Journal of Materials and Engineering Structures

Research Paper

Mechanical Properties of Concrete and Mortar Containing Low Density Polyethylene Waste Particles as Fine Aggregate

Abdulrahman S. Mohammed [a], ***Taghreed Kh. Mohammed Ali*** [b,*], ***Noor A. Rajab*** [c], ***Nahla Hilal*** [a]

[a] *Dams and Water Resources Eng. Dept. College of Engineering-University of Anbar, Iraq.*

[b] *Department of Architecture, Faculty of Engineering, Koya University Koya KOY45, Kurdistan Region – F.R. Iraq.*

[c] *College of Engineering, University of Anbar, Anbar, Iraq*

ARTICLE INFO

Article history :

Received : 26 September 2019

Revised : 27 December 2019

Accepted : 12 January 2020

Keywords:

LDPE

Ultrasonic pulse velocity

Splitting tensile strength

Compressive strength

ABSTRACT

Iraq industrial activities related to huge amounts of solid, non-biodegradable waste, waste low density Polyethylene (LDPE) plastic being among the well-known. So in this study, the scarped LDPE food boxes were transformed into fine particles and used as a sand for cement mortar and concrete. LDPE wastes were utilized to alter 0 to 25% of fine aggregates in mortar mixtures and 0% to 30% in concrete mixes at an increment of 5%. Compressive strength and dry density were tested for all mortar and concrete specimens. In addition, splitting tensile strength and ultrasonic pulse speed were tested for specimens of concrete. Results show that mass, pulse speed of ultrasonic, splitting and compressive tensile strengths were lowered as the size of LDPE raised. The lowest value of dry density, compressive strength and splitting strength was 2240 kg/m3, 18.7 MPa and 1.68 MPa, respectively, for 15% replacement of sand by the LDPE waste in concrete specimens. Whilst, the value of ultrasonic pulse velocity of LDPE concrete mixtures tends to decline lower than the reference values, but it remains nearly to the stander concrete mixtures and can be classified as excellent quality concrete. The density and compressive strength were decreased by using LDPE waste in mortar mixes for all replacement ratios reaching 12% and 42% respectively for 25% substitute.

1 Introduction

Various kinds of polymers are in use today, because of their satisfactory properties and relatively low cost. There is no doubt that this large usage is accompanied with a huge quantity of post consumed wastes. These wastes are increasing day by day and can cause a severe attack to the land and the environment. To solve this problem there is a need to set a program for the waste stream management. Unfortunately, till now most of the post consumed plastic wastes are transferred to land filling. However, this process is not accepted in most of the developed countries and other methods of recycling, including mechanical recycling, chemical recycling or the combination of the two methods usually are followed. One type of plastics

* *Corresponding author. Tel.:* +964771428729.
E-mail address: taghreed.khaleefa@koyauniversity.org

e-ISSN: 2170-127X,

RESEARCH REVIEW of Sciences and Technologies

is Polyethylene (PE); the polyethylene divided into two main kinds, the high density polyethylene (HDPE) and low-density polyethylene (LDPE). HDPE is stiffer and tougher than LDPE, and is every time white milky color, even when very thin. It is utilized for manufactures sheath and bags, detergents, fine drinks glasses, toys, cosmetic containers, jerry cans, crate, garbage and other domestic materials [1]. LDPE is smooth, flexible and cutting easy, with the candle wax feeling. When it is very thin, it is clear; when thick, it is white milky, except if added pigment. Used of LDPE in the film bags manufacture, sheeting and sacks, food boxes, bang-mildew glasses, hosepipes and pliable piping, domestic materials such as bowls and buckets, sheaths of telephone cable and toys etc.. Nowadays, there is a large amount of LDPE wastes in Iraq as a result of industrializes actions and it requires to removal this waste. There is a chance to use another method of recycling via shredding different concrete properties with a normal aggregate partly plastic aggregate altered came from different plastic wastes.

Ismail and AL-Hashmi [4] applied waste plastic utilized as a smooth aggregate partial altered by 0%, 10%, 15%, and 20% by weight and the mixtures of concrete was evaluated at period 3, 7, 14, to 28 days. These parameters include solidity index, compressive strength, fresh density, slump, dry density and flexural strength. The mixtures of waste plastic concrete slump results manifested a trend to reduce lower the plunge of the reference mix of concrete. Also, the dry and fresh density and flexural strengths and compressive have a trend to reduce with rising the ratio of waste plastic on whole treated ages.

Choi et al. [5] explained in their research the mortar characteristics and concrete including fine aggregate made from waste reprocess polyethylene terephthalate (PET) glasses as waste plastic lightweight aggregate (WPLA). The mixtures of concrete were utilized with water to cement ratio (w/c) of 0.45, 0.49 and 0.53. For each round of concrete, the alteration of WPLA by ball of fine aggregate was 0%, 25%, 50% and 75%, respectively. They reported that for WPLA 25%, 50% and 75% concrete mixtures, decreased of the compressive strength, 6%, 16% and 30% respectively, when average contrasted to the stander concrete.

Akcaozoglu et al. [6] achieved investigation on two mortar sample groups; one just synthetic with PET aggregates and the other was synthetic both sand aggregates and PET. Furthermore, 50% of cement on mass basis was replaced with blast furnace slag. The authors found that the compressive, weight of unit, the flexural and values tensile strength, sand aggregates and carbonation deepness of the mortars including PET together to be high-rise than the only PET aggregates mortars including.

Hannawi et al. [7] utilized (PET) waste and polycarbonate (PC) as partially alters of the sand in mortar. Different volume portions of sand, 3%, 10%, 20% and 50% were altered by the same used plastic volume. The results showed that the waste plastic mixtures dry density values tendency to reduce by 19% and 24%, respectively; for 50% PET and PC plastic aggregates; increasing PET and PC aggregate content lead to decreased flexibility modulus and the strength compress in the mixtures. The authors did not observe important variations in the mortar specimens up to 20 % PC-aggregates and flexural strength up to 10 % PET-aggregates with the same texture. Moreover, reduce of 9.5 and 17.9 % for mixtures with 20 and 50 % PET-aggregates, respectively, were noticed. For add with 50 % PC aggregates, a reduction of 32.8 % was calculated.

Rai et al. [8] utilized waste plastic plates as a partial sand replacement in different ratios (0%, 5%, 10%, and 15%) by volume with and without superplasticizer. The authors stated that there is a sharply declining in slump results with increase the ratio of waste plastic; fresh and dry density during all treated age tend to drop with raising ratio of waste plastic for every concrete mix. Also, they found, at every curing age, flexural strength and the compressive estimations of plastic waste concrete blends reduce by raising the ratio of waste plastic.

Rahman et al. [9] studied the possible by using waste polymeric materials recycled alteration for concrete aggregates. The waste polymer divided into three kind, namely high density polyethylene (HDPE), tire of cars and widened polystyrene (EPS), were used in this study. The results indicated that addition of waste polymer lowering absorption of water and concrete porosity. It also lowered the compressive strength with increase the waste polymer content for the concrete.

