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SOME PROPERTIES OF ECO-FRIENDLY SELF-COMPACTED CONCRETE WITH PLASTIC WASTE AGGREGATE

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ABSTRACT

This studying including the using of plastic wastes after recycles to produce Eco- Friendly self-compacted Concrete, all these wastes lead to environmental pollution, because the plastic waste isnon-biodegradable solid waste, which arefound at waste disposal areas in Iraq.The present study covers the using wastesof plastic as volumetric replacement to coarse natural aggregates to produce eco-friendly self-compacted concrete. Four self-compacting concrete (SCC) mixes were prepared containing different percentages (25, 50, 75 and 100%) of plastic wastes as a volumetric replacement tocoarsenatural aggregate. In addition to reference self-compacted concrete mix (without plastic waste aggregate).Also, 10% silica fume as a replacement by cement weight was used for each concrete mix. The properties of self-compacted concrete including, workability, fresh density, dry density, compressive strength, splitting tensile strength, and flexural strength were investigated. The results shows that the implication wasteofplastic aggregate causes an increase in flow ability, filing ability, and passing ability of self-compacted concrete through steel reinforcement. Segregation resistance decreases with the increasing of plastic waste content. Also, the results show that the implicationwaste of plastic waste aggregate causes a reduction in density, compressive strength, splitting tensile strength, and flexural strength. The percentage reduction increases with the increasingwaste of plastic waste content in self-compacted concrete

Keywords*:* Self-compacted concrete, Eco-friendly concrete,plastic waste. Environment.

I. INTRODUCTION

"Largeamounts of plasticwaste generating around the world due to the large usingof these materials.""And from the best solutions of sustainable solid waste management is the ability to Reduce, Reuse and Recycling of this waste to the maximum as possible [1, 2].""The consuming of plastics in large quantities is observed all over the world in latest years, leads to an increase wastes of plastic materials". "These wastes now a serious environmentally threat to new civilization." The slow degradation property of plastic waste materials causes a waste disposal crisis from environmental viewpoint. Plastic contains many venomous chemicals, and thus plastic pollutes air, water and soil. "Variety of toxic chemicals is released in to the air when the plastic wastes are burned, including dioxins, one of the more poisonous substance."

Recently, a significant attention has been given to use the plastic wastes in concrete industry. One of the perfect solution as for disposing of plastic wastes is to reuse plastic wastes to produce new type of concrete, which it is ecological and economic benefits[3].There is a significant possibility for the use of plastic wastes as coarse aggregate in concrete preparation. The incorporation of plastic wastes in concrete can significantly improve some self-compacted concrete properties, as plastic has low density, high toughness, and high heat capability [4].

II. MATERIALS & METHODS

Materials

"Ordinary Portland cement type (I) was used in this studying". The results shows that the cement used is corresponding with Iraqi standards No.5/1984[5]. The physical properties and sieve analysis demonstrate that the fine aggregate used is within the requirements of the Iraqi Standard No.45/1984[6]. Natural sand (with maximum

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aggregate size of 4.75mm was used. The grading and sulphate content of the natural crushed coarse aggregate satisfy the requirements of Iraqi Standard No.45/ 1984[(6)], with nominal maximum size of 12 mm was used in this studying. The water used for mixing and curing of self-compacted concrete was potable water.Also, admixture (superplasticizer) with a commercial mark of GLENIUM 54® was used. The recommended dosage by the manufacturer was in the range of 0.5-2.5 liters/100 kg of the cement. This type of admixture is free from chlorides and compatible with ASTM C494-04 type F[(7)].Silica fume is used according torequirementsof ASTM C1240-06 limitation, itscontent is 10% as a parietal replacement of cement weight.Plastic waste as shown in Figure (1a), were collected, crushed,washed and driedto get pieces ofabout 12 mm as shown in Figure (1b). Using a crusher type shown in Figure (1c).The grading of plastic waste aggregate is used in this investigation is shown in Table (1),also, the physical and chemicalproperties of plastic waste is used in this investigation is shown in Table (2).



