The Effect of Using Recycled Aggregates on Some Mechanical and Impact Properties of Concrete Slabs Reinforced with Plastic Waste Fibers.

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November 4, 2020

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Key words: recycled aggregate, waste plastic fibers, impact property.

Abstract

The products of the demolished concrete from the effects of bombing and the spread of waste plastic bottles everywhere are among the largest pollutants that threaten the environment, especially in Iraq after the wars it passed and the weak basic services. In this study, demolished concrete products were used after being crushed and replaced with coarse aggregate and the addition of fibers produced from manual chopping of plastic bottles used in preserving soft drinks to improve the impact property and some mechanical properties of concrete. Two mixtures were poured, the first containing coarse aggregate with different fibers ratios, and the second coarse aggregate was replaced by crushed concrete products with different fibers ratios. Also, two reference mixtures were poured without adding fibers to each type for the purpose of comparison. The results of concrete containing natural coarse aggregate at the percentage of adding fibers (1.2%) Showed a slight decrease in concrete density by (3.56%) And an improvement in compression resistance and bending resistance by (17.4%) (44.82%) At age (28) days, respectively, and improvement in the impact resistance of slabs by (285.71%) At age (56) days. The results of concrete containing recycled aggregates of damaged concrete at the percentage of adding fibers (1.2%) Showed a slight decrease in the density of concrete by (3.08%) And an improvement in compression resistance and bending resistance by (28.1%) (42.26%) At age (28) days respectively, the impact resistance of the slabs improved by (320%) At age (56) days.

1. Introduction

Waste is found in large quantities in dumping areas and it has high protection from biological and weather conditions, making it unsustainable. [1]. The recycling of waste compared to its high disposal rate was not sufficient. Therefore, the need to discover another method of disposal increased from time to time, especially polyethylene terephthalate (PET) which is a type of plastic commonly used to make plastic bottles [2]. The addition of PET fibers in concrete mixes is important to control the ductility shrinkage cracks in concrete. Plastic shrinkage cracks are widely visible in mortars, which have a large surface exposure to these cracks [3]. The addition of waste plastic fibers which made from manual cutting of beverage bottles can be enhanced some mechanical properties of Ferro-cement mortar [4]. Also, the replacement of natural coarse aggregate by coarse recycled aggregate in concrete mix showed that if The percentage exceeds 50% of recycled aggregate in mix the mechanical properties reduced [5].

2. Experimental Program

2.1 Materials

2.1.1 Cement

To cast the specimens as cubes, prism and slabs, (OPC - Type I) Ordinary Portland Cement production of Al-Mass company was used. It adjusted to **ASTM C150** [6] & **IQS 5/1984** [7].

2.1.2 Fine Aggregates

Natural sand has used. it was clean and has no clay and no organic materials. Table (1) listed sieve analysis and Table (2) listed the physical properties of fine aggregate. It was adjusted to **IQS 45/1984** [8].

Table (1). Sieve Analysis of Fine Aggregate.

Sieve Size (mm.)	Passing %	**IQS 45/1984**
10	100	100
4.75	93	90 – 100
2.36	82	75 – 100
1.18	69	55 – 90
0.6	47	35 – 59
0.3	18	8 – 30
0.15	6	0 – 10

Table (2). Properties of the Fine Aggregate.

properties	Result	**IQS 45/1984**
Specific gravity	2.40	-
Sulfate content (SO_3%)	0.41%	0.5% (max)
Absorption%	0.70%	-
Fineness modulus	2.85	-

2.1.3 Coarse aggregate

Natural gravel has used, it washed and submerged in water about two hours and dried in air to get saturated surface dry (SSD). Table (3 & 4) listed the properties and sieve analysis of coarse aggregate respectively. It was adjusted IQS 45/1984 [8].

Table (3). Properties of Coarse Aggregate.

Properties	Test results	**IQS 45/1984**
Specific gravity	2.66	-
Sulfate content	0.07	$\leq$0.1
Absorption %	0.54%	-

Table (4). Sieve Analysis of Coarse Aggregate.

