

Reuse of Low-Density Polyethylene (LDPE) in concrete production

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Abstrak.

The use of plastic waste as a replacement for natural aggregates in cement composites can solve the problem of the disposal of waste plastics sustainably. This study aims to investigate and compare the impact of using Low Density Polyethylene (LDPE) in concrete production to partially replace fine natural aggregate in concrete production by analyzing the physical and mechanical properties of both fresh and hardened concrete in terms of workability, density and compressive strength. Concrete mixtures containing PE was prepared as a partial volumetric replacement for fine aggregate with substitution levels of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. The tests were conducted on days 1, 3, 7, 14, 28, 42 and 56. The density values of the LDPE-based concrete decreased with the increase in LDPE aggregate. Therefore, can be considered lightweight concrete. The compressive strength of concrete at various ages is reduced as the quantity of plastic in concrete increases. As the PE replacement ratio in concrete increased, the compressive strength also declined. Up to 5% replacement on days 3, 7, 14, 28 and 42 gave 21.30, 22.07, 23.40, 23.38 and 20.50 MPa. Equally, up to 10% replacement at 7, 14 days respectively gave 20.23 and 23.42 respectively. These are acceptable physical and mechanical properties of concrete for structural purposes.

Kata Kunci

Plastic waste, Polyethylene, Compressive test, Hydrophobic nature, compressive strength

1. Introduction

Plastic production has been on a constant rise in recent years as a result of its wide range of utility and it has become an integral part of our daily lives (Aldahdooh, Jamrah, Alnuaimi, Martini and Ahmed, 2018; Dharmaraj, and Iyappan, 2016; Li *et al.*, 2020; Almeshal *et al.*, 2020b; Boucedra *et al.*, 2020). Due to the rapid increase of population in world, the amount of plastic waste is increasing rapidly (Babayemi, Innocent, Oladele and Roland, 2019). In 2011, global PET bottle consumption was 232 billion litres (61.4 billion gallons), with an expected growth to 513 billion litres by 2025 (Alqahtani and Zafar, 2021; Aslani *et al.*, 2021). The United Nations Environment Program (UNEP) estimates the global annual production of plastics at over 400 million tonnes, of which around 87% are dumped as waste plastics. As of 2015, the plastic packaging industry produced single-use plastics at an annual rate of about 141 million tonnes (USEPA, 2017). A substantial growth in the consumption of plastic is observed all over the world in recent years and this has led to huge quantities of plastic-related wastes (Wong, Ngadi, Abdullah and Inuwa, 2015). The consumption and generation of these wastes continue to pose a serious environmental concern globally because of its almost total non-biodegradable nature (Adnan and Dawood, 2021; Alabi, Awosolu Ologbonjaye and Olufirogo, 2019; Sreenath and Harishankar, 2017; Vidya, Janaradhan, Sri, Venkat and Sai, 2020). It was projected that by 2050, there would be nearly 12 billion tonnes of waste plastics dumped in landfills if measures are not put in place to curtail the current plastic production, consumption, and waste management practices (Sharma and Bansal, 2016).

It is a fact that plastic waste constitute a major environmental problem facing worldwide in general. However, the recycling concept can reduce the problem. One of the possible ways of recycling these wastes is using them in concrete construction (Aciu, Ilutiu-Varvara, Manea, Orban and Babota, 2018; Hadiuzzaman *et al.*, 2022; Plastics Europe, 2021; Sarker, Chakraborty, Paul, Chatterjee and Tribedi, 2020; Steensgaard *et al.*, 2017; Tiseo, 2022; Wypych, G. and Wypych, H., 2016). Concrete is ranked as the most widely used man-made construction material in the world (). It is mainly composed of cement, fine aggregate, coarse aggregate and water. 2018; Veerakumar and Saravanakumar, 2018; (Ghernouti, Rabehi, Bouziani, Ghezraoui and Makhoulfi, 2022). The use of river sand as fine

aggregates leads to depletion of natural resources, lowering of water table, sinking of bridge piers and erosion of river bed (Abdelmoti and Mustafa, 2019).

Sustainable development means a commitment to finding and using resources that are renewable (Saxena, Jain and Agrawal, 2016). With this philosophy in view, there is an urgent need for optimum reuse of other waste materials available. There is a general increase in researches for the use of waste materials in place of natural resources. This is done in order to make the concrete industry more sustainable, in terms of protection of the environment and reduction of the cost of the concrete (Kisku *et al.*, 2017; Kodua, 2018; Lokeshwari, Ostwal, Nipun, Saxena and Pranay, 2019; Nematzadeh, Dashti and Ganjavi, 2018). Several attempts are being made to promote the recycling of plastics.

