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Research Paper

PRODUCING GREEN CONCRETE USING WASTE PLASTIC

Suhad M Abd[1], Fahad Mohammad[2]*, Humam Abdul-sattar[2] and Mais Malallah[2]

*Corresponding Author: **Fahad Mohammad** ✉ fahadbahlol22@gmail.com*

One step of societies' development scientifically, geometrically and industrially is intellectual integration with human necessity. This study focused on producing green concrete by using waste plastic as a partial replacement for sand by 0%, 25%, 50% and 70% respectively (by volume). This study will determine the efficiency of reusing waste plastic in the production of concrete comparing with the normal concrete. All of the concrete mixtures were tested at room temperature including performing slump, density and compressive strength. Eighteen cubes were molded for compressive strength and fresh density tests; curing ages of 7 and 28 days for the concrete mixtures were applied in this work. The results showed a fall of compressive strength at 28 days about 35% and 71% or the concrete containing 25% and 70% of waste respectively and showed that we can use wastes and by-product materials as a sand-substitution aggregate and also reduce the cost of some materials, and with that green concrete born.

Keywords: Waste plastic, Green concrete, Compressive strength, Slump, Density

INTRODUCTION

The productive use of waste material represents a means of alleviating some of the problems of solid waste management (Davis and Cornwell, 1998) from different points of view, it is important to reuse waste plastic. It helps to save and sustain natural resources that are not replenished, it decreases the pollution of the environment and it also helps to save and recycle energy production processes. Wastes and industrial by-products should be considered as potentially valuable resources merely awaiting appropriate treatment and application. Waste plastic among these materials, the disposal of waste plastic has a harmful effects on the environment because of their long biodegradation period and using them in other industries and applications will reduce their negative effect on the environment (Hassani *et al.*, 2005). Concrete plays an important role in the beneficial use of these materials in construction. Although some of these materials can be beneficially incorporated in concrete, both

[1] Assistant professor, Civil Engineering Department, University of Diyala, Iraq.
[2] Civil Engineer, Civil Engineering Department, University of Diyala, Iraq.

as part of the cementitious binder phase or as aggregates, it is important to realize that not all waste materials are suitable for such use (Anon, 2003). Concrete contains numerous flaws and micro cracks. The rapid propagation of micro cracks under an applied load is considered responsible for the low tensile strength of concrete. It is reasonable to assume that the tensile strength as well as the flexural strength of concrete can be substantially increased by introducing closely spaced fibers. These fibers would arrest the propagation of micro cracks, thus delaying the onset of tensile cracks and increasing the tensile strength of the material (Yin and Hsu, 1995). Banthia and Trottier (1995) stated that the enhanced performance of fiber reinforced concrete over its unreinforced counterpart comes from its improved capacity to absorb energy during fracture, while a plain unreinforced matrix fails in a brittle matter at all occurrences of cracking stress. This energy-absorption attribute of fiber reinforced concrete is often termed "toughness". Rebeiz and Fowler (1996) found that very good flexural strength can be obtained with reinforced Polymer Concrete (PC) using unsaturated polyester resins based on recycled Polyethylene Terephthalate (PET). Soroushian *et al.* (1995) stated that polypropylene is used only as synthetic fibers to increase the toughness of concrete. Hýnýslýog¢lu and Ag¢ar (2004) investigated the possibility of using various plastic wastes containing high density polyethylene (HDPE) as polymer additives to asphalt concrete. The results indicate that waste HDPE-modified bituminous binders provide better resistance against permanent deformations due to their high stability and high Marshal Quotient; it also contributes to the recycling of plastic wastes as well as in protection of the environment. In other research, (de Assunc¸a˜o *et al.*, 2004) used sodium polystyrenesulfonate (NaPSS) produced from waste polystyrene cups as an admixture in concrete. The results proved that NaPSS can be used satisfactorily either as a plasticizer or as an admixture for water reduction in concrete. The slump increase of concrete was up to 300% with 0.3% content of NaPSS per weight of cement. (Tam and Tam, 2006) stated that technology is being developed that will enable building materials to be progressively infused with recycled plastic constituent in order to increase strength, durability and impact resistance, and enhance appearance (Jo *et al.*, 2006) investigated the mechanical properties such as compressive strength and flexural strength of polymer concrete using an unsaturated polyester resin based on recycled PET, which contributes to reducing the cost of the material and saving energy. Pezzi *et al.* (2006) used plastic material particles incorporated as aggregate in concrete and evaluated the chemical, physical, and mechanical properties. The results proved that the addition of polymeric materials in fractions 610% in volume inside of a cement matrix does not imply a significant variation of the concrete mechanical features. Marzouk *et al.* (2007) studied the use of consumed plastic bottle waste as sand-substitution aggregate within composite materials for building applications. The study demonstrates that plastic bottles shredded into small PET particles may be used successfully as sand-substitution aggregates in cementitious concrete composites, which appears to offer an attractive low-cost material with consistent properties and which would help to resolve some of the solid waste problems created by plastics production and can help improving concrete productivity process by lowering cost of the constituents (Abbas *et al.*, 2008)