Sieve Size (mm)	Passing %	**IQS 45/1984**
12.5	100	100
9.5	91	85-100
4.75	15	0-25
2.36	3	0-5

2.1.4 Recycled Aggregate

The recycled aggregate was made from crashed the demolished concrete from the effects of bombing by hand and graded to fitting the grade of course aggregate, it was also washed and submerged in the water about two hours and dried in air to get saturated surface dry (SSD). Tables (5 & 6) listed the sieve analysis and the properties of recycled aggregate respectively. plate (1) showed the recycled aggregate. the recycled aggregate adjusted to **IQS 45/1984** [8].

Table (5). Sieve Analysis of Recycled Aggregate.

Sieve Size (mm)	Passing %	**IQS 45/1984**
12.5	100	100
9.5	94	85-100
4.75	19	0-25
2.36	4	0-5

Table (6). Properties of Recycled Aggregate.

Properties	Test results	**IQS 45/1984**
Specific gravity	2.59	-
Sulfate content	0.09	≤0.1
Absorption %	0.71%	-

Plate (1). The Recycled Aggregate.

2.1.5 Waste Plastic Fibers

The waste plastic fibers that used in this study is resulting from cutting manually and its identical to **ASTM–A 820** [9]. The geometrical properties of this fibers are illustrated in Table (7). Fibers were added to the mixes as a percentage by volume of mixes of (0.6, 0.8, 1.0, 1.2) and (1.4) respectively. plate (2) show waste plastic fibers and cutting machine.

Table (7). Properties of Waste Plastic Fibers.

Properties	Length (mm)	Width (mm)	Thickness (mm)	Specific gravity (gm/cm^3)
Plastic fiber	39	4	0.35	1.1

Plate (2). Waste Plastic Cutting Machine and The Fiber.

2.1.6 Water

Ordinary drinking water was used to produce and curing all concrete specimens without any admixture. The water was conforming to **IQS1703** [10]. Table (8) showed the results of tested water.

Table (8). Properties of Used Water.

Test	Result (mg/l)	Limits of IQS1703
SO_3^{-2} ions	480	1000
CO_3^{-2} ions	66	1000
Cl_2^{-2} ions	336	500

2.1.7 Concrete Mixes

Two mixes were made in the present work of normal concrete and recycled aggregate concrete with use same mixing proportions, to arrival the required of compressive strength. Six ratios of (%WPF) added to the mixture (0.6, 0.8, 1, 1.2 and 1.4%) as volumetric ratios. The procedure of mixing was conforming to **ASTM CI92** [11].

2.1.8 Normal Weight Concrete (NWC)

The proportions of preparation the Normal-Weight Concrete mix were calculated and then mixed mechanically until all components become uniform. to produce waste-plastic concrete (WPC), the fibers of waste-plastic were added to the dry mix. All materials mixed drily until the mix becomes uniform. Then, the calculated water added and remixed all components until being homogenous. Table (9) show mix-proportions of materials used for Normal-Weight Concrete (NWC).

Table (9). Mix Properties of Materials.

Mix	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	(w/c) $\mathscr{L}$	Waste plastic fiber (Kg)
R1	21	35.5	54	9.12	0
M1	20.82	34.15	53.5	9.02	0.400
M2	20.78	34. 08	53.4	9.00	0.534
M3	20.74	34.01	53.3	8.98	0.668
M4	20.70	33.95	53.2	8.96	0.802
M5	20.66	33.88	53.1	8.94	0.936

2.1.9 Recycled Aggregate Concrete (RAC): -

To prepare the Recycled-Aggregate Concrete mix, the proportions were calculated and then mixed mechanically until all components seem homogeneous and during the mix operation the fibers added to the mix timing with addition of components. Table (10) show mix-proportions of materials used for Recycled-Aggregate Concrete (RAC).