Recent researchers studied the possibilities of replacement of conventional constituents in concrete with recycled materials and industrial by-products (StudyMode, 2015). The use of these waste plastics will achieve a critical goal in the construction industry by significantly reducing the density and deadweight of produced concrete, thereby mitigating earthquakes' dangers (Colangelo *et al.*, 2016). Incorporating recycled plastic waste in concrete production is a sustainable approach for both disposing of plastic waste and aggregate scarcity, due to its economic and ecological advantage (El-Nadoury, 2022; Mohammed, A.A. Mohammed, I.I. Mohammed, S., 2019; Ojeda, 2021; Zulkernain, Gani, Chuan and Uvarajan, 2021). Lokeshwari *et al.* (2019) worked on the utilization of waste plastic as partial replacement of fine and coarse aggregates in concrete blocks. The influence of adding plastic waste in cement composites, on density, mechanical strength and durability were evaluated by several studies (Jambeck *et al.*, 2018; Jassim, 2017). Pedreño- Rojas Morales-Conde, Pérez-Gálvez and Rubio-de-Hita (2019) verified the feasibility of using PC waste to produce lighter and mechanically improved gypsum composites, by using up to a 60wt% PC waste addition.

The influence of putrefied LDPE from plastic bags used as partial substitution of fine aggregate on the behaviour of concrete was analysed by Jain *et al.*, 2018a). As a result, the workability, density and mechanical strength of concrete samples decreased with increase in the plastic waste content. Poonyakan *et al.* (2018) found a significant reduction of thermal conductivity of LDPE-containing concrete composites at 30% volume fraction of LDPE content, when compared with the plain concrete. Sreenath and Harishankar (2017) stated that replacing sand by LDPE with 10% increased the compressive strength from 34.96N/mm² to 38.957N/mm². Jaivignesh and Sofi (2017) studied on mechanical properties of concrete using plastic waste as an aggregate. Jibrael and Peter (2016) studied the strength and behavior of concrete. Studies by these numerous authors: Alqahtani, Khan, Ghataora and Dirar (2018), Faraj, Sharwana and Daraei (2019), Kibria, Rahaman, Wahid and Salam (2017), Park and Kim (2020); Pešić, Živanović, Garcia and Papastergiou (2016) also showed a decreasing trend in the mechanical properties of concrete with an increase in synthetic lightweight aggregate content; while workability increased in some instances and decreased in some. Pedreño- Rojas *et al.* (2019) verified the feasibility of using PC waste to produce lighter and mechanically improved gypsum composites. This was attributed to the hydrophobic nature of LDPE that caused the weakness in the matrix formed by the binder and fine aggregate. The weaker bond between the binder and aggregates led to the decrease in the compressive strength of mix. Other interesting works sought to find a solution to LDPE plastic pollution was presented by Azeko *et al.* (2021). Gu and Ozbakkaloglu (2016) stated that the compressive strength of recycled plastic concrete is affected by the percentage of substitution (SPA), w/c ratio, the shape and size of particles. In this context, the objective of this study is to evaluate the effects of the total or partial substitution of river sand by processed LDPE aggregates on the workability and mechanical properties of cement-based concrete.

2.0: MATERIALS AND METHOD

2.1. Materials

The constituents of the concrete were: Cement, Sand, Granite, low-density polyethylene (LDPE), and Water.

(i). Cement

Ordinary Portland Cement (OPC) brand of Portland cement of grade 43, with a specific gravity of 3.15, obtained from Nkwo Nnewi market in Anambra State, Nigeria was used throughout this study.

(ii). Fine aggregate (River Sand)

Fine aggregate used was river sand obtained from the upland source of River Niger in Onitsha, Anambra State, Nigeria to ensure that it has low chloride content and organic impurities in

confirmation to the requirements of (BS 812) for testing aggregate.

(iii). Coarse Aggregate (Granite)

Coarse aggregate used was obtained from a quarry at Ishiagu in Ebonyi State in South Eastern Nigeria with a maximum size of 20mm.

(iv). Low Density Polyethylene (LDPE)



Plate 1: pulverized LDPE Sachet LDPE and LDPE sheet

The pulverized LDPE plastic wastes are derived from disposed waste sachets used for packaging water popularly known as “pure water”.

(vii). Water

Potable water used was obtained from the Engineering Workshop / Strength of Material Laboratory of the Nnamdi Azikiwe University, Awka. The water was free from organic matter, acids and chemicals.

2.2 Preliminary tests on the materials

The laboratory tests were carried out on the Cement, Sand, LDPE (fine aggregates) and Granite (coarse aggregate) in accordance with respective standards.

2.2.1 Cement

The following tests were conducted on cement in the laboratory:

- a. Fineness test of cement
- b. Consistency test of cement
- c. Setting time test of cement
- d. Soundness test of cement
- e. Specific gravity test of cement

2.2.2 List of Tests on Aggregates

- a. Impact Test on Aggregates
- b. Crushing Test on Aggregates
- c. Specific Gravity
- d. Water Absorption Test on Aggregates
- e. Sieve Analysis
- f. Fineness modulus

2.3 Calculation for Partial Replacement of sand with LDPE

i. Mix Design

The following was the method adopted to prepare test specimen: -
Adequate ingredients to prepare the concrete with a proper water-cement ratio were estimated.
Mix design of concrete was calculated using M25 grade of proportion 1:2:4 (cement: fine aggregate, coarse aggregate).