Safi [10] explained using of the plastic waste impact such as a fine aggregate on self-compress mortar action. The sand was replaced with the plastic waste at ratios (0%, 10%, 20%, 30% and 50% by weight of the sand). According to results obtained, the bulk density, the porosity, the compressive and flexural strengths of self-condense mortars reduced with increasing content of plastic waste at all curing ages. The results showed a little lower o sound velocity of self-condense mortar for any sand replacement by plastic waste, contrasted to the reference mortar at all treated age.

Rahmani et al. [11] discussed the concrete mechanical characteristics that contain waste PET particles at proportions (5%, 10% and 15%) as a partial altered of sand with two w/c ratios (0.42, 0.54). The results explained that the workability of fresh concrete, fresh and dry weight was lowered as the amount of PET content was raised. The optimum flexural strengths and compressive found at 5% PET replacement of sand. However, further increasing of PET contents reduced modulus of elasticity, splitting, speed of ultrasonic pulse, compressive and flexural strengths of samples of concrete.

Saikia and Brito [12] investigated using of PET waste as a concrete part substitution of, natural aggregate mixes by 5%, 10% and 15% by an same volume of three differing sized and shaped PET-aggregates results showed that fresh concrete slump somewhat raise due to the addition of PET-aggregate shaped as pellet. While, flakier plastic aggregate heavily reduces the fresh concrete slump and extra reduces as the substance and the amount of the PET-aggregate raise. Tensile splitting, compressive, modulus of elasticity and flexural strengths of concrete sour because of the combination of PET-aggregate and the worsening characteristics emphasize with higher aggregate content. The variations in PET-aggregates texture, shape and size alter the water to cement ratio in addition to the fresh concrete mixtures slump, which finally mechanical behavior change. The scraping impedance of mixtures of concrete including different kinds of PET aggregate is bestowed than that of the stander concrete.

Azhdarpour [13] utilized PET waste fragments such as substitute of sand by ratios 5% to 30% at an increment of 5% in concrete mixes. Their results revealed that dry density and fresh of concrete decreases by increasing PET fragment content. Compressive concrete strength goes up to 39% and 7.6% by alter 5% and 10% of the concrete aggregates with plastic fragments, respectively. Moreover, this replaces increased the concrete deformability and minimize elasticity modulus of concrete.

The ratio of waste plastic was raised and remediation age makes specimen more distortion prior fail; subsequently, at the30% ratio of aggregate substitute, concrete express a behavior as a creep. The sound speed reduced along with the PET ratio rise in concrete. Addition PET fragments of 5% and 10% ratio were strengthened concrete flexural strength. In spite of that, the replacement higher than 10% leads to flexural strength decrease. When added of PET in concrete aggregates replacement (5–15%), the concrete tensile strength of aged 28 days go up to 26–34%, respectively. More accurately, in all ratios, increased strength of tensile all time.

Irwan et al [14] studied patterns of reinforced concrete beam and the cracking propagation consist of PET aggregate as fine aggregate that expose to cut. The substitute of sand with PET aggregate was 25%, 50% and 75%. Their results explained that density, modulus of elasticity, compressive and split tensile strengths reduced by using PET aggregate which affect the activity of structural concrete in resisting cuts stresses. Also, they found that PET aggregate inclusion was reduce the primary cracks loading to 27%, 38% and 46% to 25%, 50% and 75% PET, respectively, contrasted with their ordinary identical cement; so that, affecting resistance of cut of the constructional ray particularly the beam capability to resist shear through interlocking and interface rubbing amidst aggregate.

Albano et al. [15] mentioned the concrete mechanical manner with PET recycled, different the PET content (10% and 20%), the size of molecules and water/cement ratio (0.50 and 0.60). Moreover, the PET thermal degradation influence in the concrete was considered, when the mixtures revealed to various temperatures (200, 400, 600 ºC). The results showed that PET-filled concrete, when the size of PET particle raised and volume proportion, expressed a decline in compress and cleavage tensile strengths, modulus of flexibility and speed of ultrasonic pulse, so that, increased the absorb of water. Furthermore, the concrete-PET flexural strength when introduce to a heat provenance was highly based on the water/cement ratio, temperature, the PET content and particle size as well. Also, the energy activity was influenced by the PET molecules site at the flags ratio of water /cement and temperature.

Al-Manaseer and Dalal [16] investigated the aggregate of plastic was effect of on the bulk density, modulus of flexibility, compress and splitting tensile strengths of concrete. They made twelve concrete mixtures with variant w/c including variables (0%, 10%, 30%, and 50%) percentages of plastic aggregates. The maximum size of used plastic aggregates was 13 mm. They concluded that all studied characteristics of concrete decreased with increasing content of aggregates plastic. Decrease the thickness of concrete by 2.5%, 6%, and 13% for concrete containing 10%, 30%, and 50% plastic aggregates, respectively. There were 34%, 51%, and 67% compressive strength decrease in the concrete containing plastic aggregates 10%, 30%, and 50% respectively. The tensile strength cleavage was present to be reduced when w/c was raised and reduced by 17% for concrete 10%contain of plastic aggregates. The samples of concrete contain aggregates of plastic which are splitting failure didn't reveal the typical fragile failure has been seen in the conventional concrete case. Higher w/c ratio reduced the modulus of flexibility which diversified amid 24.3 GPa for no plastic aggregates carrying concrete (w/c = 0.28) to 8.6 GPa for 50% plastic aggregates carrying concrete.

Marzouk et al. [17] utilized PET waste as complete and partial sand replacements in composites of concrete. Different sand fractions volume ranged from 2% to 100% were replaced by the granulated plastic at the same volume, and different PET aggregates sizes. They recorded alteration of sand at a grade beneath half through the volume with PET granulate, that superior granulated outline approaches 5 mm, impacted neither the strength of flexural nor the compressive goodness of compound and plastic tankard opened into very small molecules of PET might be efficacious utilized as sand-alter aggregates in mixes of concrete cementitious.

A value below 50% by volume with granulated PET, higher limit of grainy equals 5 mm, influenced neither the flexural strength nor the compressive strength of mixes and plastic, glass ruptured into little PET fragment might be utilized effectively like sand- aggregates alteration in mixtures of cementitious concrete.

Batayneh et al. [18] searched the compressive, impress of ground plastic on the slump, splitting and flexural strengths of concrete. Mixtures of concrete more than 20% of particles of plastic are fit to shift the smooth aggregates partially. They mentioned that the plastic material, supplemented leads to a decrease in the strength characteristics and slump. For a 20% substitute, the compressive strength manifested a high decrease more than 72% of the principle strength of 0% plastic particle content and reduced the stagnation to 25% of the reference values of slump. With 5% substitution the compressive strength revealed a lowering 23%. The same manner, so in a minimize impact, was noticed in both the flexural strengths and splitting of the specimen that assessed.