Fig. (1a): Plastic WasteFig. (1b): Crushed Plastic Waste Fig. (1c):Crusher of Plastic to Pieces of about 12 mm Waste

Figure (1): Preparation of Plastic Waste.

Table (1) Grading of Plastic Waste Aggregate.

Sieve Size (mm)	%Passing By Weight	Limits of Iraqi Standard No. 45 / 1984(68) with (5-12)mm
14	100	90-100
12.5	100	
10	76.6	50-85
4.75	3.54	0-10

Table (2): Physical and chemical Properties of Corse Plastic Waste Used in this Investigation

Type of test	Test result	ASTM Specifications
Density(kg/m^3)	**0.952**	**ASTM D792**
Water absorption (%)	**Zero**	**ASTM D570**
Color	**Color Mix**	**-----**
Sulfate Content (SO_3) (%)	**0.03**	**$\leq$ 0.1**

Concrete Mixing Procedure

Mixing of SCC was carried out in a rotary mixer with a capacity of 0.1m³. The mixing sequence was as follows:

1. The fine aggregate was added to the mixer with 1/3 amount of water and mixed for 1.5 minutes.

2. The Portland cement and silica fume were added and then another 1/3 the amount of water was added and mixed for 3 minutes.
3. Half the amount of coarse aggregate was added with the last 1/3 the amount of water and 1/3 the dosage of superplasticizer and mixing for 1.5 minute then the mixture was left to 0.5 minute to rest.
4. The remaining amount of coarse aggregate and Superplasticizerwas added and mixed for 1.5 minutes.The mixture was then discharged, casted and cured.

No compaction or vibration has been applied to the SCC specimens. This method was chosen according to the limitations of mixing taken by other researchers [(11)].

Preparation of Concrete Specimens

"The steel molds were cleaned from internal surfaces were lubricated to prevent adhesion with concrete after hardening." SCC mixes do not require compacting, so the mixes were poured into the tight steel molds (cubes, cylinders and prisms) until these molds were fully filled without any compaction. The molds were covered with polyethylene sheet for about 24 hours.

Experimental Tests

Different tests were carried out in this investigation including:

Fresh Properties Tests for SCC

Fresh properties of SCC were tested according to procedure of European Guidelines(EFNARE)[(8)]and ACI237+07[(9)]for testing fresh SCC. Three properties were achieved by conducting five tests, which were flow ability, passing ability, and segregation resistance .These tests are:

Slump Flow Test: -"This test is used toestimate of the horizontal free flow of SCC in the absence of obstructions andtoassess the flowability and deformability of SCC."

V- Funnel Test: -"The V-Funnel test is used to measure the filling ability of SCC and can be used to judge segregation resistance."

L-Box Test: -"The L–box test is used to estimate the filling and passing ability of SCC to flow through tight opening includes spaces between reinforcing bars and other obstructions without blocking orsegregation."

Sieve Segregation Resistance Test: -"This test is used to estimate the resistance of self-compacting concrete to segregation."

Fresh Density: -"The fresh density of self-compacted concrete was computed directly after mixing according to ASTM C 138M-01[(10)]."

Hardened Concrete Tests for SCC

In hardened phase, the tests carried out for hardened SCC were:

Compressive Strength Test: -"This test was carried out on concrete cubes specimens of 100 mm according to BS 1881: part116[(11)]."

Splitting Tensile Strength Test: -"The splitting Tensile Strengthwas carried out 0n concrete cubes specimens of (100*200) mm according t0according to ASTM C496-07[(12)]."

Modulus of Rupture Test:-"Themodulus of rupture test was carried out on concrete prismatic specimens (100 x 100 x 400 mm) were tested toestimate the modulus of rupture under two point loads according t0 ASTM C78-02[(13)]."