Table (10). Mix Properties of Materials

Mix	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	(w/c) $\mathscr{L}$	Waste plastic fiber (Kg)
R2	19.05	31.24	48.96	8.25	0
MR1	18.94	31.06	48.68	8.21	0.400
MR2	18.90	31.00	48.57	8.19	0.534
MR3	18.86	30.93	48.47	8.17	0.668
MR4	18.82	30.86	48.36	8.15	0.802
MR5	18.78	30.80	48.26	8.13	0.936

2.1.10 Curing

Specimens were cured under ideal conditions. All specimens submerged in water basin with fresh water. Plate (3) show the Tested specimens.

Plate (3). The Tested Specimens

2.2 Tests

2.2.1 Compressive Strength

To determine the compressive strength, a mold of the cube (150 ×150 ×150) mm was used according to **BS 1881 – 119** [12]. Three specimens of cubes were tested for each type of mix of concrete at two ages (7 & 28) days. All test results were listed in Tables (11a &11b).

Table (11a). Compressive Results for Cubes of the NWC.

Mix	WPF %	Compressive strength (Mpa)		Change in compressive strength at 28 days.
		7 days	28 days	
R1	0	27.2	40.5	-
M1	0.6	27.5	42.0	3.7 %
M2	0.8	28.0	44.0	8.6 %
M3	1.0	31.5	46.5	14.8 %
M4	1.2	30.5	44.5	9.8 %
M5	1.4	28.5	41.0	1.2 %

Table (11b). Compressive Results for Cubes of the RAC.

Mix	WPF %	Compressive strength (Mpa)		Change in compressive strength at 28 days
		7 days	28 days	
R2	0	32.0	42.5	-
MR1	0.6	33.0	44.5	4.7 %
MR2	0.8	39.5	47.0	10.6 %
MR3	1.0	44.0	50.5	18.8 %
MR4	1.2	42.0	48.0	12.9 %
MR5	1.4	34.0	45.0	5.9 %

2.2.2 Flexural Strength (Modulus of Rupture): -

According to **ASTM C 293** [13] (center-point loading), flexural strength or modules of rupture test defined as the stress in a concrete before yield in flexure. The prism dimension is (400×100×100) mm which used to determine the flexural strength of concrete in different percentages of (WPF) and normal concrete with different ages. Three specimens were tested at two ages (7 & 28) days. All test results were listed in Table (12a &12b). (Modulus of rupture) is calculated using following formula:

$$f_r = 3PL/2bd^2$$

f_r**:** flexural strength, (MPa). P**:** max. applied load (N).

L**:** Span length of specimen, (mm). b**:** average width of specimen (mm).

Table (12a). Flexural Results for Prisms of the **NWC**.

Mix	WPF %	Flexural Strength (Mpa)		Change in Flexural Strength at 28 days.
		7 days	28 days	
R1	0	2.8	4.3	-
M1	0.6	3.0	4.5	4.6 %
M2	0.8	3.2	4.7	9.3 %
M3	1.0	3.4	5.1	18.6 %
M4	1.2	3.5	5.5	27.9 %
M5	1.4	2.8	4.6	6.9 %

Table (12b). Flexural Results for Prisms of the **RAC**

Mix	WPF %	Flexural Strength (Mpa)		Change in Flexural Strength at 28 days
		7 days	28 days	
R2	0	2.6	4.3	-
MR1	0.6	3.8	4.5	4.6 %
MR2	0.8	4.2	5.3	23.3 %
MR3	1.0	4.5	5.6	30.2 %
MR4	1.2	4.9	6.0	39.5 %
MR5	1.4	4.7	5.5	27.9 %

2.2.3 Density Test: -

Density was determined by weighing the cubes after dried and dividing its weight by the measured volume of the cubes. Dry Density test was measured according to **ASTM C642** [14] and Dry density was measured three cubes of (100×100×100) mm for every mix at 28 days. Table (13a & 13b) listed the density test of the Normal-Weight Concrete (NWC) and the density test of the Recycled- Aggregate Concrete (RAC).