Ghernouti et al. [19] studied using of a plastic bag waste matter (PBW) in the concrete formulation as fine aggregate by replacement of different sand percent (10, 20, 30 and 40 %). The PBW impact on the characteristics of solid status and the fresh of concrete: intensity volume, workability, ultrasonic pulse speed examines compressive and flexural strengths of the variant concretes, were studied and compared to the control concrete. Our results revealed utilize of PBW which enhance the ability of work and decreases the density. While there was a lowered in the mechanical characteristics of concrete with the increasing PBW amount, which keeps on evermore near reference properties of concrete. They mentioned a drop of compressive strength at 28 days around 10 and 24 % for the concrete's consist of 10 and 20 % of PBW individually.

Kou et al. [20] studied the splitting strength, compressive strength, modulus of flexibility, dry shrinkage, Poisson’s ratios and the impedance to chloride ion inside of concrete PVC particles containing come from PVC pipes scraped. The decreasing in 28- day concrete mixes compressive strength prepared by 5%, 15%, 30% and 45% replacing of naturalistic fine aggregate through molecules of PVC were respectively 9.1%, 18.6%, 21.8% and 47.3% with regard to the mix control. The replacement of fine aggregate 5%, 15%, 30% and 45% by PVC molecules decrease the pliability modulus by 6.1%, 13.8%, 18.9% and 60.2%, respectively, contrasted of concrete control. They record a Poisson’s ratio increasing with raising the PVC waste aggregate contents in concrete. They found nearly 36% lower the whole freightage moved via the 28-day cured concrete, prepared by 45% natural aggregate replacing by granules of PVC compared to the reference concrete. According to them, the resistance was increased to penetration of chloride ion of concrete is referred to the blocking of impermeable molecules of PVC. There was a lower trend of drying retraction with raising PVC granule contents.

Naik et al. [21] and Naik et al. [22] developed a chemical chain between cementitious matrix and plastic particles using chemical treatments. They accomplished experimentally utilizing of post-consumer HDPE plastic waste in concrete. Added to the concrete a plastic particles ranged from 0 to 5% of the whole mixture by weight. To raise the bond strength between the concrete matrix and the plastic molecules, the plastic particles were undergone to 3 chemically treat (bleach, water, bleach + NaOH). Evaluated the concrete compressive strengths were done with molecules of plastic or without. All mixtures of concrete gave minimal compressive strength contrasted the stander concrete; so that, the plastic containing mixture handle with bleach plus NaOH gives the best performance, followed the plastic sample treated by the water. The results manifested, that 0.5% of plastic can be utilized in concrete without the pressure of the compressive strength. Following 0.5% of plastic particles addition of the concrete weight, the strength of concrete was decreased. They proposed that plastic process shall done to get peak portion ratios for enhancing the plastic filler activity because of its raised bond area and its ability of load transfer.

Ohemeng et. al [23] studied the usage feasibility of waste low-density polyethylene (LDPE) as a sand partial alteration in the concrete make pavement blocks. The ratio of the mixtures was 1: 1.5: 3 (cement: sand: coarse aggregate). The used of the plastic was to substitute the sand by volume at 0%, 10%, 20%, 30%, 40%, 50%, and 60%. It was shown, that compressive strength, density, flexural strength, and strength of splitting tensile lowered as raised the plastic content. Moreover, the soaking up of water was raised as the plastic was increased. The level of compressive strengths ranged from 14.70 MPa – 47.29 MPa were accomplished when water cement ratios of 0.30 – 0.45 were used. They concluded that the modified pavement blocks are satisfying for ways light traffic, pedestrians walking and dense traffic status respectively if 10% - 50% plastic contents are utilized; and this modified pavement block can be contributed to discarding plastic materials across the world.

Hilal NN et.al [24] used polyethylene waste as alter sand partially in production SCC and they showed it is possible to produce LWSCC by using a suitable percent of polyethylene waste substitution with fine aggregate. In addition, their workability enhanced and ductility improved, while the mechanical properties stay within the acceptable limits.

From the preceding review, the utilize of waste plastic in concrete is growing more and more depending on the necessary sustainability of aggregate and the environmental require. According to the recent reviews, it can be observed that there is a significant amount of researches that studied concrete mechanical characteristics which involved PET molecules like a fine aggregate alteration partially. So, research had been studied the impact of the LDPE- aggregates on the physical and mechanical characteristics of concrete by one study. Therefore, further research is needed to assess PE waste as an aggregate in concrete manufacture. In this work, this investigation is carried out. Research significance

2 Experimental program

2.1 Materials

The utilized materials in the present study for producing a normal strength concrete or mortar mix are water, cement, coarse aggregate, fine aggregate, and polyvinyl chloride (PE) waste granules. Ordinary Portland cement produced by the cement factory Al-Mass was adopted for all mixes. The physical and chemical, cement properties are presented in Tables 1 and 2, respectively.

Table 1- Physical Properties of Cement

Physical properties	Test result	Limits of Iraqi Specification No.5/1984
Setting time(minutes)		
Initial setting	120	≥45 minutes
Final setting	360	≤ 600 minutes
Fineness by Blaine method (m^2/Kg)	300	≥ 230
% Auto Clave	0.31	≤ 0.8

Table 2- Chemical Properties of Cement

Oxide	Weight (%)	Limits of Iraqi Specification No.5/1984
CaO	62.3	-
SiO_2	20.28	-
Al_2O_3	5.55	-
Fe_2O_3	4.20	-
MgO	2.60	< 5.0
K_2O	0.75	-
Na_2O	0.4	-
SO3	2.5	<2.8
Lime saturation factor	0.81	0.66 – 1.02
Insoluble Remains	0.5	< 1.5 %
F.L	0.65	-
Total	99.63	-
Compound	**Weight (%)**	**Limits of Iraqi Specification No.5/1984**
C3S	50.05	-
C2S	20.45	-
C3A	4.05	-
C4AF	13.20	-

It is explained that the cement used is conforming to Iraqi Specification No. 5/1984. The current study used the fine aggregate that was saturated surface dry clean river sand and its properties are given in Table 3. Fine aggregate classes were obtained from sieve analysis is shown in Fig. 1. One can show that the actual grading curve falls at of Iraqi Specification limits No. 5/1984 limits. Clean river gravel of 12.5 mm upper limit size and specific gravity of 2.66 coarse aggregates utilized for all mixtures. Sieve results analysis, examination are illustrated in Fig. 2. It is observed grading of coarse aggregate conforms to Iraqi Specification No. 5/1984 limits. Clean potable water was utilized for both concrete mixes and curing of concrete samples. PE waste granules have been taken from recycled plastic factory located in the industrial area at Baghdad. It consists of fine particles of size less than 4.75 mm and grading of the used PE is shown in Fig. 3. Table 3 showed the waste plastic mechanical and physical properties measurement. A waste plastic specimen is illustrated in Fig. 4.