Oven Dry Density and Absorption Water Tests: -"Oven dry densityand absorption in hardened concrete were determined at 28 days according to ASTM C 642 – 97[14]."

III. RESULT & DISCUSSION

Selection of Mix Proportions

The mix proportions was 1:1.72:1.97 (cement: sand: gravel), cement content of 450 kg/m³, sand 778 kg/m³ and crushed aggregate of 890 kg/m³ with nominal maximum size of 12mm, w/c ratio of 0.38 were used .This Self-compacting concrete (SCC) mix was designed according to EFNARC [8], to obtain concrete with minimum compressive strength of40 MPa at 28 days. "Several trial mixes were carried out to select the optimum dosage of high range water reducing admixture(HRWRA) that was determined by using all workability testes of SCC."According to the manufacturer, the recommended dosage of HRWRA (GLENIUM 54®) is between 0.5 and 2.5 liters per 100kg of cement (cementitious material). The experimental results in this study indicate that the optimum dosage of HRWRA is 2.2 liters per 100 kg 0f cementin this investigation.It can be seen that HRWRA leads to a significant improvement compressive strength and causes a decrease in water cement ratio in comparison with in the reference mix. "This is due to the action mode of the superplasticizer, that when it is added to cement water system, the polar chain is adsorbed on the surface of cement particles.""These surfactants give strong negative charge around the grain lowering the inter particles attraction by an electrostatic mechanism and produces amount of waterconsequently lower amount of water is required to attain equal workability [15]."Finally, 10% silica fume was used as a replacement t0 cement weight. The results indicate that the use of silica fume improve the flowability, filing ability, and passing ability of self-compacted concrete through steel reinforcement. The limits of EFNARC andACI237+07 for tests of SCC are given in Table (3),also the properties of self-compacted concrete mixes containing different dosages ofsuperplasticizerand properties of reference self-compacted concrete mix containing silica fume (10%) are given in Table (4),Also,the relationship between the
different dosages of HRWRA andcompressive strength of SCCis shown in Figure (2).

Table (3): Limits of EFNARC andACI237+07 for tests of SCC

SCC Tests	Limits of Specifications
Slump Flow (mm) Class (SF3)*	≥ 740 mm ≤ 900 mm
V-Funnel (sec.) Class (VF2)*	≥ 7 sec. ≤ 27 sec.
L- Box Class (PA2)*	≥ 0.75
Sieve Segregation Resistance (%) **	>10

*** Limits of EFNARC 2005**
**** Limits ofACI237+07**

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Table (4): Properties of Several Self-Compacted Concrete Mixtures

Mix Proportions	Silica Fume* Content (%)	Dosage of HRWRA (liter/100kg of Cement)	w/cm	Slump Flow (mm) Class (SF3)	V-Funnel (sec.) Class (VF2)	L-Box Class (PA2)	Sieve Segregation Resistance Class (SR2)	Compressive Strength (MPa)	
								7 days	28 days
(1:1.72:1.97) Cement: Sand : Gravel with Cement Content of 450 kg/m3	----	1	0.38	457	32	0.68	9.7	22.9	30.7
	----	1.5	0.38	574	28	0.72	12.4	26.4	34.2
	----	2	0.38	767	19	0.77	13.1	29.1	37.8
	----	2.2	0.38	782	11.5	0.78	12.6	31.1	42.2
	----	2.5	0.40	811	19.7	0.75	11.2	29.5	39.1
	10	2.2	0.38	794	9.5	0.8	16.2	37.75	48.74

