Solid State Technology
Volume: 63 Issue: 6
Publication Year: 2020

Reuse of high-density polyethylene waste in concrete mixes.

Alaa K. Jasim[a*],Basim M.Jasim[b]and Aqeel M.Hammood[c]

[a] Department of community health, College of health, Southern Technical University, Basra, Iraq

[b] Department of Civil Technology, Technical Institute / Basra, Southern Technical University, Basra, Iraq

c Department of Civil Technology, Technical Institute / Basra, Southern Technical University, Basra, Iraq

*Corresponding Author's mail: alaa_alderawi@stu.edu.iq

Abstract: high -density polyethylene waste in the environment is regarded as an extensive problem because of very slow degradation and the very existence of large quantities of these waste'. So, finding alternative approaches to disposing of waste by using friendly processes is becoming an essential research case. In the present research, coarse aggregate in concrete was exchanged with high- density polyethylene waste with the ratios of 0.1,0.25,0.5,0.75 and 1 for safe disposal of these wastes and the production of lightweight and low-density concrete as a compared to concrete free from waste. This study was conducted using high-density polyethylene residues from which fruit and vegetable cages are made. The results showed a gradual decrease in the density of the models, with an increase in the percentage of high-density polyethylene wastes, which led to obtaining light concrete, and a change in compressive strength values and fracture strength values at the age of Seven and Twenty-eight days.

Keywords: *High-density polyethylene, plastic, Waste, polymer, Compressive strength.*

1-Introduction

Solid waste is considered one of the most visible elements of environmental pollution. Taking this type of pollution causes environmental and health problems for humans, animals, and plants together, and also contributes to losing the aesthetic image of the place as it turns it into places that send sadness and this shows its negative psychological effects on the human. One of the most important environmental pollutants in Iraq is the material made from high density, low-density polyethylene, polypropylene and polystyrene such as vegetable & fruit packages, bags, juices bottles and water, kitchenware, car oil boxes, disinfectants bottles, plastic toys, besides of the wood residue, glass bottles, mineral juice boxes, cork pieces, and old shoes, worn rags, carton boxes, edible oils, and leftovers which are throw in houses waste and landfills [1,2].

In recent years for example in Erbil City-Iraq, reducing and recycling domestic waste has become progressively as a waste production has been increasing because of an increase in population and economic expansion. .The quantity of daily solid waste generation was around 1.27 kg/capita for the population of 1,118,187and the usual percentage ratios of recyclable materials for example plastic was 34.87% [2].

Polymers Specially Plastics have become a fundamental part of our new way of life, and worldwide polymeric production especially plastics has increased greatly during the last fifty years. Polymers collect the demand of a varied range of products because of good properties for example high strength, low density, high strength/weight ratio, simplicity of design and production, and very low price although the plastic waste disposal in the environment is regarded to be a huge problem because of its very slow biological degradation and the large quantities presence [3].

Universal production of the polymer wastes and plastics in 2015was approximately 6300 metric ton and in the 2017of approximately 8300 metric ton of the waste of plastic had been produced, about nine percent of which had been reused, twelve percent was burned, and seventy nine percent was collected in landfills and the environments. If present manufacture and waste managing tendencies continue by this way ,approximately 12,000 metric ton of waste of plastic will be in landfills and the normal environment Up to 2050[4].

More types of polymers especially plastics are slow biodegradable and are inactive in the normal environment; so such polymer products persist for decades, even for centuries, producing long-term environmental pollution [5]. The increased growth of global polymer consumption in recent years leads to an increased the large quantity of polymers-related waste requires new procedures of recycling and avoiding landfill removal [6].

Polymers possess vital properties that can be utilized, such as durability, resistance to corrosion, good isolation of cold, heat, and sound, energy saving, noise reduction and pollution reduction, they are economical and have a longer life span, and do not need maintenance, hygienic, clean, easy to handle, installation and light weight [6,7,8].

Plastic waste was used in the concrete mixture in different proportions and found to be suitable for this purpose. There are great challenges to get rid of the large accumulated quantities of plastic waste in the twenty-first century, which led to the use of it in concrete. Plastic waste causes a huge problem to the environment due to its slow biodegradation and the large quantities of it. Recently polyethylene terephthalate(PET) waste which are used in the manufacture of plastic bottles and carrying bags and Polypropylene(PP) were studied in the replacement of part of the traditional concrete aggregate. A different quantity of plastic waste can be mixed with the concrete block and in different forms, as polyethylene terephthalate and polypropylene were used for this purpose without affecting the strength of the concrete and its basic properties ,so polyethylene terephthalates were replaced with three levels of 10%, 20%, 30 by weight of coarse aggregates to prepare Concrete [9].