Table 3- Average properties of PE used in this study

Property	Values
Color	green color
Water absorption, 24 h (%)	0.02
Density [kg/m^3]	1440
Specific gravity	0.94
Tensile strength [MPa]	52.9
Modulus of elasticity [GPa]	3.14

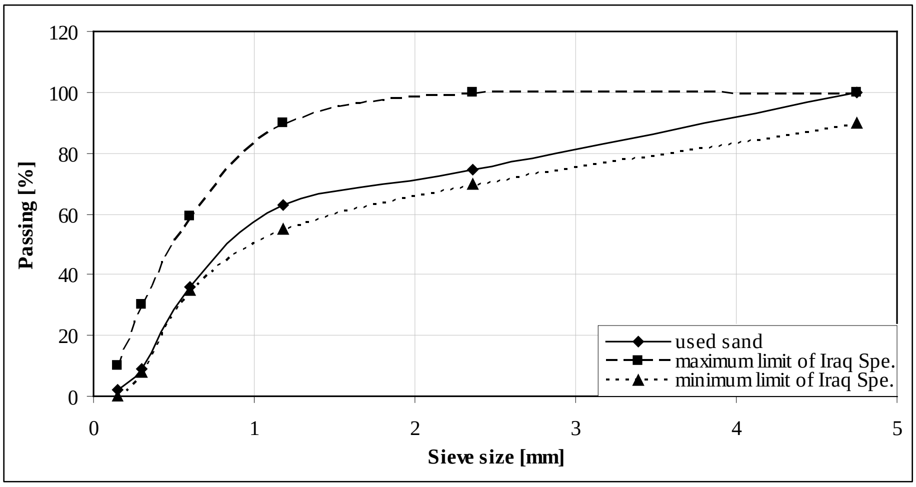

Fig. 1- Grading curves of the fine aggregate

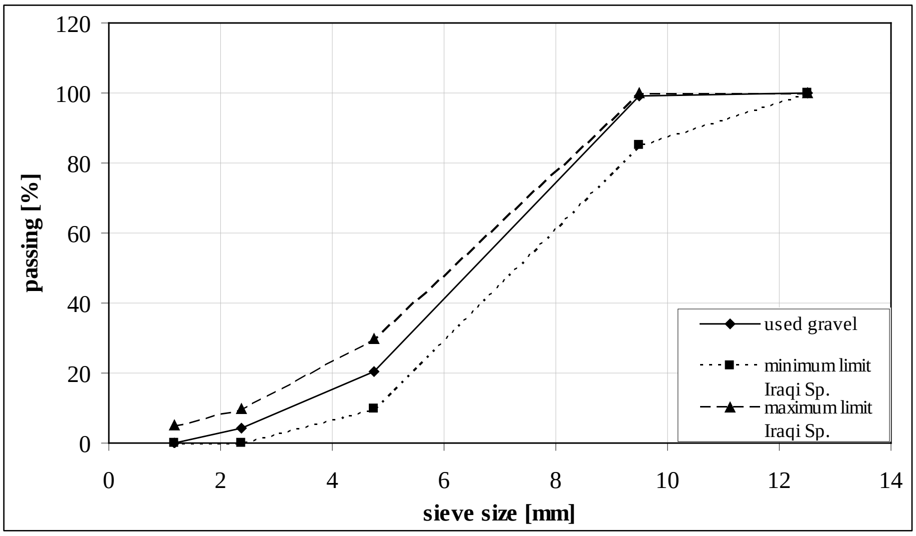

Fig. 2- Grading curves of the coarse aggregate

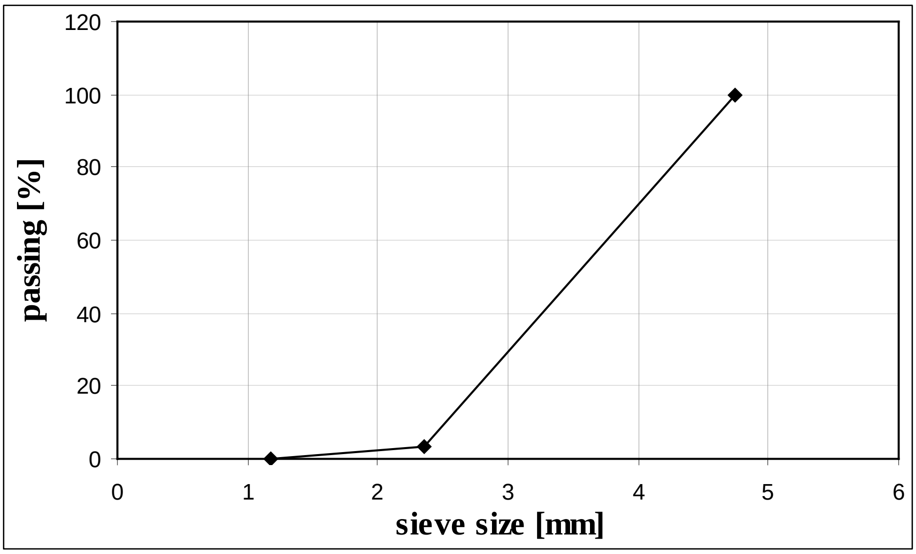

Fig. 3- Grading curves of the LDPE used

Fig. 4- Sample of waste plastic

2.2 Test Program

The test program was arranged to investigate the concrete and mortar mechanical properties with fine aggregate replacement by LDPE plastic waste granules. The mechanical characteristics of the reference concrete with 0% LDPE granules were also measured. For this purpose a test program was accomplished in the laboratory. Six mortar mixes were prepared, identical except fine aggregate is replaced with LDPE granules volumes of 0%, 5%, 10%, 15%, 20% and 25%. For concrete specimens, seven mixes were done in which fine aggregate substitute via LDPE granules volumes of 0%, 5%, 10%, 15%, 20%, 25% and 30%. Accordingly, a total of eighteen cubes of mortar of 50 x 50 x 50 mm and twenty one cube of concrete of 100 x 100 x 100 mm were cast for compressive strength, dry and fresh density tests and twenty eight cylinders of φ100 x 200 mm were cast for splitting tensile strength and ultra plus velocity experiments. It is worthy to demonstrate the designation used for concrete and mortar specimens. The symbol MP is used for mortar specimen, CP is utilized for concrete specimens and the number beside the mentioned symbols is the LDPE volume. For example CP10 is specimen made of concrete with 10% LDPE granules volume.

2.3 Concrete mixes and mixing

Mix proportion for all concrete mixtures was 1: 1.5: 3 (cement: fine aggregate: coarse aggregate by weight) with ratio of water/ cement equal to 0.4 and quantity of cement, coarse aggregate, fine aggregate and water was changed for all mixtures to keep the same proportion as illustrated in Table 4. The mix proportion for all mortar specimens was 1:2 and water/ cement ratio equal to 0.4, where the amount of cement, fine aggregate and water was altered for all blends to keep the identical proportion as shown in Table 5. The two procedures were performed utilizing electrical tilting drum of 0.16m3 capacity in the laboratory. Pre to casting, each inner surface of the molds was carefully oiled using lubricant oil. Mixing and casting were done in the laboratory at the surrounding temperature of 25±1oC. Firstly, a small amount of cement was mixed with the gravel and sand or PE granules for about three minutes until they coated by fines. The remaining cement and water were added to the mixture and the materials were let to mixtures for another 3 min (see Fig. 5)

Specimen molds were filled with concrete in 3 layers, every layer undergoes to an exterior vibration. The cast concrete or mortar top surface of well leveled using a trowel. The specimens were demolded after 24 hours from casting. Curing of all specimens was done in the lab at 25±1 Co temperature . All samples were water handled in a container for 28 days, later left in the laboratory for little days to dry before testing.