*** Replacementby weight of cement.**

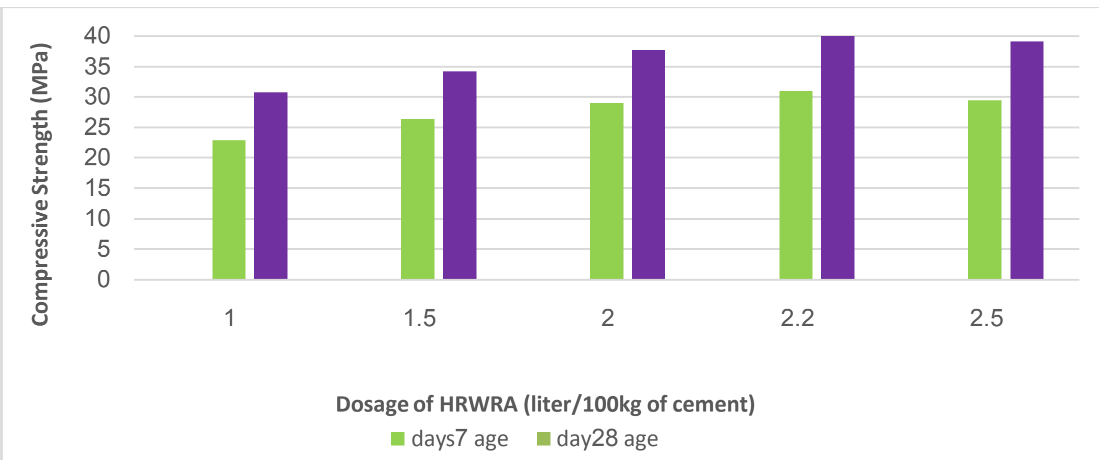

Fig. (2): The Relationship between the Different Dosages of HRWRA andthe Compressive Strength

Workability

The test results in Table (6) illustrate thatthe slump flow is increased, decreasing the filling time, and increasing speed of passing of fresh self-compacted concrete thought reinforcement bars. Thus, is because the water absorption of plastic wastes is equal to zero, while the water absorption of natural coarse aggregate is equal to 1.87%. Thus increasing of flowablity, passing ability, and filling ability of self-compacted concrete. On the other hand, the segregation resistance(S.R) of fresh concrete is decreasedwith increasing the percentage of plastic wastes as a volumetric replacement to coarsenatural aggregate.We have been selected classof (SF3)expressed by slump-flow, which is SF3 is "produced with a small maximum size of aggregates (less than 16 mm) and is used for vertical applications in very congested structures, structures with complex shapes, or for filling under formwork." Also we have been selected class of (PA2) expressed by passing ability (L-Box test), which is PA2 "is used for structures with a gap of 60 mm to 80 mm, (e.g. civil engineering structures)."Also,"we have been selected class of (VF2) Viscosity classes expressed by V-Funnel timeaccording to search requirements."

Fresh Density
Generally, the results in Table (6) shows a significant reduction in the fresh density with the increasing of plastic waste content compared with the reference mix (without plastic waste). This is due to the low density of plastic waste 0.952kg/m^3 compared with the density of coarse natural aggregate 2.53kg/m^3, the percentage reduction increases with the increase of plastic waste content in concrete.

Oven Dry Density and Water Absorption
Table (6) shows a significant reduction in dry density for SCCspecimens containing plastic waste;this is due to the low density of plastic waste 0.952 kg/m^3 compared with the density of coarse natural aggregate 2.53kg/m^3.The percentage decrease increases with the increase of plastic waste content in concrete. On the other hand,the water absorption for self-compacted concrete is increased with increasing the percentage of plastic wastes in concrete."This is due to the shape of plastic aggregate (fluky and elongation), that leads to increasing the continuous path between pores andincreases porosity.""Also, the low density of plastic waste leads to unsuitable compaction then more pores are formed." The water absorption for all self-compacted concrete specimens is ranged from 1.09 to 2.03.