Baboo et al was obtained that the compressive strength and workability were reduced because of partial substitution of sand by the waste plastic in different percentages by volume to yield waste plastic mixt concrete with plasticizer [7].
The strength properties of reinforced and unreinforced polymers concrete have been investigated by Rebeiz using unsaturated thermoplastic resins based on recycling polyethylene terephthalate waste. The results explained that there is a good chance to yield an excellent quality of precast concrete [10]. Batayench et al and Choi et al have studied the effect of waste polyethylene terephthalate bottles aggregate on properties of concrete and found that the waste plastic reduced the compressive strength and the weight of normal concrete [7, 11,12].

Marzouk et al explained that compressive strength and concrete density decreased when the addition of aggregateof polyethylene terephthalate more than fifty percentage by volume of sand [7, 13]. However, Pezzi et al explained that the polymeric waste addition in fraction less than ten percentage in volume inside of the cement matrix does not involve a considerable variation of the mechanical properties of concrete [7, 14]. Binici H. was found that the recycling of polyethylene bottles wastes and production of very high ductile material can be possible by using this waste in cementless mortar production. [15].

Polymers and special plastic materials have good properties Like durable and corrosion-resistant, good the cold and heat isolation, saving energy, economical, has a longer life, and lightweight, also In from an environmental point of view, it is very important disposal of the large quantities from polyethylene waste which cause water and soil pollution [1,6], So, in this research, the direct recycling of polyethylene was proposed to realize to reducing pollution of plastic materials and making of lightweight concrete By substituting the coarse aggregate with waste plastic.

High-density polyethylene waste was mixed with Portland cement, sand and coarse aggregate to make light plastic concrete, and the effect of substituting coarse aggregate by the waste fibers of high-density polyethylene in a different ratio was examined .

2-Materials and Methodology

A. Materials:

Cement: Normal Portland Cement type I was used through this labor, it is conforming to the Iraqi specification No. 5/1999[16]

Fine aggregate: Use fine aggregate, which is sand, brought from the Desert of Basrah City-Iraq, it is conformed to the requirements of the (B.S.882/1992) [17]

Coarse aggregate: Gap-graded natural coarse aggregate brought from the Desert of Basrah City-Iraq, it is conforming to the requirements of the (B.S.882/1992 – Zone 3) in all sieve numbers but sieves with opening equal to 10 mm.

Water: water used in this study was purified by a reverse osmosis process with following specifications:

Contents	Concentration(PPM)
T.D.S	80
Calcium	21
Magnesium	08
Sodium	10
Potassium	1.2
Sulfate	20
Nitrate	01
Chloride	30
PH=7.2	

Waste plastic: The waste plastic used in this research are boxes made of high-density polyethylene, that has been collected from landfills and municipal as a waste that results from the sale of fruits and vegetables and extrusion of their boxes, which is cutting into very small sizes by using specific cutting and shredding machine to produce small pieces(small fibers). During the experimentation, the waste plastic is sieved to get the plastic waste with size from
5-10 millimeters and removal fine and other particles.
The resulting grinding polyethylene waste to be ready for mixing with normal Portland cement, fine aggregate, coarse aggregate, and purified water as shown in the figure1.

Figure 1: waste boxes of HDPE before and after shredding and grinding by shredding machine.

Casting molds: Iron molds with a dimension (150 x 150 x 150) mm are used to obtain concrete cubes that have been used in Compressive strength tests.
, and the use of iron molds with a dimension (100 x 100 x 500) mm to obtain prisms of concrete that were used in the fracture strength tests.

B. Methodology:

Concrete mixtures: The mixture of concrete was designed to find out the effect of substitution of Coarse aggregate by small pieces of high-density polyethylene wastes. Normal Portland cement, sand, Coarse aggregate, and water were mixed with small pieces polyethylene wastes using different ratios of wastes as shown in table1. Concrete mixtures were used according to the following Weight ratios:-

Table 1: Concrete mixtures and its ratios.

Concrete mixture	Mixing ratios					
	Portland cement	Sand	Coarse aggregate	HDPE waste	Water/Cement ratio	Waste % (weight)
PW0.00	**1**	**2**	**4.00**	**0.00**	**0.55**	**0.00**
PW0.10	**1**	**2**	**3.90**	**0.10**	**0.55**	**1.32**
PW0.25	**1**	**2**	**3.75**	**0.25**	**0.55**	**3.31**
PW0.50	**1**	**2**	**3.50**	**0.50**	**0.55**	**6.62**
PW0.75	**1**	**2**	**3.25**	**0.75**	**0.55**	**9.93**

PW1.00	**1**	**2**	**3.00**	**1.00**	**0.55**	**13.24**

Concrete mixtures and small pieces of high-density polyethylene wastes were blended with purified water to obtain a plastic concrete to pour in the templates. The Samples left in the six molds till it dried, later place in purified water for three to five days for stiffening and curing to rise their cohesion. Then, the six samples left the water to dry and exam their properties. The next step is placing the six samples once more in water for seven and twenty-eight days to examine the effect of water and stability.