Table 4- The materials used for concrete mixtures

Symbol	Cement [kg/m^3]	Gravel [kg/m^3]	Sand [kg/m^3]	Water [kg/m^3]	LDPE [%]	LDPE [kg/m^3]
CP0	417.7	1251	626.55	167.1	0	0
CP5	407.6	1221	590.15	163.4	5	30.57
CP10	397.6	1191	555.8	159	10	59.46
CP15	388.1	1164	523.8	155.2	15	87.42
CP20	379.2	1137	492.7	151.7	20	113.8
CP25	370.9	1113	463.79	148.4	25	139.1
CP30	362.5	1088	435	145	30	173.3

Table 5- The materials used for mortar mixtures

Symbol	LDPE [%]	LDPE [kg/m^3]	Cement [kg/m^3]	Sand [kg/m^3]	Water [kg/m^3]
MP0	0	0	679	509.4	271.6
MP5	5	67.94	641	471	256.4
MP10	10	128.68	607	434.6	242.8
MP15	15	183.74	576	402	230.4
MP20	20	233.32	549	372.8	219.6
MP25	25	290.97	524	345.8	209.6

Fig.5- Casting of concrete specimens

2.4 Test of specimens

1. “Fresh densities: all cubes are measured after molding and compacting immediately according to B.S.1881, part 5 [25].

2. Dry densities: The cubes taken from the curing water basin just before compression strength measured according to B.S.1881, part 5.

3. Compression strength test: (50* 50 *50) mm mortar cubes and (100* 100 *100) mm concrete cubes were prepared according to B.S.1881, part 7. The cubes were tested directly after taken out of water while they were still wet.

4. Strength of splitting tensile test: The splitting tensile strength has been done according to the ASTM C496-04 [26]. Cylinders of (100×200) mm were used and tested at 28 days. Placed two thick steel strips between the specimen and both the upper and the lower bearing blocks of testing machine, which was a hydraulic compression machine (see Fig. 6). The consists of test are put a compressive force with the cylindrical concrete specimen length until occurs the failure.

5. Ultrasonic pulse velocity test: The ultrasonic pulse velocity (UPV) test was applied according to ASTM C597 -09 [27]. PUNDIT device as shown in Fig. 7 was used in testing cubes and cylinders at age of 28 days.

The method of measuring (UPV) depended on the time (T) needed for the waves to pass a distance (L) in concrete. In order to ensure stable transit time, grease and pressure were applied between the test object and the contact faces of the transducers".

Fig. 6- Testing of cylinder specimen

Fig. 7- UPV test of cube specimen

3 Results and Discussion

3.1 Density of concrete and mortar

Results of dry densities of LDPE granule concrete and mortar mixes are seen in Fig. 8. This data show the dry density of concrete tends to reduce by the same manner reaching upper decreasing 8.6% for CP30 as given in Table 6. Whilst dry density of mortar is decreased by slightly higher difference contrasted to density of concrete and upper reduction reached 12% for MP25 and lowest density as presented in Table 6. This decreasing may be attributed to density of LDPE particles which are less than the sand and leads to dry density reduction. However, the lowest dry density is 2240 kg/m^3 for CP30. From obtained data, the Mathematical model for prediction of density (kg/m^3) of concrete and mortar is as follows:

$$\gamma cd_P / \gamma cd = 0.9897 - 0.0051(V_{LDPE}) + 9*10^{-5} (V_{LDPE})^2 \quad (1)$$

$$\gamma md_P / \gamma md = 0.9858 - 0.0114 (V_{LDPE}) + 0.0003 (V_{LDPE})^2 \quad (2)$$

In which γcd, γmd are dry density of concrete and mortar without LDPE, γcd_P, γmd_P are dry density of concrete and mortar with LDPE and V_{LDPE} is the LDPE volume. For the relationship one R^2 is equal to 0.90 and R^2 is 0.88 for relationship two.

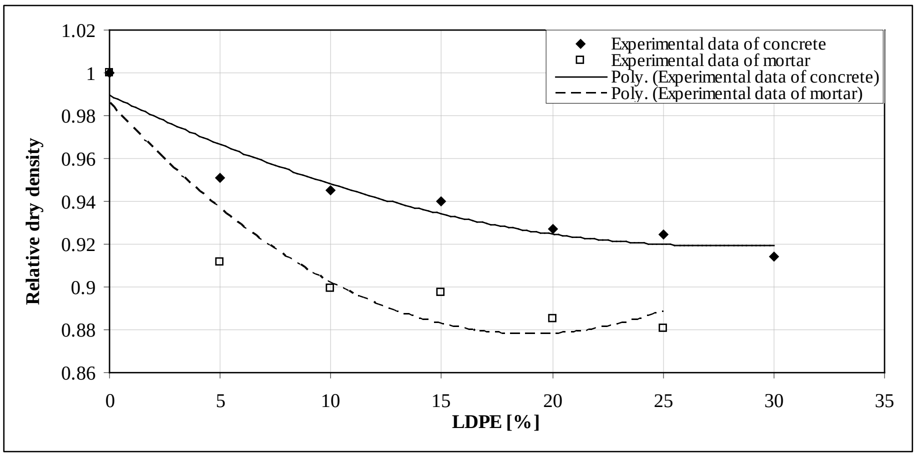

Fig. 8- Relative dry density and LDPE volume for concrete and mortar

3.2 Concrete compressive strength

The Fig. 9 showed the results of compressive strength. One can find that there is decreasing of the strength of mortar and concrete when different volume of LDPE particles is added, as given in Table 6. This decreasing can be attributed to the decrease LDPE aggregate elastic modulus contrasted to ordinary fine aggregate, huge volume of molecules of LDPE aggregates than ordinary fine aggregate, and weak of bonding between cement paste and LDPE aggregate because of water internal bleeds from the lightweight aggregates wholly saturated that surrounded and amassed the granules of waste LDPE. Also, the concrete compressive strength is decreased when LDPE granules are added, reaching less decrease 76 % for CP30 compared to plain concrete (control mix). Additional reasons behind this strength lessening are approximately identical size of PE particles which led to increase pores size in the concrete internal structure and caused a strength reduction, and plastic is a hydrophobic material that may be restricted the water essential for hydration of cement from step inside a concrete specimens structure during a remediation period. Moreover, every compressive strength value is greater than the lower compressive strength requisite for structural of concrete to be 17.24 MPa.

The failure samples of the concrete that consist of LDPE aggregates under effect of pressure not revealed the usual brittle kind of failure generally good for ordinary concrete. The experimental failure was further step by step failure, based on PE aggregates content. While LDPE aggregates content was raised, the failure type turned into more flexible. At end of the test, these samples including LDPE aggregates were able of carrying the compress for a little minutes with no full crush (see figure 10). Mathematical models using Excel programmed are getting to explain the relation between compressive strength (MPa) and PE aggregate content for concrete and mortar, which are as follows:

$$fm_P/fm = 0.9494 - 0.0414\ (V_{LDPE}) + 0.0011\ (V_{LDPE})^2 \quad (3)$$

$$fc_P/fc = + 0.9738 - 0.0078\ (V_{LDPE}) \quad (4)$$

In previous relationships *fm*, *fc* are compressive strength of mortar and concrete without LDPE and fm_P, fc_P are compressive strength of mortar and concrete with LDPE. For the relationship three R^2 is equal to 0.89 and R^2 is 0.96 for relationship four.