Natural Compressive, Splitting Tensile and Flexural Strengths
The effect of the different percentages of plastic waste as a volumetric replacement to coarse aggregate (25%, 50%, 75%, and 100%) on the SCC compressive strength, splitting tensile strength, and flexural strength at age 28 days is illustrate in Table (6) .The compressive strength 0f SCC containing different percentages of plastic wastewas reduced compared with the reference specimens(without plastic waste).The percentages reduction for SCC with 25%,50%,75% and 100% are 23.65%,42.63%, 52.56% and 65.63% respectively relative to self-compacted concrete specimens without plastic waste aggregate ."The decrease in compressive strength is because of the reduction in the bond strength between the cement paste and plastic waste aggregate" this correspond with mentioned by **Kinda et al.**[(16)]. In addition, the natural aggregate is stronger than plastic aggregate, and as the most strength of concrete is from the strength of aggregate because approximately three quarters of the volume of concrete an occupied by aggregate [(17)]."Therefore,"the amount and the strength of aggregate play an important role in the strength of concrete[(18)]."The splitting tensile, flexural strength of self-compacted concrete containing different percentages of plastic waste(25%, 50%, 75%, and 100%) at 28 days age were reduced compared with the reference specimens (without plasticwaste) for the same reasons mentioned for the compressive strength of self-compacted concrete. Details ofconcrete mixes used in the present investigation, also the results of thewater absorption, fresh density, oven dry density, compressive, splitting Tensile, and flexural strengths of different self- compacted concrete mixes is shown in Table (5), and Table (6)respectively. Also,the relationshipbetween plastic waste content and the compressive strength of self-compacted concrete is shown in Figure (3).

Table (6): Water Absorption, Fresh density, Oven Dry Density, Compressive, Splitting Tensile, and Flexural strengths of Different self- compacted Concrete Mixes.

Mix Symbol	SCC Tests		Fresh Density (kg/m^3)	Oven dry Density (kg/m^3)	Water Absorption (%)	Compressive Strength (MPa.)	Splitting Tensile Strength (MPa.)	Flexural Strength (MPa.)
S.F	Slump (mm)	794	2362	2285.5	1.09	48.74	3.21	3.51
	V-funnel(sec.)	9.5						
	L-box	0.79						
	S.R (%)	16.2						
25% P.	Slump(mm)	807	2254.5	2087.7	1.35	37.21	2.79	3.09
	V-funnel(sec.)	8.7						
	L-box	0.81						
	S.R (%)	13.9						
50% P.	Slump(mm)	819	2162.1	1901	1.62	27.96	2.48	2.72
	V-funnel(sec.)	7.2						
	L-box	0.81						
	S.R (%)	11.2						
75% P.	Slump(mm)	832	2036.1	1814	1.91	23.12	2.31	2.55
	V-funnel(sec.)	6.5						
	L-box	0.82						
	S.R (%)	10.7						
100% P.	Slump(mm)	845	1952.1	1767.5	2.03	17.1	2.09	2.31
	V-funnel(sec.)	5.9						
	L-box	0.82						
	S.R (%)	10.1						

Table (5): Details of Concrete Mixes Used in the Present Investigation.

Mix Symbol	Silica Fume as Replace by Weight of Cement (%)	Plastic Waste as a Volumetric Replace to Natural Coarse Aggregate (%)	Age (days)	Mix Proportion by Weight for the Reference Mix (R)
SF	10	----	28	1:1.72:1.97 (Cement Sand: Gravel) Cement Content of 450 kg/m^3, w/c=0.38, HRWRA= 2.2 Liter /100kg Cement
25P	10	25	28	
50P	10	50	28	
75P	10	75	28	
100P	10	100	28	

