

## Mechanical Properties of Concrete Mixture Mix Types C30 & C45 With Recycled HDPE Replacement as Coarse Aggregate

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**Abstract:** The utilization of recycled plastic in concrete production is an innovative approach that addresses both the environmental issues associated with plastic waste and enhances the properties of concrete. An experimental mixture of standard concrete (C30&C45) was made, with coarse aggregate replaced by (0,10,20,30%) for each mixture. In this study, cubes (150 mm x 150 mm x 150 mm) at 7 days and 28 days old were examined. This study assesses C30 and C45 concrete containing 10–30% recycled HDPE as a coarse aggregate substitute. The slump and unit weight diminished (slump decreased by 6.5–16%, density correspondingly), and the compressive strength declined by 8–27% at 28 days. Conversely, splitting tensile and flexural strengths were enhanced, with tensile strength rising by up to 26%, attributable to HDPE's fiber-like characteristics. The results demonstrate that HDPE improves crack resistance while reducing compressive strength, making it more suitable for non-structural or lightweight applications.

**Keywords:** Plastic Coarse Aggregate; Compressive Strength; Modulus of rupture; Recycled HDPE

### 1. Introduction

It is estimated that worldwide concrete production is approximately 25 billion tons per year. Almost two billion tons of Portland cement and enormous volumes of natural aggregates are currently used in the concrete building industry. Overconsumption of raw materials can lead to the emission of greenhouse gases, contributing to global warming. Thus, to reduce the need for landfill space and conserve natural resources, recycled materials should be used in place of traditional building materials. The majority of waste products are non-biodegradable, and their quantity rises with population growth. Environmental pollution can result from excessive dumping of non-biodegradable materials. To address this pressing issue, recycling non-biodegradable materials is crucial [1-2].

Concrete contains cement, sand, water, admixtures, and NCA. Concrete is commonly utilised in construction owing to its strength, durability, adaptability, and on-site moldability. A substantial component of concrete, NCA significantly enhances the material's strength. Many nations now struggle with a lack of NCA and must import large amounts to meet their need [3]. HDPE, a synthetic thermoplastic polymer, belongs to the PE microplastic group. PE polymer has an infinite number of hydrocarbon chains, each consisting of two carbon atoms bonded to two hydrogen atoms and two additional carbon atoms. HDPE's polymer chain has low branching; therefore, linear molecular chains crystallize consistently. Semi-crystalline HDPE polymers have bending strengths of 20–45 MPa due to their regular polymer chain structure, which boosts density, stiffness, and ductility. [4-6]. HDPE is more flexible, has a low density of 950–970 kg/m<sup>3</sup>, and has a high tensile strength of 20–32 MPa [4-6]. Additionally, HDPE is chemically inert [4-6]. Material ignition temperature is 487 °C, and the melting point is 130 °C [7]. This study enhances existing knowledge by providing systematic experimental data on the optimal HDPE replacement levels (10–30%) in typical structural concretes. In these concretes, compressive strength is lowered, while tensile characteristics are improved.



The results elucidate the prospective uses of HDPE-modified concrete, especially for non-structural and lightweight components, and endorse sustainable construction methodologies by repurposing plastic waste. This study aims to assess the impact of recycled HDPE as a partial substitute for coarse aggregate on the workability, density, and mechanical properties of C30 and C45 concretes. Systematic research on standard structural concretes (C30 and C45) at varying replacement levels (0–30%) and curing ages is limited. This study evaluates the mechanical and physical properties to identify the optimal HDPE content and highlights its suitability for structural and non-structural applications.

## 2. Lecture review

In 2018, Rao & Ravula examined the properties of HDPE (High-Density Polyethylene) concrete to assess its potential as a gravel alternative. Four coarse aggregate compositions (95:5, 90:10, 85:15, and 100:0) are available, each with a different HDPE waste volume ratio. According to the experiments, the tensile strength of concrete using HDPE particles increases by a maximum of 195% at a 15% replacement compared to the control mix., slump values dropped, and the compressive strength for concrete using HDPE particles diminished by as much as 81% at a 15% replacement level compared to the control mix as for The flexural strength of concrete using HDPE particles diminishes by up to 43% at a 15% replacement proportion to control mix. Experimental research recommends the use of plastic-waste concrete for standard residential projects [8].