The density of a 1:2:4 mix of $0.15m \times 0.15m \times 0.15m$ concrete cube is $2400kg/m^3$

Density = Mass / Volume

Mass = Density x Volume = $2400 \times 0.15^3 = 8.1kg$

Mass of individual components in the concrete of Cement, Sand and Granite is in the ratio of 1:2:4

Value of each component in a control concrete =

Cement = $\frac{1}{7} \times 8.1 = 1.157kg$

$$\text{Fine Aggregate} = \frac{2}{7} \times 8.1 = 2.314kg$$

$$\text{Coarse Aggregate} = \frac{4}{7} \times 8.1 = 4.629kg$$

Using a water /cement ratio of 0.6, weight of water= $0.6 \times 1.157 = 0.6942$

Converting it to volume (liters), multiply by 1000

$$= 0.6942 \times 1000 = 694.2 \text{ liters}$$

The fine aggregate was replaced in different percentages (0, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90 and 100%). 3 cubes were casted for every percentage of replacement per curing period. The dimension of test cube was $= 0.15m \times 0.15m \times 0.15m$. The prepared concrete was then casted in the form of test cubes. The cube while being filled was tamped by tamping rod to reduce the number of voids in concrete.

ii. Production of the cube

A manual procedure was used to prepare the mixes, according to the proportions of material. The cement and the fine aggregates were mixed on a watertight non absorbent platform until the mix was thoroughly blended to avoid a heterogeneous dispersion of the particles. The coarse aggregate was added and mixed with the cement and fine aggregate until the coarse aggregate was uniformly distributed throughout the batch. Once samples were removed from the moulds, these were cured according to conditions established by standard BS 1881-108 1983

iii. Casting the concrete

The casting iron moulds were oiled with grease on the inside. The concrete was casted in 3 layers of approximately 5cm and properly compacted to avoid formation of honeycomb.

iv. Compaction

A tamping rod (steel bar) of 16mm diameter and 60cm was used to compact it. Each layer was compacted with not less than 35 strokes with the rod. The top surface was leveled and smoothed with trowel. The batch was marked for identification. The cast specimens were stored in moist air for 24 hours undisturbed before they were removed from the moulds. Thereafter, they were weighed before curing.

v. Curing of cubes

The cubes were kept submerged in clean clear water for curing until taken out for tests. The curing was done for 1, 3, 7, 16, 28 42 and 56 days.

vi. Preparation for crushing

The removed specimen for curing was wiped off of the excess water and kept to dry. The weights were again taken.

vii. Crushing

The specimen was centrally placed between the plates (on the base plate of the machine) with prepared alignment. The load was gradually applied to the specimen continuously until the specimen failed. The load at which the specimen failed was taken as the maximum load and this was noted as the crushing value of the cube. A minimum value of 3 specimens was tested for each selected age (curing days). The average of the 3 specimens was taken as the crushing strength or the compressive value of the selected concrete batch.

2.4 Tests on the light weight concrete

The following tests were conducted on the prepared concrete:

Slump

Bulk Density

Compressive Strength

2.4.1 Slump Test

The test was carried out under BS EN 12350-2 2009 to determine the workability.

i). Apparatus for Slump Test:

Mould: The mold is of the shape of a cone known as the Abrams cone made of steel.

Tamping Rod: Rod was made up of steel, 600 mm in length and has a diameter of 16 mm diameter.

Baseplate: The base plate was made of steel.

Tape Measure: The standard measuring tape was used to take the slump value measurement.

Steel Brush: The brush was used to clear the last remaining concrete left on the mold.

Trowel: This instrument helped to lift the concrete and put it into the mold.

ii). Procedures for Slump Test

All the apparatus parts were placed together. The internal surface of the slump cone was cleaned and oil was applied. The cone was placed on a smooth, horizontal, non-porous base plate. The cone was filled with the prepared concrete mix in approximately equal layers. The first layer was tamped (25 times) with the rod. The second layer of concrete was added to the mold and again tamped 25 times with the rod.

The third layer of concrete was added after the proper tamping. Again 25 strokes were done to do the proper compaction. Excess concrete was removed from the above. In four-step, the cone was lifted upward correctly at angle 90 degrees. After the final layer has been tamped, the concrete level was strike off with the top of the cone. Measuring tape was used to get the slump value and this was noted on paper.

2.4.2 Bulk Density

The BD of the concrete cubes was determined in accordance with BS 812-2 1995.

The weight of each concrete cube was divided by the known volume of the concrete cube, which correspond to the volume of the cube moulds to give the BD at that curing age. Three representative samples were tested for BD at each curing age and the average value gave the bulk density for the respective curing age.