Table (13a). Density of the **NWC** specimens

Mix	WPF%	Density (kg)		Change in density at 28 days.
		7 days	28 days	
R1	0	2358	2388	-
M1	0.6	2368	2348	-1.68%
M2	0.8	2363	2345	-1.80%
M3	1.0	2345	2335	-2.22%
M4	1.2	2325	2305	-3.48%
M5	1.4	2293	2272	-4.86%

Table (13b). Density of the **RAC** specimens.

Mix	WPF%	Density (kg)		Change in density at 28 days.
		7 days	28 days	
R2	0	2358	2368	-
MR1	0.6	2355	2338	-1.27%
MR2	0.8	2335	2323	-1.90%
MR3	1.0	2295	2280	-3.72%
MR4	1.2	2245	2229	-5.87%
MR5	1.4	2235	2218	-6.33%

2.2.4 Impact Test for Slabs

To demine Low-Velocity Impact Tests, a method of Repeated Falling Mass was used (1300) gm steel ball falling freely from height 2.4 m, six slabs for every mix with (56) day age (400×400×50) mm dimension were tested. The number of blows to cause the first crack and failure was recorded. Tables (14a & 14b) listed a number of blows.

Table (14a). No. of blows for **NWC** slabs.

Mix	WPF %	(No. of blows).		Change in Impact Resistance in 56 days
		First crack	failure	
R1	0	2	7	-
M1	0.6	3	15	114.3 %
M2	0.8	1	17	142.8 %
M3	1.0	2	18	157.1 %
M4	1.2	3	23	228.5 %
M5	1.4	4	21	200 %

Table (14b). No. of blows for **RAC** slabs.

Mix	WPF %	(No. of blows).		Change in Impact Resistance In 56 days
		First crack	failure	
R2	0	1	10	-
MR1	0.6	2	22	120 %
MR2	0.8	2	31	210 %
MR3	1.0	2	35	250 %
MR4	1.2	2	42	320 %
MR5	1.4	3	29	190 %

3. Results and Discussions

3.1 Compressive Strength Test

Test results in Table (12a & 12b) at ages (7 & 28) days for (0, 0.6, 0.8, 1.0, 1.2 & 1.4%) of (WPF) by volume and plotted in Figure (4) showed That compressive strength increased with compared to the reference mix without (WPF) up to (14.8 %) and (18.8 %) for both mixes respectively. This increasing caused by the ductility and elongation of (WPF) through cracks beside, the compressive strength increased with age because of the concrete be stiffer and strength due to complete processes of hydration and reduces in porosity and after that there was dropped in result, Plate (4) shows the tested cubes.

Fig. (4). The increasing of compressive strength at age of **(28)** days.

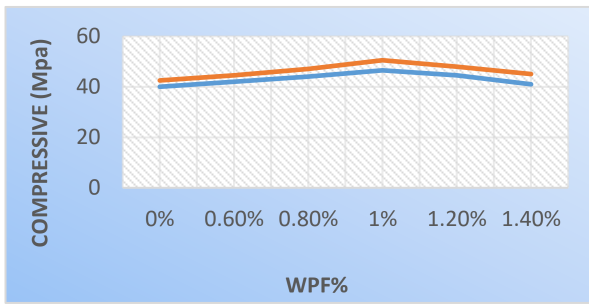


Plate (4). the tested cubes.

3.2 Flexural Strength Test

All results for flexural test of both concrete mixes with (WPF) listed in Tables (13a & 13b) respectively. Its plotted in Figure (5) at (7 & 28 days) for (0, 0.6, 0.8, 1.0, 1.2 and 1.4%) of (WPF) as volume. Flexural strength increased with increased (WPF) also increased with curing time. because the presence of (WPF) make tight the microscopic coracles to propagate and reinforced the concrete matrix. Plate (5) shows the tested prisms.

Fig. (5). Changing in flexural strength at age of **(28)** days.

