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Experimental Investigation on the Efficacy of Polyethylene Aggregate on Impact Resistance of Concrete Slab

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ABSTRACT

The impact resistances of concrete slabs have a different volume fraction replacement of waste plastic aggregate has been examined in this study as a fine aggregate as: 0% (reference), 10%, 20% and 30%. These tests include the splitting tensile, density, compressive strength. Also, the (ultrasonic pulse velocity tests) was carried out. Repeated falling mass was used in order to carry out the low-velocity impact test in which a 1300 gm steel ball was utilized. From a height of 2400mm, the ball falls freely on concrete panels of (500×500×50 mm) with a network of waste plastic aggregate. As per the results, a prominent development was seen in the mechanical properties for mixes involving polyethylene aggregate up to 20% as compared to the reference mix. A significant development was seen in low-velocity impact resistance of all mixes involving waste plastic fine aggregate as compared to reference mix. As per the results, the greater impact resistance at failure is offered by the mix with (20%) waste plastic aggregate by volume of sand than others. The reference mix increased by (712.5%).

1. Introduction

A massive number of packages made using a polyethylene materials such as nitro packs ,shampoo sachets, water pouches, milk and packaged foods …etc., which are frightened in waste household and landfills is a significant environmental issue in the majority of the areas in Iraq [1]. In order to minimize the consumption of the energy and the natural resources, original kinds of engineering involving sustainable engineering and green engineering have been discovered by scientists. Green engineering intends to minimize impact while increasing the welfare of the environment, society, and the economy at the same time [2].

The cost of materials is minimized and some solid waste harm caused by plastic is also removed by reutilizing waste plastic as sand in concrete [3]. The plastic aggregate (*PA*) is included at a substitute level of 25% in the concrete mix, which can be utilized in both structural and non-structural application requirement sensible strength and ductility [4].

The values slump of concrete mix that result is decreased by including some kinds of plastic aggregate like firm polyurethane foam waste or modified waste expanded polystyrene aggregates (MEPS) because of the presence of a large number of surface pores in these aggregates [5,6,7]. Fresh density concrete is minimized when plastic is included as a fine aggregate [8].

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According to few researchers, the decrease in the densities between the fresh and dry samples remained the same as in the samples have plastic aggregates, but this decrease was a larger than before. The concrete bulk density is reduced due to increasing in the plastic aggregates content [9]. It has been seen that by including recycling waste plastic as sand in mortars at amount (0%, 10%, 20%, 30% and 50% by weight of the sand), the mortars having 50% of plastic waste provide better outcomes as compared to the other proportion of the waste and mechanical strength sufficient for lightweight materials [10].

According to some researchers, the control concrete and slump were minimized by increasing the percentage of plastic waste replacement, compressive strength and flexure strength [11]. Many researchers have studied about effect of pet fibres on reinforced concrete and the found it's improve mechanical properties [12-15].

2. Objectives

The objectives can be summarized as follows:

1- Recycling the waste of boxes rather discarding them to produce an environment-friendly concrete.
2- Manufacturing lightweight concrete (LWC).
3- Studies the mechanical properties of fresh concrete and investigates the impact behavior by using a Polyethylene waste as plastic aggregates.

3. Materials

The following materials have been utilized in the experiment:

1- Ordinary Portland cement: (MASS) Ordinary Portland cement of grade (CEM I 42.5R) had been utilize in the experiment. It stored in airtight bags to avoid exposure to different atmospheric conditions. Table 1 and 2 show the physical and chemical properties of cement, respectively.

Table 1. physical properties for cement according to Iraqi specification

Physical Properties	Test Result	Limits of Iraqi Specification No.5, 1984
<u>Setting time (min.)</u>		
Initial setting	120	≥ 45 minutes
Final setting	360	≤ 600 minutes
Fineness by Blaine method (m2/Kg)	300	≥ 230
% Auto Clave	0.31	≤ 0.8

Table 2. chemical properties for cement according to Iraqi specification

Oxide	Weight (%)	Limits of Iraqi Specification No.5, 1984
CaO	62.3	-
SiO2	20.28	-
Al2O3	5.55	-
Fe2O3	4.20	-
MgO	2.60	< 5.0
K2O	0.75	-
Na2O	0.4	-
SO3	2.4	< 2.5
L. S. F.	0.81	0.66 – 1.02
Loss of Ignition	1.65	< 4.0
Insoluble Remains	0.5	-
Free Lime	0.65	-
C3S	50.05	-
C2S	20.45	-
C3A	4.05	-
C4AF	13.20	-

2- Coarse aggregate: In this experiment, crushed gravel with maximum size of ten mm was utilized as coarse aggregate.
3- Fine aggregate: A fine aggregate was achieved from local quarry. This sand is completely uncontaminated and free of organic matters. Table 3 depicts the achieved physical properties.