2.4.3 Compressive strength

The Compressive strength (CS) for all the concrete cubes was determined in accordance with BS EN 12390 Part 3, 2009 and each concrete was prepared in accordance to calculated mix proportion. Three samples for each curing age and three samples for each % LDPE replacement were tested. The CS of each cube was determined on 600Kn Avery Denison Universal Testing Machine at a loading rate of 120 KN/min which complies with the requirements of BS EN 12390 Part 4, 2000. The maximum load divided by the area of each specimen gave the CS of that sample. The average of the CS for three specimens was taken as the CS at that curing age and also for each % LDPE replacements.

3.0 RESULT AND DISCUSSION

3.1 Cement Characterization

Table 3.1 Chemical composition of OPC

Calcium oxide	62.68%
Silica	20.36%
Alumina	6.87%
Iron oxide	3.67%
Magnesia	1.77%
Sulphuric anhydride	2.24%
Tricalcium silicate	42.57%
Dicalcium silicate	26.33%
Tricalcium aluminate	2%
Tetra calcium alumino-ferrite	2.24%

Table 3.2 Properties of cement

Properties	Values obtained	Standard Values	Codes
Consistency	6.0mm		
Fineness	2.5%	Should be less than 10	BS EN196- (2016)
Initial setting time	40 minutes	Not less than 30 minutes	BS EN196- 3(2005)
Final setting time	280 minutes	Not more than 600 minutes	BS EN196- 3(2005)
Specific gravity	3.15 g/cc.	3.1-3.16	BS 812: part 2: 1995

The standard value of the fineness of cement should be less than 10 % as per BS EN196- (2016). The brand of cement that was used passed the test because the fineness was 2.5%, which is less than 10%.

The specific gravity is within the range of (3.1-3.16). The result shows that the cement is of good quality, having good initial setting time of (40mins) and final setting time (280mins). It can be used for the purpose of cube casting.

Characterization of the Aggregates

The following tests were performed on fine aggregate and results were obtained

Table 3.3 Properties of fine aggregate (Sand)

Properties	Sand	LDPE
Fineness modulus	3.98	3.27
Specific gravity	2.6	0.918
Water absorption	1.9% <3%	0.29%
Moisture Content	3%	0.27%
Bulking density of sand	1.6%	

The results are in accordance to the BS Standard. These have good properties and can be used in the concrete mix.. The fine aggregates have less water absorption and this shows that aggregate will not absorb much water and hence less quantity of water is utilized.

Table 3.4 Sieve analysis of fine aggregate (sand)

Sieve size (mm)	Mass Retained(g)	%Mass Retained	Cum. Retained %	Cumulative% Finer
2.00	36	3.6	3.6	96.4
1.18	58	5.8	9.4	90.6
0.85	84	8.4	17.8	82.2
0.6	186	18.6	36.4	63.6
0.425	228	22.8	59.2	40.8
0.3	184	18.4	77.6	22.4
0.15	180	18	95.6	4.4
0.075	28	2.8	98.4	1.6
Tray	16	1.6	0	0
Total	1000		ΣF= 398	

$$\text{Fineness Modulus} = \frac{\Sigma F}{100} = 3.98$$

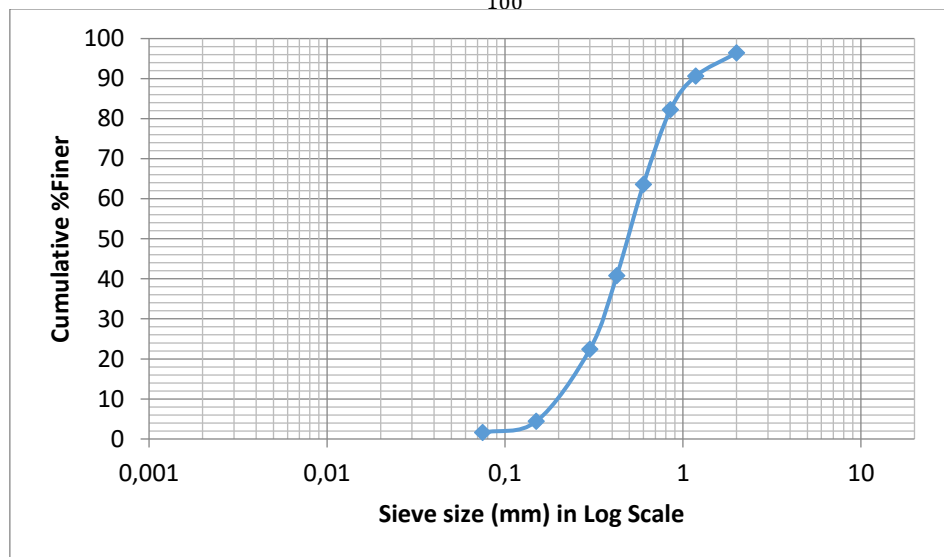


Fig.3. 1 Sieve Analysis graph of Fine Aggregate (Sand)

a). Calculation of the Coefficients of the Sand

$$\text{Coefficient of Uniformity (Cu)} = \frac{D_{60}}{D_{10}}$$

From the Sieve Analysis graph of Fine Aggregate $D_{60} = 0.6$; while $D_{10} = 0.2$