3- Results and discussions

[3-1]The products shape

Figures number 2 and number 3 explain the wet plastic concrete shape, that produced from blending normal portland cement, sand, Coarse aggregate, and water with pieces polyethylene wastes before and after molding and drying respectively.

Figure 2: Concrete with pieces polyethylene waste after mixing.

Figure3: Concrete with pieces of high-density polyethylene waste blended after molding and drying with various ratios of high-density polyethylene 1.(0.0) HDPE; 2.(0.1)HDPE; 3.(0.25) HDPE; 4.(0.5) HDPE; 5. (0.75) HDPE; and 6.(1.0) HDPE.

[3-2] Samples density

The plastic concrete density which was prepared in this research was determined and the results explain in table 2.

Table 2: The plastic concrete density of six samples

Sample No.	HDPE %	HDPE Ratio	Cement Ratio	Sand Ratio	Coarse aggregate Ratio	Water/Cement Ratio	Density (gm/cm^3)
1	0.00	0.00	1.00	2.00	4.00	0.55	2.314
2	1.32	0.10	1.00	2.00	3.90	0.55	2.239
3	3.31	0.25	1.00	2.00	3.75	0.55	2.150
4	6.62	0.50	1.00	2.00	3.50	0.55	2.086
5	9.93	0.75	1.00	2.00	3.25	0.55	1.855
6	13.24	1.00	1.00	2.00	3.00	0.55	1.627

The plastic concrete density decrease as the ratio of high-density polyethylene waste increase in the concrete mix, because of the low density of HDPE waste as compared with the coarse aggregate that was replaced, which is reflected in the density of the models under study.

[3-3] Moisture of the samples

The moisture of the six samples of plastic concrete which were prepared in this work after immerged seven and twenty-eight days in purified water is explained in table 3. The results were explained that the moisture after twenty-eight days of immersing in water less than the moisture of plastic concrete that immerged seven days. The finest moisture percentage has been got with the high-density polyethylene waste percentages were(1.32%,3.31% and6.62%) in the mixing concrete.

Table 3:The plastic concrete moisture percentage of the six samples which were prepared in present work which were immersed seven and twenty eight days in purified water.

Sample No.	HDPE %	HDPE Ratio	Moisture percentage After seven days	Moisture percentage After twenty eight days
1	0.00	0.00	2.10	2.55
2	1.30	0.10	3.48	3.04
3	3.33	0.25	3.59	3.20
4	6.60	0.50	3.91	3.33

5	10.0	0.75	5.42	3.77
6	13.0	1.00	7.30	4.79

[3-4]Compressive strength

The results of the compressive strength tests shown in Table (4) and Figure (4) show that the Compressive strength increases with the age of concrete. The results of the tests also show that the Compressive strength increases with the increase of the percentage of waste plastic which was added to the mixture in the waste ratio 1.30% and 3.33%, however, it decreases with waste ratio 6.62%,9.93%, and 13.24%, also it was noted that the increase in the compressive strength is relatively few where the increase by the age of seven days from16.01 to 20.20% of the Compressive strength of the reference concrete and It was from 8.32 % to12.90 at the age of twenty-eight days. This increase in the compressive strength at an early age is explained by the fact that the fibers are working to increase the bonding of the concrete mixture, similar to the principle of concrete reinforcement. these fibers work at an early age, in particular, to increase compressive strength because it works to link concrete components, resist side effects, and reduce their impact during the loading process, however, the increase of the ratio of waste plastic in the range from 6.6% to 13%, cause a decrease in the values of compressive strength of waste plastic concrete mixtures at each curing age because of the adhesive strength decreasing between the high-density polyethylene waste and the cement paste due to a weak bonding force between the high-density polyethylene and concrete components especially when was the ratio of the waste plastic was high.

Table 4: Compressive strength of concrete mixtures

Sample No.	Compressive strength (Nm / mm^2) *	
	(7) days	(28) days
1	29.10	42.15
2	33.76	45.66
3	34.98	47.59
4	26.37	33.90
5	19.12	25.75
6	12.87	19.32

* The above readings represent an average of at least three readings for the test samples.