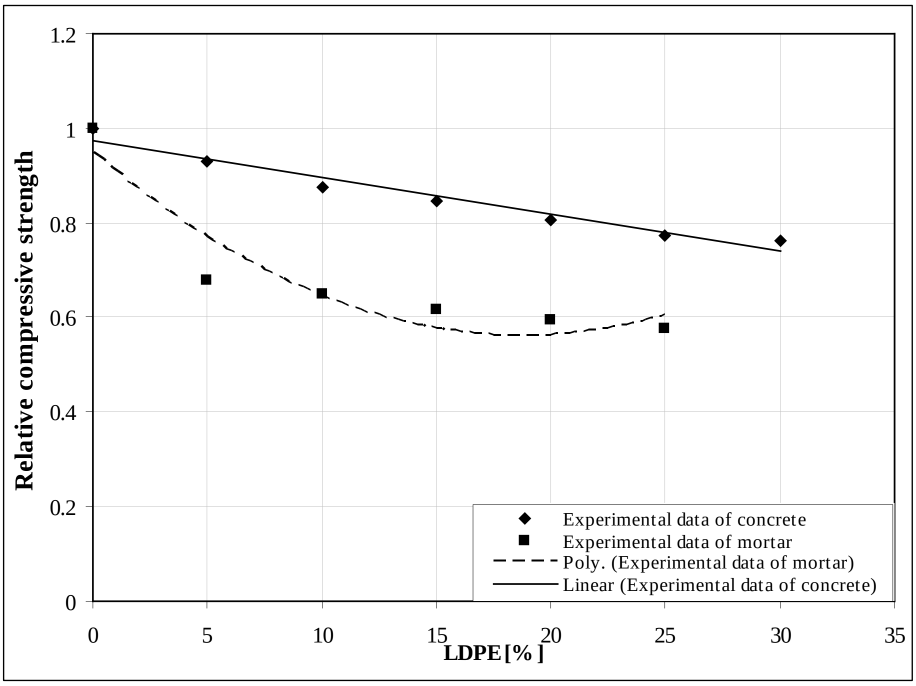

Fig. 9- Relative compressive strength and LDPE volume relationship for concrete and

(a) **(b)**

Fig. 10- views of specimens after compression test (a) CP10and (b) CP5

3.3 Splitting tensile strength

The splitting tensile strength results as in Fig. 11. It can be observed that all concrete mixes showed a strength of splitting tensile was reduce with raise volume of LDPE aggregate. The concrete tensile splitting strength is highly affected by interfacial transition zone (ITZ)characteristics; when the carriage attains its maximum value the possibility of engage amide LDPE particles on cracked surfaces decline because of short cylinder form of LDPE particles and its elasticity, reduce flexible modulus of granules of LDPE than that of the cement paste and internal bleed water from normal aggregates that surrounded and amassed the waste LDPE granules .In general, specimens consist of LDPE aggregates splitting fail do not reveal typical brittle failure, which showed in case of control specimens. It found that these specimens with LDPE particles were more able of the splitting load resist afterward fail in the absence of full degradation. The specimens do not divided into two fragment after reaching tensile strength, which because the approximately cylindrical shaped of LDPE aggregates can work as a viaduct amide the two pieces that splitted (see figure 12). Also, it noticed that the fail happened smoothly without whichever noise within fraction. From the experimental data, the empirical model for prediction splitting tensile strength (MPa) of concrete is as follows:

$$fsp_P/fsp = + 1.0007\text{-}0.0056\ (V_{LDPE}) \quad (5)$$

In prior relationships *fsp* is concrete splitting tensile strength without LDPE and fsp_P is concrete splitting tensile strength with LDPE. For this empirical equation R^2 is equal to 0.99. Experimental data of mortar.

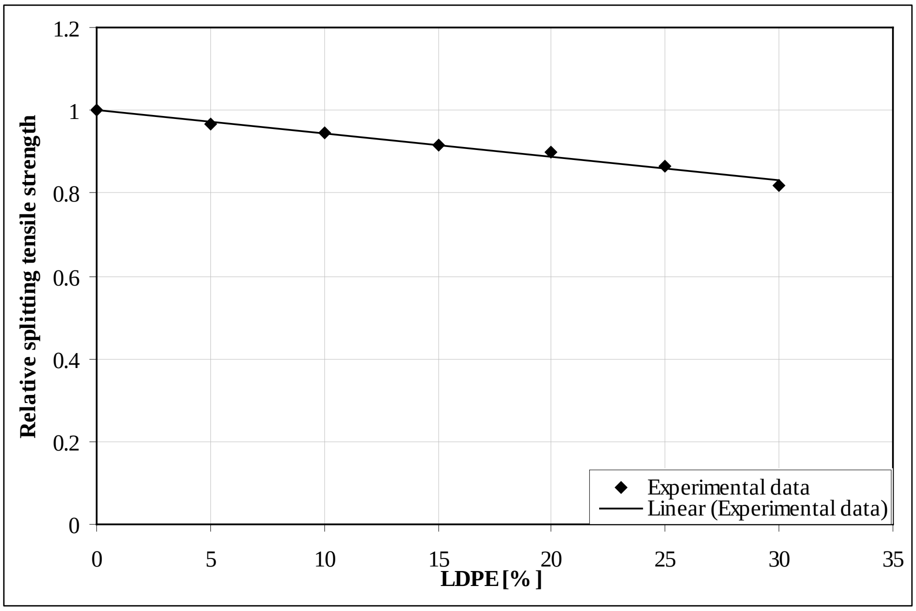

Fig. 11- Relative splitting tensile strength and LDPE volume relationship for concrete

(a) (b) (c) (d)

Fig. 12- views of specimens after splitting tensile test, (a) CP0 (b) CP10,(c) CP20 and (d) CP30

3.4 Splitting tensile strength and compressive strength relation

From gotten data, it could suggested the splitting tensile strengths and compressive are intimately related. In fact, this is the case, but there is no direct proportion; the two strengths ratio based on the general concrete strength level. In other hand, as the increases of the compressive strength and the tensile strength, also raise, but at a lessen rate [28]. From Fig. 13, it is apparent that splitting tensile strength is a compressive strength, function and the graph indicate that raising compressive strength will lead to raise in splitting tensile strength. It found an empirical formula to express relation between split tensile strength and compressive strength, which is as following:

$$fsp = - 2.6341+ 0.3679fc-0.0072\, fc^{2} \tag{6}$$

For this earlier formula R^2 is equal to 0.96.