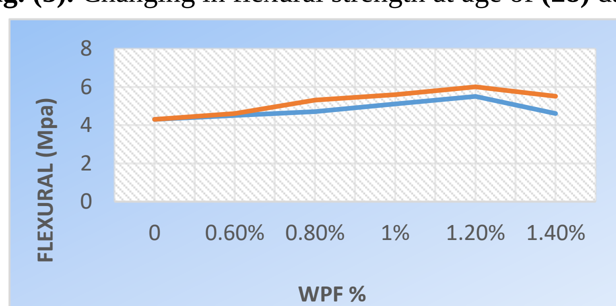
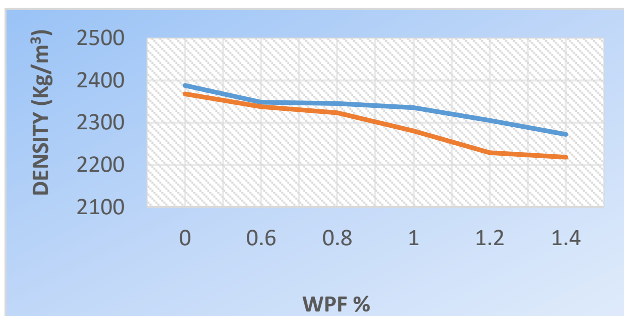


Plate (5). the tested prisms.

3.3 Density Test

Tables (11a & 11b) listed the density of tested specimens of both mixes. The results showed that the density decreased with increasing the volume ratio of (WPF) for both mixes. This is caused by that replacing of concrete components with plastic fibers as volume reducing the density due to the density of plastic is much less than concrete components. Figure (6) showed the changes in density for both mixes.

Fig. (6). The decreasing of density at age (28) days.



3.4 Impact Test

Results of impact resistance listed in tables (16 a) and (16 b) for both mixes. The results showed increasing in numbers of blow for the slab specimens with increased of (WPF) with respect to reference mixes. This increasing due to enhancing the ductility because of the fibers bridges the cracks and prevent it of developed. The maximum increasing of blows resistance was (228.5%) and (320%) at (1.2%) of (WPF) for both mixes respectively. Figure (7) showed the changes in numbers of blows for both mixes. Plate (6) shows the tested slabs.

Fig. (7). The increasing of no. of blows with compared to the reference mixes at age of **(56)** days.

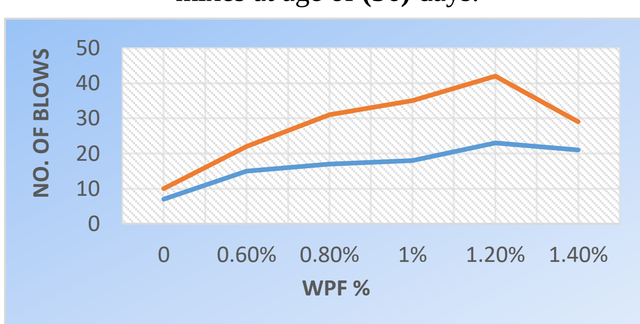


Plate (6). the tested slabs.

4. Conclusions

Based on the experimental work and results obtained in this study, the following conclusions can be presented:

1- Waste fiber addition with different ratios enhancing the compressive strength at age of (28) days compared with both reference mixes. The magnitudes of enhancing at (1.0%) of (WPF) about (14.8%) and (18.8%) for both mixes respectively at age of 28 days.
2- Waste fiber addition with different ratios increases the flexural strength at age of (28) compared with both references mixes. The maximum magnitudes of increasing at (1.2%) of (WPF) about (27.9 %) and (39.5%) for both mixes respectively at age of 28 days.
3- Waste fiber addition with different ratios decreases the density at age of (28) days compared with both references mixes.
4- Waste fiber addition with different ratios increases the impact resistance at age of (56) days compared with both references mixes. The maximum magnitudes of increasing at (1.2%) of (WPF) about (228.5 %) and (320 %) for both mixes respectively at age of (56) days.

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