$$\frac{D_{60}}{D_{10}} = \frac{0.6}{0.2} = 3$$

$$\text{Coefficient of Curvature (Cc)} = (D_{30})^2 / D_{60} \times D_{10}$$

$$D_{30} = 0.35$$

$$(D_{30})^2 = 0.35^2 = 0.1225$$

$$D_{60} \times D_{10} = 0.6 \times 0.1225 = 0.12$$

$$\text{Coefficient of Curvature} = \frac{0.1225}{0.12} = 1.02$$

In line with the Table 3.4 above, it showed that the maximum size of the sand was approximately 2mm, while Figure 3.1 showed that the river sand was better distributed. The river sand had coefficients of uniformity (Cu) and curvature (Cc) of 3.0 and 1.02 respectively as calculated above. The Cc value is within the range of $1 \leq Cc < 3$ recommended for sand by Unified Soil Classification System (USCS) but below the Cu value of ≥ 6 recommended for sand by (ASTM, C136M-14). Hence, it is classified as poorly-graded clean sand. The sand had Fineness Modulus (FM) of 3.98 which is slightly above the FM range of 2.3-3.1 recommended by (ASTM, D2487 2006) for FA. However, (ACI, E-701 2007) stated that some natural sands may have FM that is outside the given range. In terms of Specific Gravity, the specific gravity of sand (2.60) is within the range of 2.4 and 2.9 recommended by (ACI, E-701 2007) for natural.

Table 3.5 Sieve analysis of burned LDPE

Sieve size (mm)	Mass Retained(g)	%Mass Retained	Cumulative %Finer	Cumulative %Retained
4.75	138	13.8	86.2	13.8
3.35	124	12.4	73.8	26.2
2	246	24.6	49.2	50.8
1.18	196	19.6	29.6	70.4
0.85	82	8.2	21.4	78.6
0.6	90	9	12.4	87.6
Tray	124	12.4		ΣF= 327.4
Total	1000			

$$\text{Fineness Modulus of fine (LDPE) aggregate} = \frac{\Sigma F}{100} = 327/100 = 3.27$$

b). Calculation of the Coefficients of LDPE

$$\text{Coefficient of Uniformity (Cu)} = \frac{D_{60}}{D_{10}}$$

From the Sieve Analysis graph of Fine Aggregate $D_{60} = 2.5$; while $D_{10} = 0.6$

$$D_{60}/D_{10} = 2.5/0.6 = 4.17$$

$$\text{Coefficient of Curvature (Cc)} = (D_{30})^2 / D_{60} \times D_{10}$$

$$D_{30} = 1.3$$

$$(D_{30})^2 = 1.3^2 = 1.69$$

$$D_{60} \times D_{10} = 2.5 \times 0.6 = 1.5$$

$$\text{Coefficient of Curvature} = \frac{1.69}{1.5} = 1.13$$

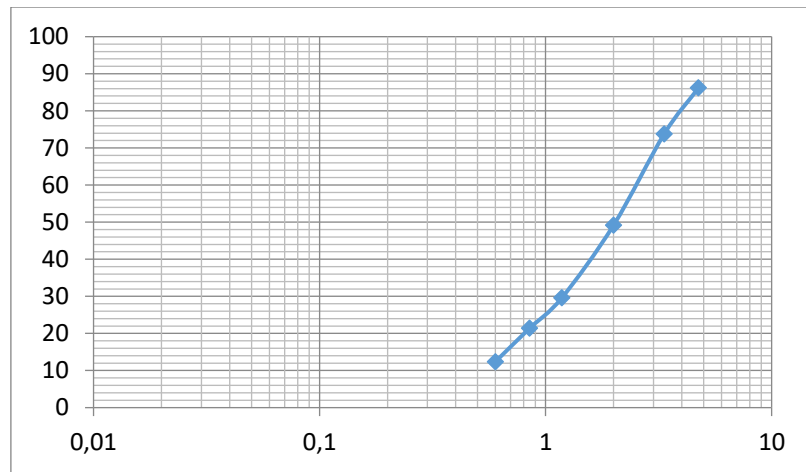


Fig 3.2 Sieve Analysis graph of Fine Aggregate (LDPE)

Table 3.5 showed that the maximum size of the LDPE granules was approximately 4mm while Fig. 3.2 showed that the LDPE was not well distributed. The pulverized LDPE had a C_u of 4.17 and a C_c of 1.13. The C_c value is within the recommended range of $1 \leq C_c < 3$ but below the C_u value of ≥ 6 recommended for sand. Hence, the pulverized LDPE plastic waste can be classified as poorly-graded fine aggregate. In terms of FM, the pulverized LDPE had FM of 3.27 which is slightly above the FM range of 2.3-3.1 recommended by (ASTM, C136M-14 2014) for FA. However, (ACI, E-701, 2007) stated that some natural sands may have FM that is outside the given range.