In 2019, Lopez et al. examined the impact of replacing some coarse particles with high-density polyethylene on the mechanical and physical characteristics of acrylic polymer pervious concrete (AcPPC). Two distinct sizes of coarse aggregate, measuring  $\frac{1}{2}$ " and  $\frac{3}{4}$ ", were evaluated in the study at different ratios of 10%, 20%, and 30%. Partial replacement of AcPPC with recycled HDPE increased the porosity and permeability of the mixture. Conversely, it decreased the AcPPC's compressive and flexural strengths. This is the only adjusted pervious concrete that achieved a compressive strength within the allowable limit for pervious concrete, utilizing  $\frac{1}{2}$ " 10% HDPE and 15% Acrylic Additive (PCHA). The  $\frac{1}{2}$ " 10% PCHA and  $\frac{3}{4}$ " 10% PCHA had flexural strengths that were within the usual norms for pervious concrete. Therefore, the  $\frac{1}{2}$ " 10% PCHA was the ideal mix for this experiment. PCHA can only be applied to pervious concrete installations in the traditional way [9].

Punitha and colleagues' 2021 Investigation of the use of Metakaolin and recycled HDPE plastic in varying proportions in concrete to enhance economic viability while achieving desired qualities and minimizing the use of naturally sourced building materials. Six percentages of HDPE plastic powder (5%, 10%, 15%, 20%, 25%, and 30%) and 10% metakaolin are added to fine aggregate and cement. A concrete mixture containing 10% metakaolin and 15% HDPE plastic powder exhibits higher compressive strength than normal concrete. Concrete flexural and split tensile strengths may be replaced by 80% and 90%, respectively, using 10% metakaolin and 5% HDPE plastic powder [10].

In 2021, Surman et al. [11] replaced concrete fine aggregate with plastic. Plastic bottles and food containers generate most garbage. In concrete, they employed 5%, 10%, and 15% recycled Polyethylene Terephthalate and Polypropylene as fine aggregate. To determine how Polyethylene Terephthalate and Polypropylene affect compressive strength and workability. PET and PP offer high workability and compressive strengths of up to 10% and 5%, respectively. The test findings show that 5% and 10% polypropylene (PP) and PET fine aggregate in concrete are best.

Temesgen et al. [12] used an expert-designed mix in 2021. Six C-25 concrete samples make up the 72-sample mix. They substituted 1, 2, 3, 4, and 5% PET plastic waste aggregate for fine aggregate in the test samples. Also, a control mix without fine aggregate substitution was employed for comparison. The concrete cubes, cylinders, and beams were tested in the lab. The trials included material property, slump, unit weight, compressive, splitting tensile, and flexural strength tests. The test results were compared with conventional concrete characteristics and showed that replacing PET aggregates increased compressive strength by 3% and reduced it by more than 3%. Additionally, increasing the PET bottle aggregate content increased tensile strength by 3%. However, replacing fine aggregate with PET bottle fiber above 3% reduces tensile and flexural strength. This research reveals that PET bottles may substitute fine particles in concrete up to 3%.

Milad and colleagues' study 2022. Test beams, measuring 2000 mm in length and 180 mm by 280 mm in cross section, underwent bending loads applied at four points. Three beams were swapped out for sustainable concrete made of a combination of high-strength concrete (HSC) and shreds of recycled plastic type "HDPE" plastic taken from material cartons. 10%, 20%, and 30% of HDPE were used in the concrete. The fourth beam, which is not replaced with HDPE, serves as the reference beam. Test findings showed that while the 30% replacement beam's toughness increased by 24%, its load-carrying capacity decreased by 7%. Both the failure time and the cracking mechanism were comparable to those of the reference beam. The findings indicate significant potential for a 30% partial replacement of gravel with HDPE, while maintaining structurally acceptable flexural performance [13]. In 2023, Sumanth et al. [14] evaluated a mortar mix in ferrocement that partially replaced fine aggregate with discarded rubber tires. The mix was 1:2, 1:3, and 1:4 with a 0.5 water-to-cement ratio and two layers of hexagonal wire mesh. By replacing 0%, 1%, 2%, 3%, 4%, 5%, and 6% of fine aggregate, waste tire rubber was added to the concrete. The specimen dimensions were (900×250×50) mm for bending and (100×100×100) mm for compression tests. As the crumb rubber concentration increased in cement mortar, a partial replacement for fine aggregate at different volume fractions, flexural and compressive strength decreased. Adding crumb rubber to ferrocement increases ductility, energy absorption, and weight reduction. Shukur et al. [15] tested concrete in 2023 using PET and PEP aggregates. PET and PEP replaced the aggregates in concrete up to 15%. This research shows that two types of plastic waste may partially replace fine or coarse aggregate in concrete mixtures. PEP's irregular forms reduce workability and may increase mixed component interaction, reducing slump, whereas PET increases this material attribute. Concrete density was 10% lower than controls. Recycling plastic reduced compressive, tensile, and flexural strengths by 31%, 22%, and 60%, respectively, compared to normal concrete.