Table 3. physical properties of sand according to Iraqi specification

Sieve No. (mm)	Accumulated (Percentage Passing) Type II	Limits of Iraqi Specification No.45, 1984
4.75	100	90 - 100
2.36	74.57	100 - 70
1.18	62.77	90 - 55
0.6	36.20	59 - 35
0.3	9.15	30 - 8
0.15	2.36	10 - 0

4- Water.
5- Plastic aggregates: Green Polyethylene having Gs-0.94 was utilized as a partial substitution of sand and it was cutting by cutting machine in plastic factory, as shown in Fig. 1.
6- Steel mesh: A BRC having square openings and dimensions of (70 × 70 mm) and 3 mm diameter were utilized as reinforcement for two-way slab examined in this research. Have a look at Fig. 2.

Fig.1. plastic aggregates

Fig.2. B.R.C.

4. Mix Proportions and Preparation of Concrete Slab (Casting, Compaction and Curing)

(Cement : Sand : Gravel) the ratio in this research was (1 : 2 : 4), a water/cement ratio of (0.5) and plastic aggregate ratio (10, 20, 30) % by volume of sand. By weight the mix content is show in table 4.

Concrete was made after calculated the exact amounts of all material. A mechanical mixer of (0.1 m3) run by electrical power was used to mix the dry cement, sand and gravel and mixing was continued until the dry mixture became homogeneous. Then, add the water to the mixture and continue mixing until it becomes homogeneous, again. After that, the concrete was transferred to the mould as shown in Figs. 3.

Then the samples were remoulded cautiously, marked and placed in a tank of water until the test period. The samples were examined at the age of 28 days.

Figs.3. preparation of concrete slab

Table 4. mix contents

Mix	Cement	Sand	Gravel	Plastic	Water
0% plastic	335	670	1340	0	134
10% plastic	320	640	1280	67.84	128
20% plastic	307	614	1228	130.47	122.8
30% plastic	295	590	1180	188.08	117.92

5. Testing

The experimental method in order examines how the plastic aggregate with normal concrete will affect on the impact resistance and mechanical properties of the concrete. Different test were included i.e. splitting tensile strength, compressive strength, dry density and ultrasonic pulse velocity according to (*BS* 1881. Part 4, ASTM C496-90, ASTM C642-04 and *BS* 1881: Part 203) (See Figs. 4) [16-19].

Four (500×500×50 mm) slabs specimens were examined for every group with low velocity impact load which were 20 specimens. In order to achieve the impact resistance, a steel ball having (1300Kg weight) is falling freely from a height of (1.68 m) (See Figs. 5).

Figs. 4. test of the concrete specimens

Figs. 5. tests of the concrete slab in University of Anbar lab.

6. Results and Discussions

Below, the results obtained from the laboratory tests will be discussed:

6.1. Compressive Strength

(Fig. 6) shows the compressive strength improvement at curing period (28 days) for all kinds of concrete by increasing in plastic content especially, in the content 20% because the round plastic granules absorb the external loads that affect them as well as their round surface which provides enough compressive space before failure occurs, but this strength began to decrease gradually when increasing of the proportions of plastic aggregates. The reason of this behaviour was the friction forces between the concrete particles, because of the smooth of plastic aggregates surfaces and thus caused to slipping these grains when increasing the external loads and the result was decrease in the compressive strength.

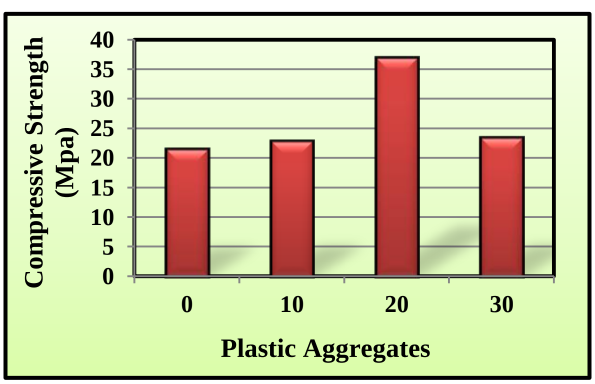


Fig. 6. compressive strength with plastic aggregates content

6.2. Splitting Tensile Strength

After 28 days, the splitting tensile strength was examined for moist cured concrete specimens. Fig. 7 shows the test outcomes of the splitting tensile strength. As per the results, generally all kinds of specimens displayed with plastic aggregated kept increasing in splitting tensile strength with increase the plastic aggregates portions particularly, at 20%.