3.3 Testing on Coarse Aggregate

The following tests were performed on coarse aggregate and results are obtained

Table 3.6 Granite Sieve Analysis

Sieve size (mm)	Mass Retained(g)	%Mass Retained	Cum. %Retained	Cum. % Finer
26.5	24	2.4	2.4	97.6
25	10	1	3.4	96.6
19	148	14.8	18.2	81.8
14	344	34.4	52.6	47.4
12.5	158	15.8	68.4	31.6
10	50	5	73.4	26.6
9.5	26	2.6	76	24
Tray	240	24	$\Sigma F = 294.4$	
Total	1000			

Fineness Modulus of Coarse (Granite) aggregate = $\Sigma F + 500/100$

$$= 4294.4 + \frac{500}{100} = \frac{794.4}{100} = 7.94$$

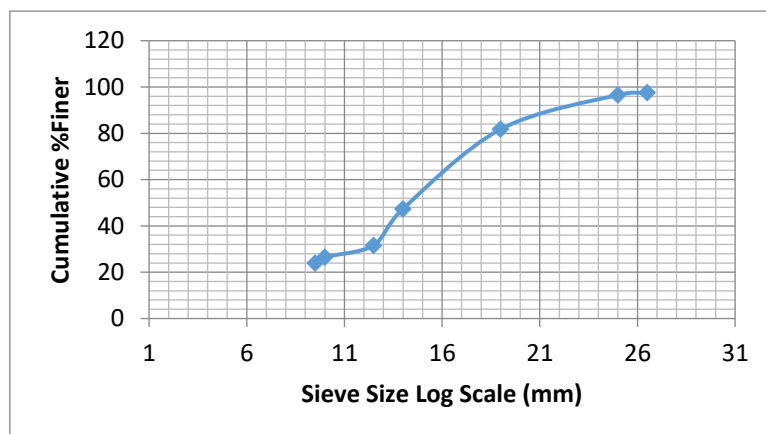


Fig. 3.3 Sieve Analysis graph of Coarse Aggregate (Granite)

Table 3.7 Properties of Course (Granite) Aggregate

Properties	Values	BS Code
Fineness modulus	7.4	BS EN 933 Part 1, 2009
Specific gravity	2.88	BS 812: part 2: 1995
Water absorption	1.1%	BS 882: 1992
Aggregate impact value	27.06	BS 812: part 112: 1990
Aggregate crushing value	24.30	BS 812: part 110: 1990
Moisture Content	10%	BS12350 -2; 2009
Bulk Density	1.66g/cc	BS 812-2 1995

3.4 Tests on the concrete

a). Workability

The consistency and workability of each freshly prepared mix blend was assessed by conducting slump cone test at 0, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90 and 100% LDPE as replacement of fine aggregate. The results are tabulated in the Table 3.8.

Table 3.8 Slump values and workability of concrete

Percentage of LDPE	Slump Value (mm)
Control	90
5 %	95
10%	90
15%	60
20%	30
25%	20
30%	18
40%	15
50%	10
60%	10
70%	0
80%	0
90%	0
100%	0

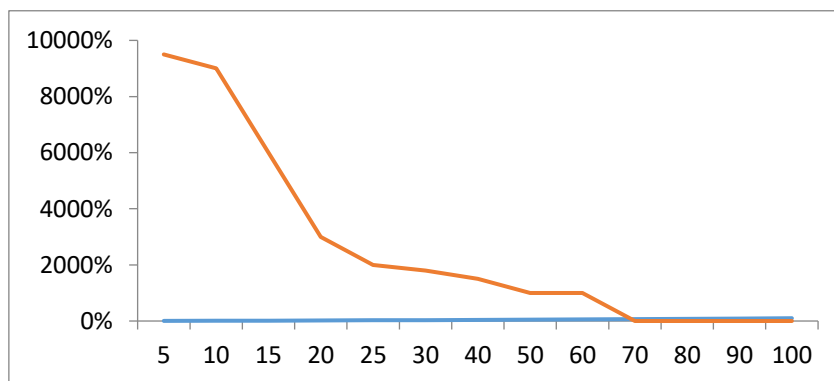


Fig 3.4 LDPE Slump Curve

From the test results it was observed that, the slump value was getting reduced as the percentage of LDPE was increasing. A slump value of 90 mm was obtained for the control concrete mix. The 5% partial replacement of the LDPE gave the highest slump value of 95mm. As the content of LDPE granules increased from 5% to 60%, the slump value reduced from 95 mm to 10 mm, respectively. The concrete mix with 10% LDPE replacement ratio yielded a slump similar to that of the control concrete mix. The decrease in workability of modified concrete mixes was due to the hydrophobic nature of the LDPE, the irregular shape, angularity as well as the surface smoothness of the plastic. The different and non-uniform shaped LDPE particles considerably failed in filling the voids and obstructed the flow of the concrete mix, with the increase of LDPE aggregates. This was

also attributed to the hydrophobic nature of LDPE which led to the formation of dry mixes, weak binding. The reduction in the workability is in agreement with the results gotten by Ishaya *et al.*, (2016); Kodua, (2018); Li, Niu, Wan, Jin and Yin (2016). Similar results were gotten by Suganthi *et al.*, (2013) who opined that the aggregate shape, size, and surface texture influenced the concrete workability and the bond between aggregates and cement/binder matrix, which in turn impact the mechanical performance in concrete.