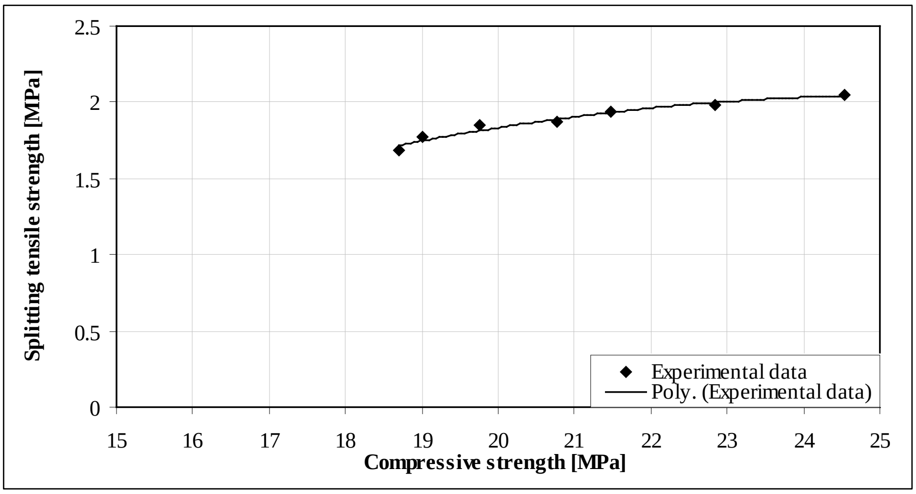

Fig. 13- Splitting tensile and compressive strengths relationship for concrete

3.5 Ultrasonic pulse velocity (UPV)

Figure 14 presents the effect of LDPE aggregate on UPV for cubical and cylindrical specimens. It can be showed a slight decrease in UPV with increase PE aggregate content in the mixture. This is due to the fact that when an occurrence, wave goes through various elements (concrete, LDPE, holes), it be inverted and transferred partly, so, decreases its speed. As the UPV is a properties of the flexibility and volumetric components function concentrations, so replacement fine aggregate by LDPE granules will decrease UPV.

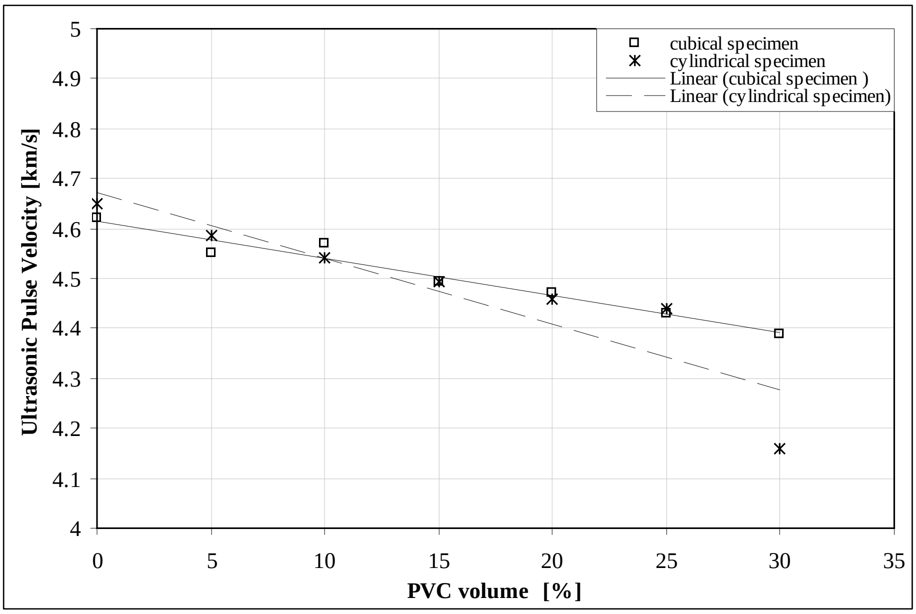

Fig. 14- Ultrasonic pulse velocity and PE volume relationship of cubical and cylindrical concrete specimens

As seen in Table 6 reduction ratios of UPV are approximately similar for cubical and cylindrical specimens except CP30 is dissimilar. Although UPV reduces with increasing PE aggregate content, but its values are still in excellent category of concrete till 20% PE content and in a good class of concrete for (25% and 30%) LDPE content when evaluated with reference [29]. Results of UPV approve that incorporating LDPE granules in concrete mixtures do not make internal structures of blends more porous when the content of LDPE is low. From obtained data, empirical formula found to relate the UPV with LDPE volume, which is as following:

$$UPE = 4.6139 - 0.0074(VPE) \tag{8}$$

$$Upv_y = 4.6729 - 0.0131(VPE) \tag{9}$$

In prior formulas *UPE* and Upv_y are ultrasonic pulse velocity of concrete cube and cylinder specimen with PE. For formula (8) R^2 is equal to 0.96 and R^2 is 0.82 for relationship (9).

Table 6- Results of concrete and mortar specimens

Symbol	**Dry density [kg/m³]**	**Compressive strength [MPa]**	**Splitting tensile strength [MPa]**	**Ultrasonic Pulse velocity of cube[km/s]**	**Ultrasonic Pulse velocity of cylinder [km/s]**	**Symbol**	**Density [kg/m³]**	**Compressive strength [MPa]**
CP0	2450	24.54	2.05	4.62	4.65	MP0	2387	42.79
CP5	2329	22.84	1.99	4.55	4.59	MP5	2176	29.02
CP10	2316	21.48	1.94	4.57	4.54	MP10	2147	27.72
CP15	2304	20.76	1.88	4.50	4.50	MP15	2141	26.41
CP20	2272	19.77	1.85	4.47	4.46	MP20	2112	25.37
CP25	2265	19.00	1.78	4.43	4.44	MP25	2101	24.61
CP30	2240	18.70	1.68	4.39	4.16			

4 Conclusions

The mortar and the concrete contained LDPE, as partial replacement of fine or coarse aggregate was discussed in this research. The compressive strength and dry density were obtained for the mortar. The UPV, dry density, compressive and splitting tensile strengths for the concrete were determined.

When LDPE was used as partial replacement of fine or coarse aggregate in mortar and concrete respectively the dry density and compression strength were decreased. The rate of reduction in dry density and compressive strength for the mortar specimens was higher than those for the concrete specimens. The minimum values of the dry density were 2101, 2240 kg/m^3 for the mortar and the concrete respectively. The smallest values of compressive strength were 24.61, 18.70 MPa for the mortar and the concrete respectively. The splitting tensile strength of concrete decreased when the LDPE utilized as partial replacement of coarse aggregate, reaching 1.68 MPa for replacement 30% coarse aggregate by LDPE. Ultrasonic pulse velocity also decreased when LDPE was used as a partial replacement of coarse aggregate. The rate of reduction in UPV values of cubical specimens was slightly less than this rate of cylindrical specimens. However, the values of UPV indicated that concrete containing LDPE is still in a good class. Utilizing the LDPE as fine or coarse aggregate in mortar or concrete, respectively, changed the failure type from a brittle to a ductile.

It can be said that using LDPE in mortar or concrete can save the natural aggregate, reduce the disposal of waste materials, and achieve less density and suitable compressive and splitting tensile strength for structural applications.