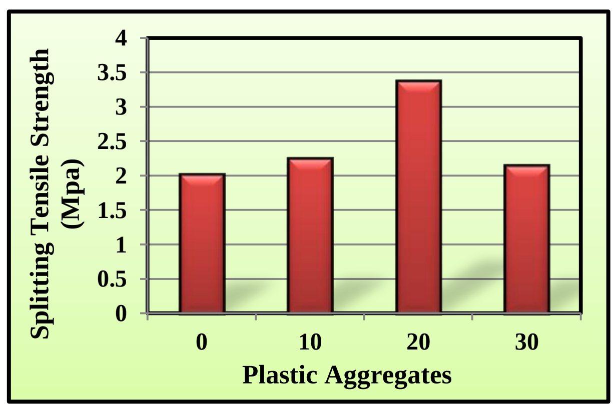


Fig. 7. splitting tensile strength with plastic aggregates content

6.3. Dry Unit Weight

With the increase percentage of plastic aggregates, the dry unit weight minimizes. Fig. 8 depicts that the weight of the plastic is lighter than the sand, which leads to lower density.

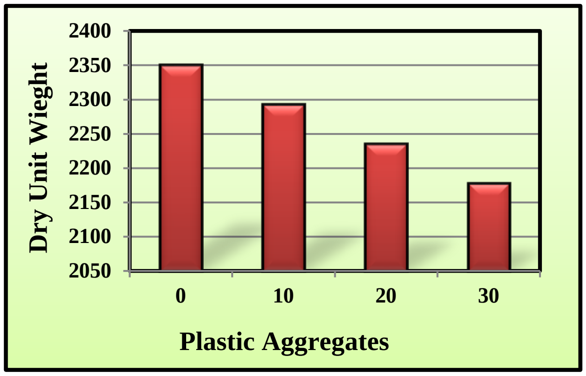


Fig. 8. dry unit weight with plastic aggregates content

6.4. Ultrasonic-Pulse Velocity Test

C372N (High performance) Tester which has frequency of 54 kHz and sensitivity at passing time measuring about 0.10 micro second, was used in measuring of ultrasonic Pulse velocity test to give more accurate readings of time. The ultrasound velocity was calculated by using the following equation:

$$V = \frac{L}{T} \tag{1}$$

Where:

V: Velocity frequency's (km/second)

L: Length of frequency (mm) i.e. is a distance between 2 sample surfaces vertical on cast direction.

T: Time of frequency penetration (microsecond) measured by PUNDIT.

The results of test are shown in Fig 9. The velocity decreased with increasing of plastic aggregate content because of the low density of concrete with a plastic aggregate.

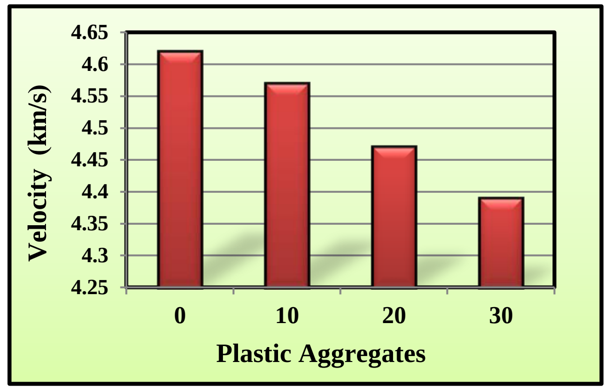


Fig. 9. the relationship between UPV and plastic aggregates

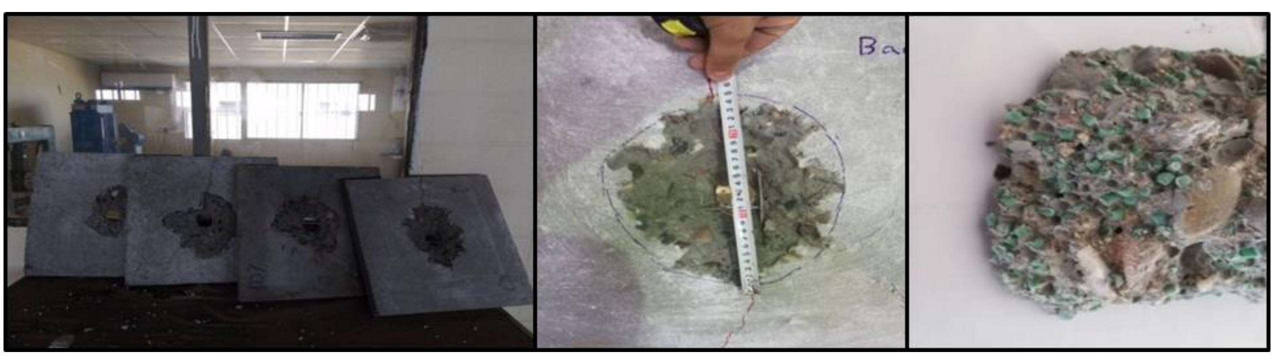
6.5. Impact Resistance

The test was made on prepared slabs (500×500×50mm) subjected to repeated impact blows by falling mass (1300 gm) dropped from a height (1.68 m) at ages of 28 days.