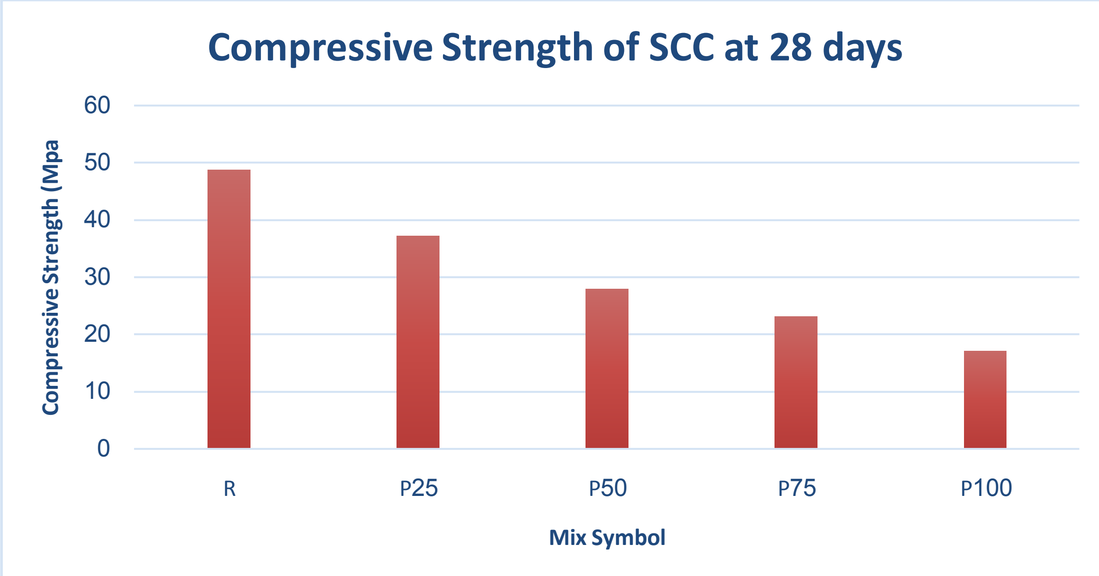

Figure (3): Relationship between Plastic Waste Content and the Compressive Strength of self-compacted Concrete.

IV. CONCLUSIONS

1. Plastic waste with maximum size (12mm) can be used as a v0lumetric replacement to naturalcoarse aggregate in self-compacted concrete.
2. The slump flow diameter is increase as the content 0f coarse plastic waste aggregate increased in SCC mix .The value for the reference SCC mix are 794mm,while for SCC mixes with different content of plastic waste aggregate are in the range of 807- 845mm.The percentage increase increases with the increase of plastic waste content in self-compacted concrete.
3. The V-funnel flow time, L-box ratio, and the segregation resistance are decrease as the content of coarse plastic waste aggregate increased in SCC mix.The values for the reference SCC mix are 16.2sec.,0.8,and 9,2 respectively, while for SCC mixes with different content of plastic waste aggregate are in the range of 8.7- 5.9 sec,0.79-0.77,and 13.5-9.2 respectively.The percentage decrease increases with the increase of plastic waste content in self-compacted concrete.
4. The compressive, splitting tensile and flexural strengths with the use of plastic waste in different percentages (25%.50%, 75%, and 100%) as a volumetric replacement t0 coarse aggregate in self-compacted concrete are decreased.The percentages reduction in compressive, splitting tensile , and flexural strengths for reference mix SCC with 100% natural coarse aggregate are 48.74,3.21, and 3.51 MPa respectively, while for mixes with different content of plastic waste aggregate are in the range of 37.21-16.75, 2.79-2.09, and 3.09-2.31 MPa respectively. The percentage decrease increases with the increase 0f plastic waste content in self-compacted concrete.
5. The use of plastic waste in different percentages (25%.50%,75%,and 100%) as a volumetric replacement to natural coarse aggregate in self-compacted concrete mixessignificantly reduces ofthe fresh, and dry densitycompared with the reference mix (without plastic waste). The percentage decrease increases with the increase of plastic waste content in concrete.
6. Structural light weight aggregate SCC can be produced using plastic waste aggregate up to 25% as a volumetric replacement to natural coarse aggregate in SCC .
7. Concretespecimens containing different content of plastic waste shows anincrease in waterabsorption compared with the reference SCC concrete(without plastic waste)

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