References

[1]- Assessment Guidelines, Converting Waste Plastics Into a Resource. Compiled by United Nations Environmental Programme (UNPE) , Division of Technology, Industry and Economics International Environmental Technology Centre Osaka/Shiga , 2009.

[2]- R. Siddique, J. Khatib, I. Kaur, Use of recycled plastic in concrete: a review. Waste Manage. 28(2008) 1835–1852. doi:10.1016/j.wasman.2007.09.011.

[3]- L. Gu, T. Ozbakkaloglu, Use of recycled plastics in concrete: A critical review. Waste Manage. 51(2016) 19-42. doi:10.1016/j.wasman.2016.03.005

[4]- Z.Z. Ismail, E.A. AL-Hashmi, Use of waste plastic in concrete mixture as aggregate replacement. Waste Manage. 28(2008) 2041–2047. doi:10.1016/j.wasman.2007.08.023

[5]- Y.W. Choi, D.J. Moon, Y.J. Kim, M. Lachemi, Characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles. Constr. Build. Mater. 23(8) (2009) 2829–2835. doi:10.1016/j.conbuildmat.2009.02.036

[6]- S. Akcaozoglu, C.D. Atis, K. Akcaozoglu, An investigation on the use of shredded waste pet waste bottles as aggregate in lightweight concrete. Waste Manage. 30(2010) 285-290. doi:10.1016/j.wasman.2009.09.033.

[7]- K. Hannawi, S. K. Bernard, W. Prince, Physical and mechanical properties of mortars containing PET and PC waste aggregates. Waste Manage. 30(11) (2010) 2312–2320. doi:10.1016/j.wasman.2010.03.028.

[8]- B. Rai, S.T. Rushad, B. Kr, S.K. Duggal, Study of Waste Plastic Mix Concrete with Plasticizer. ISRN Civil Eng. (2012) 469272. doi:10.5402/2012/469272

[9]- Md. M. Rahman, Md. A. Islam, M. Ahmed , Md. A. Salam, Recycled Polymer Materials as Aggregates for Concrete and Blocks. J. Chem. Eng. 27(1) (2012) 53-57. doi.org/10.3329/jce.v27i1.15859.

[10]- B. Safi, M. Saidi, D. Aboutaleb, M. Maallem, The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties. Constr. Build. Mater. 43(2013) 436–442, doi:10.1016/j.conbuildmat.2013.02.049.

[11]- E. Rahmani, M. Dehestani, M.H.A. Beygi, H. Allahyari, I.M. Nikbin, On the mechanical properties of concrete containing waste PET particles. Constr. Build. Mater. 47(2013) 1302–1308. doi:10.1016/j.conbuildmat.2013.06.041.

[12]- N. Saikia, J. De Brito, Mechanical properties and abrasion behavior of concrete containing shredded PET bottle waste as a partial substitution of natural aggregate. Constr. Build. Mater. 52(2014) 236–244. doi:10.1016/j.conbuildmat.2013.11.049.

[13]- A.M. Azhdarpour, M.R. Nikoudel, M Taheri, The effect of using Polyethylene Terephthalate particles on physical and strength-related properties of concrete; a laboratory evaluation. Constr. Build. Mater. 109(2016) 55–62 .doi:10.1016/j.conbuildmat.2016.01.056.

[14]- J.M. Irwan, M.M.K. Annas, A.K. Aeslina, N. Othrnan, H.B. Koh, R.M. Asyraf, S.K. Faisal, Cracking Propagation of Reinforced Concrete using Polyethylene Terephtalate (PET) bottles as Fine Aggregate. Adv. Mater. Res. 911(2014) 474-478. doi:10.4028/www.scientific.net/AMR.911.474.

[15]- C. Albano, N. Camacho, M. Hernandez, A. Matheus, A. Gutierrez, Influence of content and particle size of waste pet bottles on concrete behavior at different w/c ratios. Waste Manage. 29(10) (2009) 2707-2716. doi:10.1016/j.wasman.2009.05.007.

[16]- A.A. Al-Manaseer, T.R. Dalal, Concrete containing plastic aggregates. Concrete Int. 19(8) (1997) 47- 52.

[17]- O.Y. Marzouk, R.M. Dheilly, M. Queneudec, Valorization of post-consumer waste plastic in cementitious concrete composites. Waste Manage. 27(2007) 310–318. doi:10.1016/j.wasman.2006.03.012.

[18]- M. Batayneh, I. Marie, I. Asi, Use of selected waste materials in concrete mixes. Waste Manage. 27(12) (2007) 1870–1876. doi:10.1016/j.wasman.2006.07.026.

[19]- Y. Ghernouti, B. Rabehi, B. Safi, R. Chaid, Use of Recycled Plastic Bag Waste in the Concrete. J. Int. Sci. Publ. Mater. Method. Technol. 8(2014) 480-487.

[20]- S.C. Kou, G. Lee, C.S. Poon, W.L. Lai, Properties of lightweight aggregate concrete prepared with PVC granules derived from scarped PVC pipes. Waste Manage. 29(2) (2009) 621-628. doi:10.1016/j.wasman.2008.06.014.

[21]- T.R. Naik, S.S. Singh, B.S. Brodersen, Construction materials containing polymeric substances and used plastics. A CBU Technical Report, Center for By-Products Utilization, University of Wisconsin- Milwaukee, U.S.A., 1994.

[22]- T.R. Naik, S.S. Singh, C.O. Huber, B.S. Brodersen, Use of post-consumer waste plastic in cement-based composites.

Cement Concrete Res. 26(10) (1996) 1489-1492. doi:10.1016/0008-8846(96)00135-4.

[23]- E.A. Ohemeng, P.P. Yalley, J. Dadzie, S.D. Djokoto, Utilization of Waste Low Density Polyethylene in High Strengths Concrete Pavement Blocks Production. Civil Environ. Res. 6(5) (2014) 126-135.

[24]- N.N. Hilal, Q. Kareem, M.T. Nawar, Influence of Polyethylene Waste on Some Fresh & Mechanical Properties of Self - Compacting Concrete. J. Eng. Appl. Sci. 13(14) (2018) 10901-10911. doi: 10.3923/jeasci.2018.10901.10911

[25]- B.S.1881, Methods of testing concrete. British Standard Institution, BSI, London, 1952.

[26]- ASTM C496-04, Standard Test Method for Splitting Tensile of Cylindrical Concrete Specimens. American Society for Testing and Materials, 2006.

[27]- ASTM C597-09, Standard Test Method for Pulse Velocity through Concrete. American Society for Testing and Materials, 2009.

[28]- A.M. Neville, Properties of Concrete. Fifth edition, Prentice Hall, 2011.

[29]- R. Jones, I. Facaoanu, Recommendations For Testing Concrete By The Ultrasonic Pulse Method. Materials and Structures Research and Testing, Paris, 2(19) (1969) 275. (Cited by IAEA, Guidebook on Non-Destructive Testing of Concrete Structures. International Atomic Energy Agency, Vienna, 2002).