[3-5]Flexural strength (fracture strength)

The results in Table (5) and Figure (5) show that the fracture strength increases with increasing age for the all blends used in this research in the waste ratio 1.30% and 3.33%, also it can be inferred that the fracture strength which represented by the value of the Flexural strength in the models made from the mixtures containing different proportions of the small fibers of the plastic waste was higher than concrete reference mixture,

the highest percentage for an increase in fracture strength was 45.80% compared to the bending resistance of the reference plan, where the percentage of increase in resistance at the age of seven days reaches 45.8% From the resistance of the reference mixture, while that ratio at the age of twenty-eight days it reaches approximately 19.59%. The percentage of increase in flexural strength (fracture coefficients) at early ages was greater, where it yielded a higher initial resistance than the reference mixtures. This increase in resistance in the early ages can be explained by the fact that the waste plastic additives fiber will work to contribute to the resistance to stresses tensile inside the concrete structure and bridge cracks whereas the reference concrete (non-armed fiber) is weak due to the lack of those fibers that contribute to resisting stresses tensile, however, the increase of the ratio of waste plastic in the range from 6.6% to 13%, cause decrease the values of Flexural strength of high-density poly ethylene waste and concrete mixtures at each curing age for the same reason of decreasing of values in the compressive strength .

Table 5: Flexural Resistance (fracture strength) for Concrete Mixtures.

Sample No.	Flexural Resistance (fracture strength) (Nm / mm^2) *	
	(7) days	(28) days
1	2.62	4.44
2	3.71	5.07
3	3.82	5.31
4	2.02	4.09
5	1.83	3.25
6	1.33	2.27

* The above readings represent an average of at least three readings for the test samples.

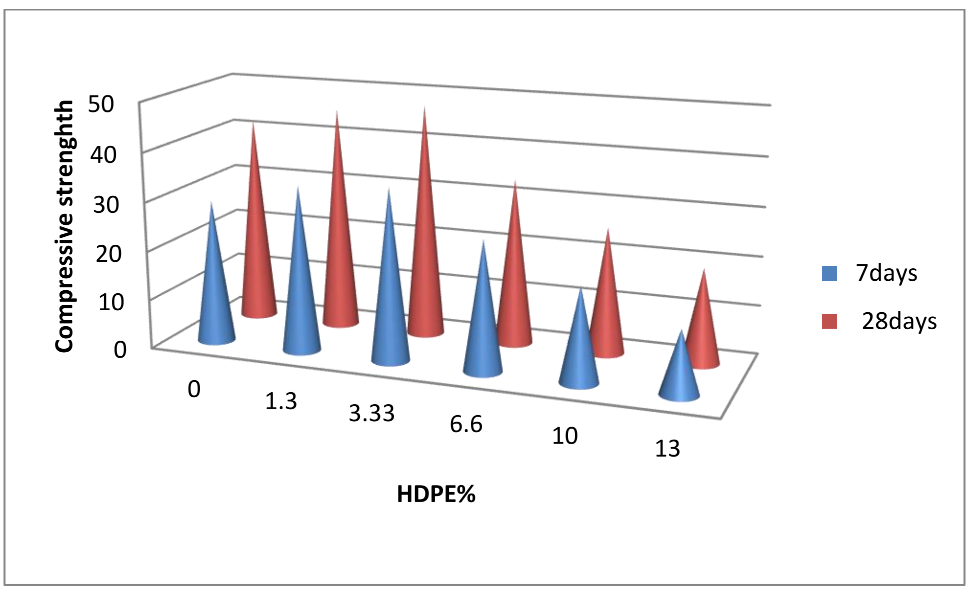

Figure 4: The relation between Compressive strength and waste of HDPE% at seven and twenty-eight days