The influence of LDPE used as partial substitution of fine aggregate on the behaviour of concrete was also analysed by Jain *et al.* (2019). Gu and Ozbakkaloglu (2016); Jain *et al.* (2018a); Ohemeng and Ekolu (2019), Poonyakan *et al.* (2018), Reddy *et al.* (2019) respectively worked on the influence of putrefied LDPE from plastic bags used as partial substitution of fine aggregate on the behavior of concrete. The results showed that the workability of the concrete decreased with increase in the plastic waste content.

b). Density

The hardened cube specimens of each mix were weighed to calculate the density. The density of concrete samples decreased with increase in the plastic waste content. The measured densities were less than the conventional concrete. This is in agreement with what other researchers like Azeko *et al.* (2021); Jain *et al.* (2019); Mohammed, Taghreed, Ali, Rajab and Hilal (2020) Rabar, Aryan and Ako, (2019) had. This is probably due to the light weight of LDPE aggregate that resulted in poor bonding. Similar findings were also recorded by Hameed and Ahmed (2019), where the density of light weight concrete decreased to 2.15 g/cm³. In another study, Akinyele and Toriola (2018) used crushed PP in 5, 10, 15, 20 and 100% to produce concrete as fine aggregate. The density of concrete was reduced as the amount of PP increased. These previous studies highlighted that the addition of PW reduced the density, produced light-weighted construction material. According to Kamaruddin, Abdullah, Zawawi and Zainol(2017); Kodua (2018) the reason for the reduction of density in LDPE aggregate concrete with the increase of LDPE was mainly due to the difference in the densities of LDPE (950 kg/m³) and sand (1600 kg/m³).

Sharma and Bansal (2016) conducted researches on concrete containing plastic aggregate particles and indicated that the concrete density decreased with the increase in plastic content. Ohemeng, Yalley, Dadzie and Djokoto (2014) studied the usage feasibility of waste low-density polyethylene (LDPE) as a sand partial alteration in the concrete made pavement blocks. The ratio of the mixtures was 1: 1.5: 3 (cement: sand: coarse aggregate). The use of the plastic was to substitute the sand by volume at 0%, 10%, 20%, 30%, 40%, 50%, and 60%. It was shown, that density lowered as raised the plastic content. Also Ghernouti *et al.* (2014) studied using of a plastic bag waste matter (LDPE) in the concrete formulation as fine aggregate by replacement of different sand percent (10, 20, 30 and 40 %). The PBW impacted on the characteristics of solid status and the fresh of concrete: the workability, compressive and flexural strengths of the variant concretes, were studied and compared to the control concrete. Guendouz *et al.* (2016) reported that replacing 40% of the sand by using LDPE powder decrease 10% of bulk density of the concrete at 28days.

c). Compressive strength (CS)

The compressive strength of the concrete was tested on 1, 3, 7, 14, 28, 42 and 56 days. The CS for all the concrete cubes was determined in accordance with (BS1881-116; 1983); and each concrete was prepared in accordance to the appropriate mix proportion. THE RESULT IS SHOWN IN Table 3.9

Table 3.9 The strength of the partial replacement with LDPE at a glance

DAY	5%	10%	15%	20%	25%	30%	40%	50%	60%	70%	80%	90%	100%
1	17.67	14.83	13.52	6.85	5.85	3.28	2.41	1.42	1.02	0.91	0.86	0.79	0.70
3	21.30	17.26	14.70	7.50	8.59	5.14	2.51	1.71	1.23	1.17	1.13	0.80	0.61
7	22.07	20.23	19.50	12.96	10.52	5.53	3.47	1.93	1.39	1.34	0.88	0.79	0.49
14	23.40	23.42	19.70	13.21	11.91	4.30	2.91	1.84	0.99	0.94	0.87	0.73	0.44
28	23.38	18.98	19.41	12.07	8.00	3.98	2.91	0.85	0.44	0.44	0.42	0.38	0.29
42	20.50	18.13	15.38	8.47	5.85	3.28	2.82	1.42	0.25	0.22	0.21	0.20	0.20
56	18.22	16.24	13.52	6.85	8.59	3.19	2.61	0.70	0.22	0.18	0.17	0.15	0.14

LEGEND:

The ones in the GREEN boxes are those with 20 MPa and above.

The ones in the WHITE background are those having MPa between 10 and 19.

The ones in the YELLOW boxes are those within 10 and 2 MPa.