MATERIALS AND MIX DESIGN

Materials

The materials used in this study are as follows:

Cement: Type I Portland cement conforming to I.Q.S. No. 5/1984 was used in all types of aggregate content mixtures. The chemical and physical properties of the cement are presented in Tables 1 and 2, respectively.

Table 1: Physical Properties of Cement

Physical Properties	Test Results	Standard Specifications IQS 5/1984
Specific surface area (Blaine method), m^2/kg	495	≥230
Setting time (Vicate apparatus),		
Initial setting, h:min		
Final setting, h:min	2:55	≤00:45
	4:35	≥10:00
Compressive strength, MPa		
3 days	33.5	≤15
7days	38.6	≤23
Soundness (Autoclave) method, %	0.3	≥0.8

Table 2: Chemical Composition of Cement

Oxides Composition	Content %	Standard Specifications IQS 5/1984
CaO	63.06	-
SiO_2	22.	-
Al_2O_3	6.25	-
Fe_2O_3	3.13	-
MgO	2.95	<5
SO_3	3.03	<2.8
LOI	3.33	<4
Insoluble residue	1.21	<1.5
Lime Saturation Factor L.S.F	0.88	0.66-1.02
Mineralogical Composition (Bogue's equations)		
C_3S	47.04	-
C_2S	28.11	-
C_3A	10.98	-
C_4AF	6.98	-

Fine Aggregate: The fine aggregate was natural sand of 4.75 mm maximum size obtained from the Al-Ukaider area in Iraq. The properties of the fine aggregate was determined and fulfilled according to I.Q.S. No. 45/1984. Table 3 presents the properties of the sand, and its gradation is presented in Table 4.

Table 3: Properties of Fine Aggregate

Properties	Limit
Sulfate %	0.8
Finesse modulus	2.43
Absorption %	2.71
Max size (mm)	4.75
Density (kg/m^3)	1688
Specific gravity	2.57

Table 4: Gradation of Fine Aggregate

Sieve Size (mm)	Passing %	Standard Passing % of Zone (2)
4.75	93	90-100
2.7	83.4	75-100
1.18	69	55-90
0.6	47.31	35-59
0.3	15.405	8-30
0.15	0.707	0-10

Coarse Aggregate: Natural crushed stone aggregate of maximum size 12.5 mm and bulk density of 2300 kg/m3 was used. gradation of coarse aggregate Is presented in Table 5 .

Table 5: Gradation of Coarse Aggregate

Sieve size (mm)	Passing %	Limit of Iraq Specification No.45-1984
12.5	100	100
9.5	88	100-85
4.75	10	25-0
2.36	2.5	5-0

Waste Plastic: The product of shredding big plastic water containers that were brought from plastic shredders located in Kamaliya area. Waste plastic is analyzed in terms of some physical properties such as density, water absorption, as presented in Table 6 , Figure 1 presents a sample of the used waste plastic.