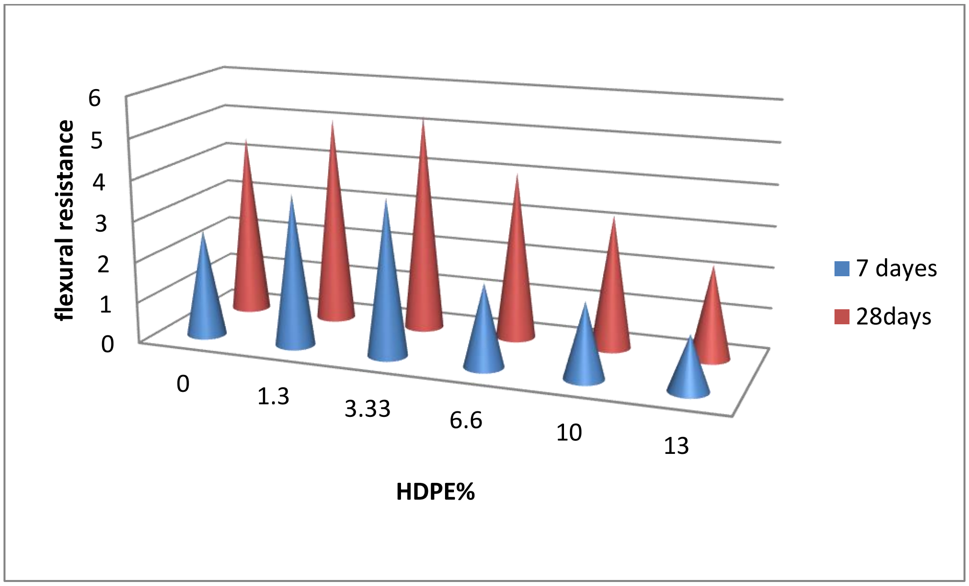

Figure 5: The relation between Flexural Resistance and waste of HDPE% of concrete at seven and twenty – eight days.

4- Conclusions

1-Take advantage of reuse of industrial waste represented by the plastic boxes used to transport vegetables and fruits by converting them into plastic fibers, after cutting them with the appropriate dimensions and then adding them to concrete.

2- The addition of products for cutting boxes of fruits and vegetables improves some mechanical properties, such as breaking standards and compression resistance.

3- The use of these boxes as fibers added to concrete has a good environmental impact, which is the disposal of these wastes, which when put into the environment, causes a negative environmental impact.

4- The possibility of using this waste in the production of lightweight concrete.

REFERENCES

[1] Tapkire, G., Patil, P., & Kumavat, H. R. (2014). Recycled Plastic used in concrete paver block.

[2] Aziz, S. Q., Ismail, S. O., & Omar, I. A.(2019). Recyclable Solid Waste Materials Management in Erbil City-Iraq. International Journal of Engineering Inventions, 8(1), 57-62.

[3] Ozbakkaloglu, T., Gu, L., & Gholampour, A. (2017). Short-term mechanical properties of concrete containing recycled polypropylene coarse aggregates under ambient and elevated temperature. Journal of materials in Civil Engineering, 29(10), 04017191.

[4] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.

[5] Thompson, R. C., Moore, C. J., Vom Saal, F. S., & Swan, S. H. (2009). Plastics, the environment and

human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2153-2166.

[6] Patil, P. S. (2015). Behavior of concrete which is partially replaced with waste plastic. International Journal of Innovative Technology and Exploring Engineering IJITEE, 4(11).

[7] Rai, B., Rushad, S. T., Kr, B., & Duggal, S. K. (2012). Study of waste plastic mix concrete with plasticizer. ISRN civil engineering, 2012.

[8] Binici, H. (2013). Effect of aggregate type on mortars without cement. European Journal of Engineering and Technology, 1(1), 1-6.

[9] Achitra, M., Rajasree, R. A., Pandit, R. V., Saranya, V., & Scholar, U. G. (2018). Recycled Plastic and Coconut Fibre used in Concrete Paver Block. Int. J. Eng. Sci. Comput, 8(4), 16827-16830.

[10] Rebeiz, K. S. (1996). Precast use of polymer concrete using unsaturated polyester resin based on recycled PET waste. Construction and Building Materials, 10(3), 215-220.

[11] Batayneh, M., Marie, I., & Asi, I. (2007). Use of selected waste materials in concrete mixes. Waste management, 27(12), 1870-1876.

[12] Choi, Y. W., Moon, D. J., Chung, J. S., & Cho, S. K. (2005). Effects of waste PET bottles aggregate on the properties of concrete. Cement and concrete research, 35(4), 776-781.

[13] Marzouk, O. Y., Dheilly, R. M., & Queneudec, M. (2007). Valorization of post-consumer waste plastic in cementitious concrete composites. Waste management, 27(2), 310-318.

[14Pezzi, L., De Luca, P. A., Vuono, D., Chiappetta, F., & Nastro, A. (2006). Concrete products with waste's plastic material (bottle, glass, plate). In Materials Science Forum (Vol. 514, p. 1753). Trans Tech Publications Ltd..

[15] Binici, H., Gemci, R., & Kaplan, H. (2012). Physical and mechanical properties of mortars without cement. Construction and Building Materials, 28(1), 357-361.

[16] Walker, P. J. (1995). Strength, durability and shrinkage characteristics of cement stabilised soil blocks. Cement and concrete composites, 17(4), 301-310.

[17] Standard, B. (1992). Specification for aggregates from natural sources for concrete. London: BSI, 1-9.