### 3. Materials and Methods

Concrete mixes made from cement and aggregate (sand & gravel) were employed in this investigation. These are intended to be classified as medium or greater concrete strength. In this case, cube strengths of 30 MPa and 45 MPa are considered medium-strength concrete. The mixes were supplemented with HDPE lamellar material in several diameters to investigate its impact on concrete characteristics. Calculations for specific gravity, unit weight, slump value, tensile strength, and compressive strength were performed in accordance with ASTM and ACI standards. The standard tests employed in this inquiry are listed in Table 1.

Table 1. Test requirements for concrete.

Standard	Focused Testing
ASTM C33-99a	Adequate grading requirement for sieve analysis
ASTM C-127	Specific gravity of gravel
ASTM C29/C29M-07	Unit weight for sand and gravel
ASTM C131/C131M-20	Resistance to degradation by abrasion on small-size gravel
ACI 211.1-91	Standard Practice for Selecting Proportions for Normal, Mass Concrete, and Heavyweight
ASTM C496	Tensile strength
ASTM C39	Compressive strength
ASTM C143	Slump test

### 3.1 Materials used

#### 3.1.1 Cement

Tables 2.1 and 2.2 of this study's report on the Sinjar cement factory's physical and chemical Portland cement. To ensure quality, Iraqi standards were used to test the cement against the Standard Specifications for Ordinary Portland Cement (Iraqi Standard Specification No. 5, 2019). The tables below reveal the test results, which provide vital information about the cement and its suitability for the research.

Table 2.1 Cement Physical Properties

Properties	Outcomes	limits
Standard ductility	0.28	--
Initial Setting Time in minutes	120	$\geq 60$
Final Setting Time in hours	4:15	$\leq 10$
2 days Compressive Strength MPa	22.8	$\geq 10$
28 days Compressive Strength MPa	43.0	$\geq 42.5$
Fineness Sieve no. 170(%)	2.5	$\leq 10$
Le Châtelet method expansion (mm)	2.0	$\leq 10$

Table 2.2 Cement Chemical Properties

<b>Compound Chemicals</b>	<b>%</b>
SiO <sub>2</sub>	21.30
Al <sub>2</sub> O <sub>3</sub>	5.16
Fe <sub>2</sub> O <sub>3</sub>	4.52
CaO	63.87
MgO	2.49
Free lime	1.46
So <sub>3</sub>	1.91
Loss on ignition	1.29
Solid solution	18.53
Insoluble residue	1.17
C <sub>2</sub> S	26.68
C <sub>3</sub> S	45.59
C <sub>3</sub> A	6.03
C <sub>4</sub> AF	13.75
L.S.F	90.93

### 3.1.2 Hyperplast PC200

The research utilized 1.0 liters of cement per 100 kg. Hyperplast PC200 is a high-performance super-plasticizing additive composed of long-chain polycarboxylic polymers that enhances the water content of concrete. For maximum durability and performance, flowable and high-strength concrete mixes with the technical specifications in Table 3 may benefit from this effect.

Table 3. Typical properties of Hyperplast PC200

Properties	Results
Colour	Yellow-light liquid
Freeze Point(°C)	-3°C
Gravity Specific	1.05+0.02
Air Entrainment	At usual doses, less than 2% air is entrained above the control mix.

### 3.1.3 The Aggregates

A supplier in Al-Mosul provided 4.75-mm Natural Fine Aggregate. The Concrete Technology Laboratory at Mosul University performed sieving analysis and physical testing. Tables 4.2 and 5.1 reflect Iraqi Standards No. 45/1984 for grading and physical properties. Al-Mosul-based suppliers supplied 12.5 mm Natural coarse Aggregate. The Concrete Technology Laboratory at Mosul University's College of Engineering performed sieving analysis and physical testing. Tables 4.1 and 5.2 show Iraqi Standards No. 45/1984 for NCA grading and physical properties. Additionally, Figure 1 presents a Sieve analysis for the aggregate.