Table 6: Properties of Waste Plastic

Density (kg/m^3)	454
Shape of particles	Pieces with average length of 0.1–4 mm and width of 0.1–3 mm
Color	Different colors
Water absorption, 24 h (%)	0.021
Compressive strength	Poor

Figure 1: Sample of Waste Plastic

Mix Proportions

Reference concrete mixture : this mixture consisted of 375 kg/m^3 cement , 680 kg/m^3 sand , 960 kg/m^3 gravel and w/c ratio of 0.47. This mixture was 0% of waste plastic .

Waste plastic mixtures : these mixtures are presented in Table 7.

Table 7: Waste Plastic Concrete Mixtures

No.	Gravel (kg)	Sand (kg)	Used sand (kg)	Sand replaced by plastic (kg)	Cement (kg)	Water (lits)	w/c	Plastic %	Vol. (m^3)
T	7.68	5.44	5.44	——	3	1.42	0.47	0	0.008
Tp 1	6.72	4.76	3.57	1.19	2.625	1.233	0.47	25	0.007
Tp 2	7.68	5.44	2.72	2.72	3	1.42	0.47	50	0.008
Tp 3	7.68	5.44	1.632	3.808	3	1.42	0.47	70	0.008

Where Term (T) represents the sample without waste plastic, term (Tp1,TP2 ,TP3) refers to mixtures contain 25%, 50% and 70% of waste plastic respectively.

Test of Specimens

18 cubes of concrete of (100 *100* 100) mm were molded for compressive strength, and fresh density tests and as follows:.

1. Casting, compaction and curing: Accomplished according to B.S.1881, part 7 and B.S.1881, part 6.
2. Slump test: Fulfilled according to B.S.1881, part 2.
3. Fresh densities: Measured for all cubes after molding and compacting immediately according to B.S.1881, part 5. The fresh density represents the mean of fresh densities for.
4. Compression strength test: Concrete cubes were prepared according to B.S.1881, part 7. The Forney machine was used for the compression test. The cubes were tested immediately after taken out of water while they were still wet. The average of compression strength of 3 cubes was recorded for each testing age (7 and 28 day).

RESULTS AND DISCUSSION

Slump test: The results of the slump tests of waste plastic concrete mixtures showed that there was clear increasing of slump with increasing percent addition of waste plastic in the concrete mixture. This rise can be attributed to the fact that particles of waste plastic are cannot absorb water waste content increases the fluidity of concrete, this improvement can be attributed to the fact that plastic particles have an outer smoother surface than that of the sand, therefore an excess of water which improves the workability are suitable for use in precast applications and large sites because of the easy and suite workability that's give us many chooses for concrete mixtures has a broad range from very low (at slump = 0–25 mm) applied for vibrated concrete in roads or other large sections, to high workability (at slump = 100–180 mm) applied for sections with congested reinforcement (Koehler and Fowler, 2003), also these results made sureness by application for the study of Concrete products with plastic material have easy workability (Naik *et al.,* 1996). Table 8 shows the results of slump, see Figure 2.

Density: Table 9 shows us the results of densities of waste plastic concrete mixtures ,These results indicate that the density tends to decrease by 2.8%, 8.6%, and 21% , respectively comparing with the reference mixture.

The substitution of sand by plastic waste reduced the density of all mixtures with increasing