The ones in the BLUE boxes are those with MPa less than 2

From the results, it was observed that the compressive strength of the mixes was getting reduced with the addition of LDPE. The optimum CS of 23.42 was gotten at the 10% replacement on the 14-day of curing, but 23.38 was the optimum on the 28-day gotten at 5% replacement. This is in agreement with the results obtained by some researchers like Adewumi, Savija, Chandra and Vivi (2018), Akhila, Ajith, Deepankumar, Jeeva and Senthilkumari (2018), Bhosale *et al.* (2019), Gu and Ozbakkaloglu (2016); Hossain, Bhowmik and Shaad (2016), Jambeck *et al.* (2018), Jassim (2017), Sharma and Bansal (2016). The hydrophobic nature of LDPE made the matrix formed by the binder and fine aggregate to be weak. The weaker bond between the binder and aggregates leads to the decrease in the compressive strength of mix.

Studies by these other authors: Alqahtani *et al.* (2018), Faraj *et al.* (2019), Ghernouti *et al.* (2015), Harshit, Bhavani and Naranya (2017), Park and Kim (2020); Pesic *et al.* (2016) also showed a decreasing trend in the mechanical properties of concrete with an increase in plastic waste aggregate content. Azeko *et al.* (2021) used low density polyethylene (LDPE) type of plastic partial replacement of the fine aggregates in the concrete. Amalu, Hashim, Rejith and Vijitha (2019), Mohammed *et al.* (2020) used recycled plastic material to replacing the fine aggregates in the concrete mixture with concrete grade M20 as it is most commonly used in the constructional work. In all these experiments, there were decrease in the compressive strength.

Bhosale *et al.* (2019) investigated the results of replacement of sand by the PVC plastic waste in the paver block. The compressive strength tests were taken for 7, 14, and 28 days. They experienced reduction in compressive strength as the percentage of plastic increased. Gu and Ozbakkaloglu (2016) conducted researches on concrete containing plastic aggregate particles and indicated that the concrete mechanical properties such as compressive strength, splitting tensile strength and flexural strength significantly decreased with the increase in plastic content. Harshit *et al.* (2017) showed that compressive strength test results decreased in strength when the PVC waste was increased. Successfully it often replaced sand up to 20 %, but the optimum value in which it gave best results was 10-12.5%. Results of the investigation indicated that the compressive strength of the concrete at 7, 14, 21, 28 days. 7 days strength of the concrete varied from 35.5 to 70.01 MPa, but at the optimum value of PVC (10%) the compressive strength value were 56.28 MPa. Hossain *et al.* (2016) performed work on use of waste plastic in concrete as a constituent material; replaced coarse aggregates in proportion of 5%, 10% and 20% in concrete. It was found that the concrete was lighter in weight. But the compressive strength was lesser than that of conventional concrete. The results also found that the concrete with 10% plastic aggregates showed strength nearly similar to the conventional concrete. Kibria *et al.* (2017), stated that the compressive strength of recycled plastic concrete affected by the percentage of substitution (SPA), w/c ratio, the shape and size of particles. Results indicated that comprehensive strength declined as SPA increased. This was attributed to different factors; inhabitation of cement hydration due to the hydrophobic properties of PW concrete; and low cement-plastic bond which was due to poor bond between cement and the plastics. Yang, Yue, Liu and Tong (2015) reported a significant reduction, ranging from 34 to 70%, in the 28-day concrete compressive strength when 20 to 100% of the conventional fine aggregate was substituted directly with plastic. However, Sreenath and harishankar (2017) had a contrary result. They stated that replacing sand by LDPP with 10% increased the compressive strength from 34.96N/mm² to 38.95N/mm².

4.0: CONCLUSION AND RECOMMENDATION

The present study is aimed at the use of plastic waste (LDPE) as replacement in concrete. The properties of plastics were tested for physical properties and compressive strength. From the result of the sieve analysis, the waste LDPE can be effectively used as fine aggregate replacements. The compressive strength of the concrete decreased as the percentage of LDPE, increased respectively. It was observed that the workability of the modified mixes were decreasing as the percentage of LDPE

increased in the mix. It was observed that the density of modified mixes was less compared to the conventional mix. The compressive strength, of the mixes were getting reduced compared to the conventional mix by the addition of LDPE. From the preliminary analysis, these materials possess the quality of replaceable materials can be used for such. The paper presents the necessity of sustainable construction in present world and the possibility of waste LDPE, recycling and using into concrete production. According to the test which has been carried out in the laboratory, results shown by testing the multiple samples that good quality concrete could be produced with the use of plastic (LDPE) wastes in concrete. In general, it can be concluded that concrete that contains plastic can be used for non-structural elements that do not require high compressive strength. From the results, the compressive strength between 10 and 20 N/mm² can be used for lintels in building and non-load bearing structures while the ones with compressive strengths between 2 and 10 N/mm² can be used for Sandcrete blocks, Interlocking stone and Kerbs where beautification is of importance (aesthetic). In addition, high permeability and low absorption caused by plastic can be exploited in concrete and be used in many applications which need good water drainage such as pavements and floors of sport courts.

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