decrease in adhesive strength between the surface of WPF and the cement paste.
- The splitting tensile strength increased slightly with the increase in fibers volume of all ages for different types of concrete mixtures cured by drainage water and by sewage water. This increasing in splitting tensile strength can be attributing to the fact that the waste plastic fibers arrest cracks progression. Also, the addition of waste plastic fibers contributed to strengthen the interior tensile stresses.

- This study prove that, the use of derange water and sewage water with same specifications limited to that use in this research, for curing of waste plastic reinforced gap-graded concrete.

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