Table 8: Slump of Waste Plastic Concrete

Slump(cm)	% Waste Plastic	Mixtures
1.5	0	T
2.5	25	Tp 1
9	50	Tp 2
15	70	Tp 3

Table 9: Densities of Waste Plastic Concrete

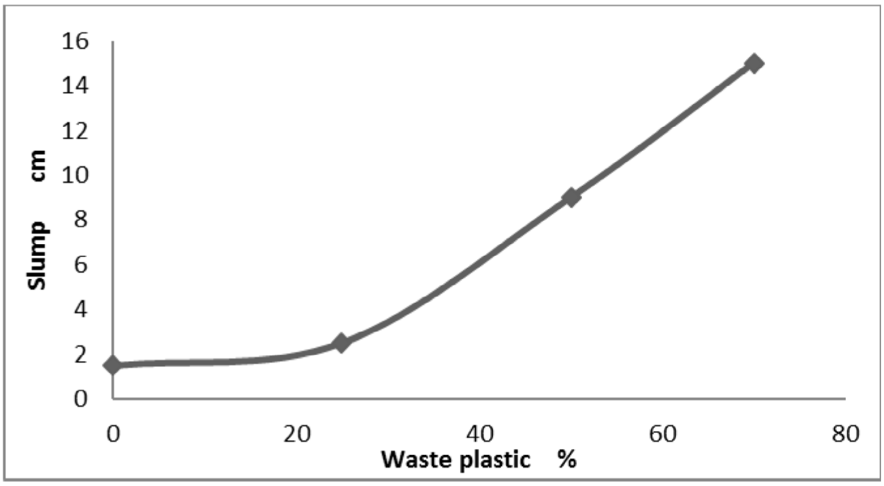
Waste Plastic %	Density (kg/m³)
0	2300
25	2235
50	2100
70	1810

Table 10: Compressive Strength in 7, 28 days

Waste plastic %	Compressive strength (Mpa) in 7 days	Compressive strength (Mpa) in 28 day
0	25	31
25	15.6	20
50	14.1	17.3
70	6.5	9

Up to 40% of the waste, the bulk density of concrete's was reduced to 11.5%. The mortars with 40% of plastic waste, the bulk density were 2100 kg/m^3 . This result has been proved by (Safi *et al.,* 2013). As an example, the results obtained by (Al-Manaseer *et al.,* 1997) showed that density of concrete was reduced by 13% for concrete containing 50% of plastic waste as aggregate.

Figure 2: Slump of Waste Plastic Concrete



the waste plastic ratio because the density of plastic is lower than that of sand by 70% that's clearly shown in Figure 3. This observation was already verified by several authors (Baboo *et al.*, 2012 and Ferreira *et al.*, 2012).

This decrease in density concrete's is probably due to the substitution of a heavier material (sand) by the lighter material.

3. Compressive Strength: The compressive strength are tested at 7 and 28 days, each obtained value are presented from tests performed on three specimens. The evolution of the compressive strength of concrete's is represented in Table 10, Figure 4. We noticed