The slab with plastic aggregate (PAS) exhibited superior performance in impact resistance with an increase in plastic aggregate content compared with the reference mix (*RM*), see (Figs. 10).

This behaviour is mainly ascribed to the high capacity of plastic aggregate to absorb a great amount of energy earlier to failure, so the energy input that essential for initiating the first crack and for yield failure in a concrete fibre was greater than that for reference concrete. These features were reflected in their very high impact resistance both at first crack and failure.

The proportion of the increased number of blows, which caused the first crack for (PAS) relative to (*RM)* was 16.7%, 33.3% and 16.7% for (PAS) with 10%, 20% and 30% plastic aggregate by volume of sand, respectively (See Fig. 11).



Figs. 10. concrete slab failure under impact loads

The percentage of the increased number of blows, which were caused failure for (PAS) relative to (*RM)* was 541.7%, 712.5% and 350.0% for (PAS) with 10%, 20% and 30% plastic aggregate by volume of sand, respectively (See Fig. 12).

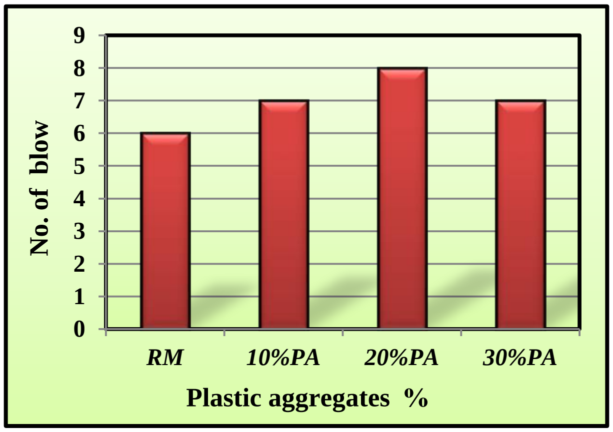


Fig. 11. the relationship between plastic aggregates and No. of blows at first crack

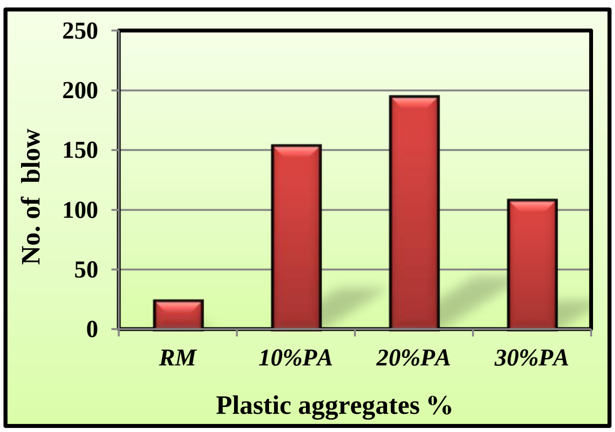


Fig. 12. the relationship between plastic aggregates and No. of blows at failure

7. Conclusions

1- The compressive strength of the concrete was increased with the different percentage of plastic aggregate especially at 20% plastic aggregate.
2- The results indicated that in general, all types of concrete specimens exhibited with plastic aggregate continued increase in splitting tensile strength with the development of plastic aggregate content, especially at 20% plastic aggregate.
3- The dry unit weight decreased with the increase in percentage of plastic aggregate content.
4- The velocity of ultrasonic pulse decreased with increasing of plastic aggregate content because of low density of concrete with plastic aggregate.
5- The slab with plastic aggregate exhibited superior performance in impact resistance with an increase in plastic aggregate content compared with the reference mix.

Nomenclature

L.S.F	lime saturation factor
PAS	slab with plastic aggregates
PA	plastic aggregates
RM	reference mix
ASTM	American Society for Testing and Mate-
BS	British Standards
LWC	lightweight concrete
MEPS	modified waste expanded polystyrene
UPV	ultrasonic pulse velocity
WECR	waste electrical cable rubber

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