Table 4.1 Grading of gravel

Sieve Size	Passing (%)	Iraqi Standard No.45 (1984)
19	100	100
12.5	94	100-90
9.5	59	70-40
4.75	1	15-0
2.36	0	5-0

Table 4.2 Grading of sand

Size of Sieve	Passing in %	Iraqi Standard No. 45 (1984)
4.750	96.6	90-100
2.36	79	75-100
1.18	65.4	55-90
0.6	55.3	35-59
0.3	27.9	8-30
0.15	4.8	0-100

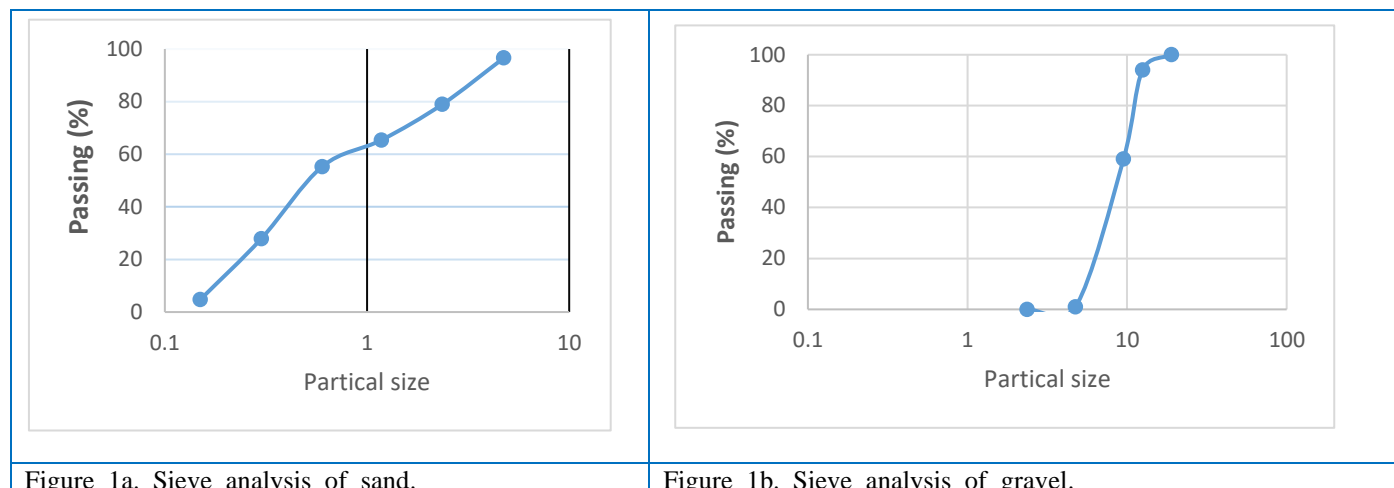


Figure 1a. Sieve analysis of sand.

Figure 1b. Sieve analysis of gravel.

Table 5.1 Properties of Physical for fine aggregates

Physical Properties	Test Result	Iraqi Standard No.45 (1984)
Sulfate Content	0.110	≤0.50
Specific Gravity	2.585	-
% Porosity	2.70	-
Density kg/m <sup>3</sup>	2.639	-

Table 5.2 Physical Properties of coarse aggregates

Physical Properties	Test Result	Iraqi Specification No.5 (1984)
Sulfate Content, %	0.0320	≤ 0.1
Specific Gravity	2.60	-
Porosity %	62.10	-
Density, kg/m <sup>3</sup>	2.6250	-

### 3.1.4 Plastic Coarse Aggregate

HDPE plastic components from Mosul landfills were gathered for future attempts to eliminate non-sustainable rubbish that pollutes aquifers and waterways. Before being chopped, they were thoroughly cleaned. Lamellar particle formation is seen in Figure 2c. The plastic boxes were shredded using the

apparatus shown in Figure 2b. As indicated in Figure 2d, the requisite amount of recycled plastic fragments was collected. (Figure 2c), cleaned and then allowed to dry before being sieved using standard gravel sieves (Table 6.6, Figure 3). While the colors and forms of the plastic bits varied by the source box's color and its constituent sections, they were essentially flat plastic pieces. Table 6 lists the physical parameters of regenerated plastic waste aggregate. All properties matched HDPE recycled plastic [16].