Figure 3: Density of Waste Plastic Concrete

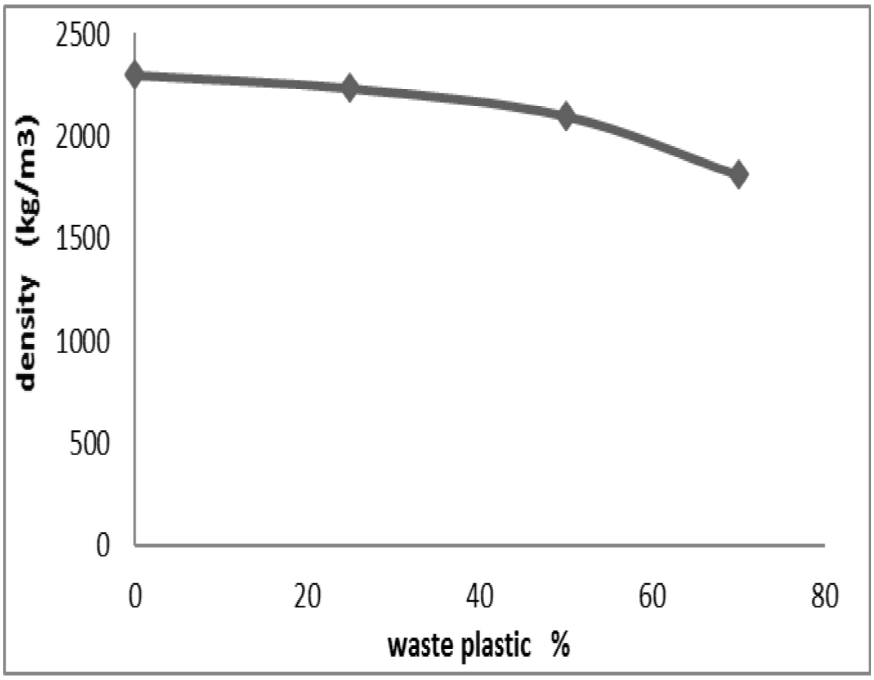
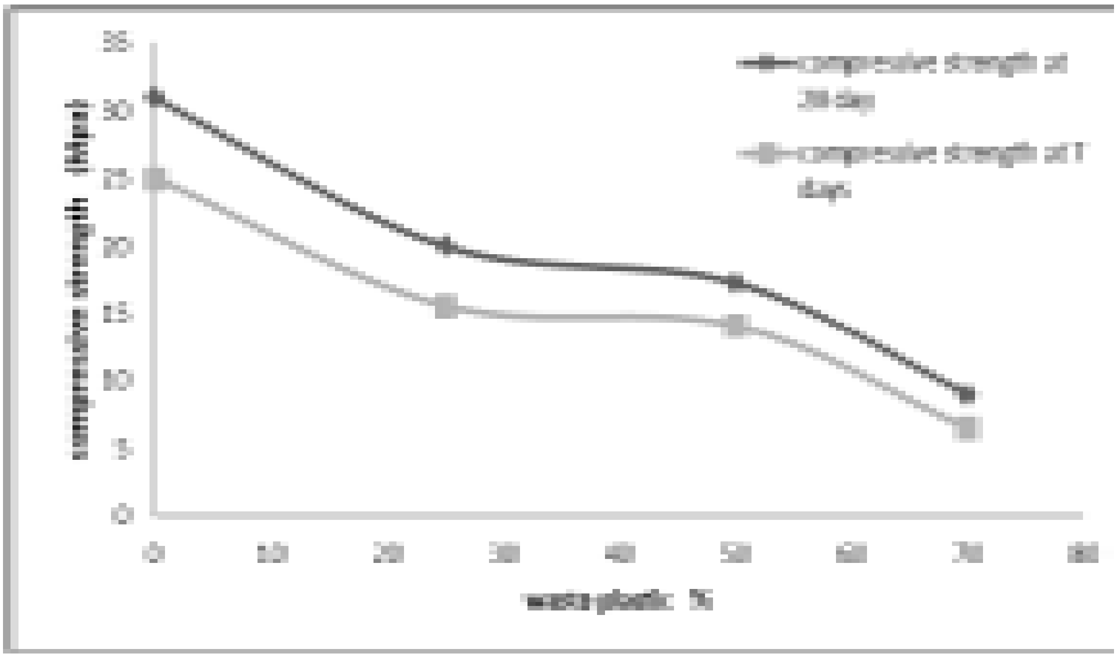


Figure 4: The Compressive Strength of Waste Plastic Concrete in 7 and 28 Days



a reduction in strength according to the increase in percentage of waste plastic in the concrete. This reduction is related to decreasing in concrete density which lead in decrease in compressive strength especially at the age of 28 days as the strength at this age become more sensitive to density variation and much more related to density of concrete mix, the percentages of decrease in concrete compressive strength are; 37% , 43% and 74 % respectively in 7 days and 35% , 44% and 71% respectively in 28 days .

CONCLUSION

Based on the Experimental result following points are summarized with regard to partial replacement effect of waste plastic on the properties of concrete:

1. Compressive strength of concrete is affected by addition of plastic pieces instead of fine aggregate (sand) and it goes on decreasing as the percentage of plastic increases replacement of 1% of plastic in concrete causes about 3.2% reduction in strength after 28 days curing.
2. From the above discussion it is identified that the use of plastic can be possible to improve the properties of concrete which can act as a one of the methods for improvement workability given that fluidity is significantly improved by the presence of this waste.
3. The density values of waste plastic concrete mixtures tend to decrease but they are still averaged to the reference concrete mixture.
4. A reduction in the mechanical resistance according to the increase in percentage of waste plastic, which remains always close to the reference concrete, when we recorded a fall of compressive strength at 28 days about 35% and 71% or the concrete's containing 25% and 70% of waste respectively.
5. Finally, Waste plastic aggregates can be used successfully to replace conventional aggregates in concrete without any long term detrimental effects and with acceptable strength development properties.

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