Figure 2. The procedure for turning discarded plastic into coarse aggregate. (a) Raw plastic container. (b) Shredding the plastic container. (c) Collecting the plastic pieces. (d) Sieve analysis

Table 6. Physical properties of the recycled plastic coarse aggregate

Property	Value	ASTM Specification
Density (kg/m <sup>3</sup> )	0.9490	ASTM D792 (ASTM D792-20, 2020)
Water Absorption	0.0	ASTM D570 (ASTM D570-98R18, 2018)
Modulus of Elasticity (MPa)	358.70	ASTM D638 (ASTM D638-14, 2014)
Compressive Strength (MPa)	26.40	ASTM D695 (ASTM D695-15, 2015)
Tensile Strength (MPa)	7.70	ASTM D638 (ASTM D638-14, 2014)
Flexural Strength (MPa)	878.30	ASTM D790 (ASTM D790-17, 2017)

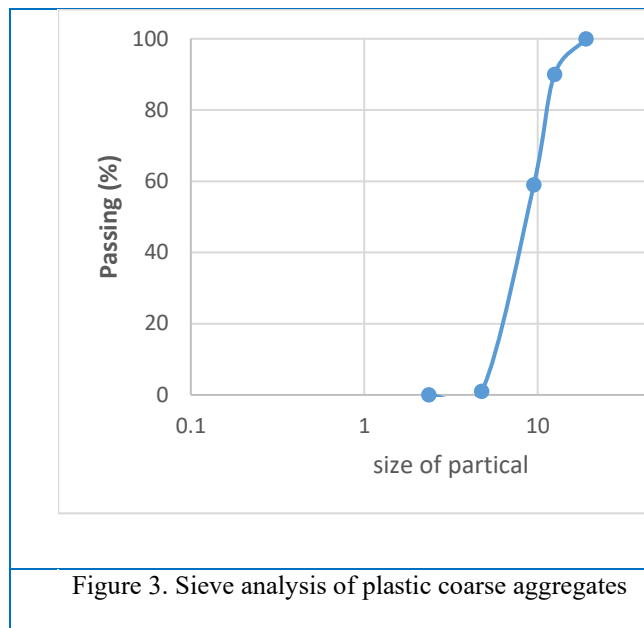


Table 6. Grading of plastic coarse aggregate

Sieve Size	Passing (%)	Iraqi Specification No.45 (1984)
19	100	100
12.5	90	100-90
9.5	59	70-40
4.75	1	15-0
2.36	0	5-0

### 3.1.5 Job Mix Design

Table 7 presents the concrete mix formulation and the material composition for the two types of concrete. Finding the appropriate ratio of concrete mixture according to the recommended procedure for choosing ratios for mass, heavyweight, and regular concrete (ACI 211.1-91) [17]. To ensure the final qualities complied with the quality control designs, concrete strength tests were carried out on 28 and 7 days after casting. The following day, the concrete samples were taken from their forms. After casting was complete and the concrete had reached full solidification and hardening, it was placed in a water tank maintained at 27 °C, fully immersed, and left for 7 days or 28 days. To ensure the combination would be both cost-effective and practical in the field, we set the slump values of the two concrete classes within the same range. W/C 0.47 for C30, depending on water-to-cement ratio, and for C45, it was (W/C) 0.33. We adjusted the w/c ratio to achieve this goal at various levels. The compressive strength test involved 12 samples per replacement ratio, with six assessed after 7 days and the remaining six after 28 days. The meaning was calculated for each category, excluding the irrelevant data. The subsequent tests consisted of three cylinders for the splitting test, and the average was calculated from these samples. One prism beam was used for the rupture modules.

### 3.1.6 Mixing Procedure

Table 7 presents the design trials for the two concrete types (C30 & C45), including the Amount of cement, Acceptable aggregate content, Coarse aggregate content, Amount of water, and hyperplastic PC200. Before adding water, the various types of cement and aggregates were mixed for a few minutes in a dry environment. Each type of concrete was then mixed with lamellar particles until the mixture was homogeneous and uniform in texture. For each replacement ratio, The compressive test is conducted on twelve cubes, six cube for 7 days (three for C30 and three for C45) and remain for 28 days (three for C30 and three for C45) 150x150x150 mm cubes of mixture, following B.S 1881, part 116: 1983 [18], Figure (9) shows the testing machine., three cylinders for each types concrete with dimensions 150 mm × 300 mm were tested at the age of (28) days to measure the splitting tensile strength of concrete according to ASTM C496-17 [19], Figure (11) shows the testing machine, and one prism beam for each types concrete with dimensions 100 mm × 100 mm × 500 mm were cast using the requisite quantity of the mixture to measure the flexural strength (modulus of rupture (fr)) following ASTM C293-18 [20]. Figure 13 shows the testing machine.

Table 7. Concrete job mix design.

Description	C30	C45
Targeted average compressive (MPa)	30	45
Amount of cement (kg/m <sup>3</sup> )	350	450
Acceptable aggregate content (kg/m <sup>3</sup> )	850	800
Coarse aggregate content (kg/m <sup>3</sup> )	950	900
Amount of water (kg/m <sup>3</sup> )	165	150
hyperplast PC200(kg/m <sup>3</sup> )	---	4.5

The following terms are used: B0 denotes regular concrete that complies with the work mix design specifications but does not include HDPE lamellar replacement, whereas B10 denotes concrete that contains 10% HDPE replacement, and so on. The volume of coarse aggregate used determines the number of HDPE particles required for the empirical investigation. Per ASTM C143, slump testing was one of several experiments conducted to assess the impact of introducing HDPE lamellar particles [18].

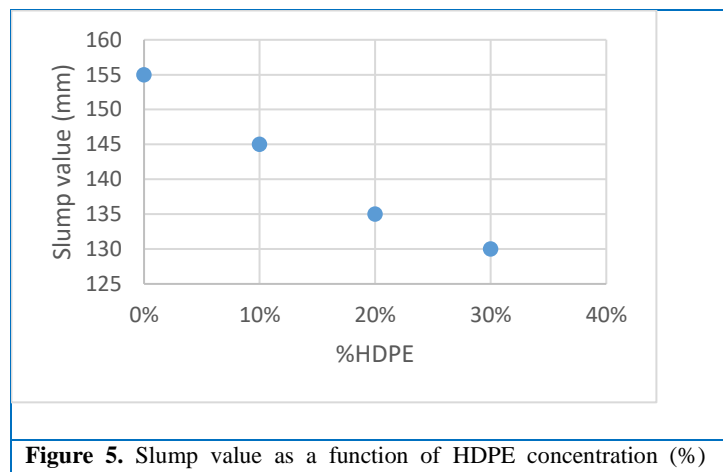
#### 4. The Results

When using well-concrete components, the concrete's mechanical properties must be thoroughly examined. This study substituted recycled plastic for the natural coarse aggregate (NCA) in concrete in the same volumetric ratio. Experimental testing measured concrete's compressive, splitting, and flexural strengths.

##### 4.1 Slump Test for Concrete

Workability, as measured by concrete slump, depends on several factors, including mixing techniques, concrete composition, and the use of admixtures. These factors also cause workability to vary over time. Figure 4 illustrates how the specimens for this slump test were prepared using the mold (slump cone). Before testing, various HDPE particles were incorporated into the new concrete. The inclusion of a higher quantity of recycled plastic in the concrete mix resulted in a reduced slump value, as illustrated in Figure 5. With a 10% HDPE lamellar replacement, the slump value for C30 concrete (Figure 5) decreased by 6.5% with HDPE partials, while for B20 and B30, it decreased by 13% and 16%, respectively. B30 (Figure 5) showed the lowest percentage reduction in slump value, while B10 showed the highest. We discovered that the most significant decrease across all Samples used ranged from 5 to 20 mm relative to the reference value.





There is an explicit agreement between this experience and previous studies (Rao, M. M., & Ravula, R. G., 2018) [8] in the slump test, as plastic is a non-absorbent material. Its surface is smooth rather than rough, leading to weak adhesion between the plastic and the cement paste and reducing the mixture's ability to move and flow.

#### 4.2 Unit Weight of Concrete

Concrete unit weight is mass/volume. ASTM C29 [21] (Figure 6). It correctly evaluates sample concrete density. Compare each sample's weight to its significant volume to obtain its unit weight. Figure 7 compares concrete unit weight, HDPE lamellae content, and dimensions. Due to the low HDPE content in C30 and C45, more lamellar particles were added, resulting in lighter concrete. However, each HDPE sheet had the same value for a given %, hence the sheet size did not affect the concrete unit weight.

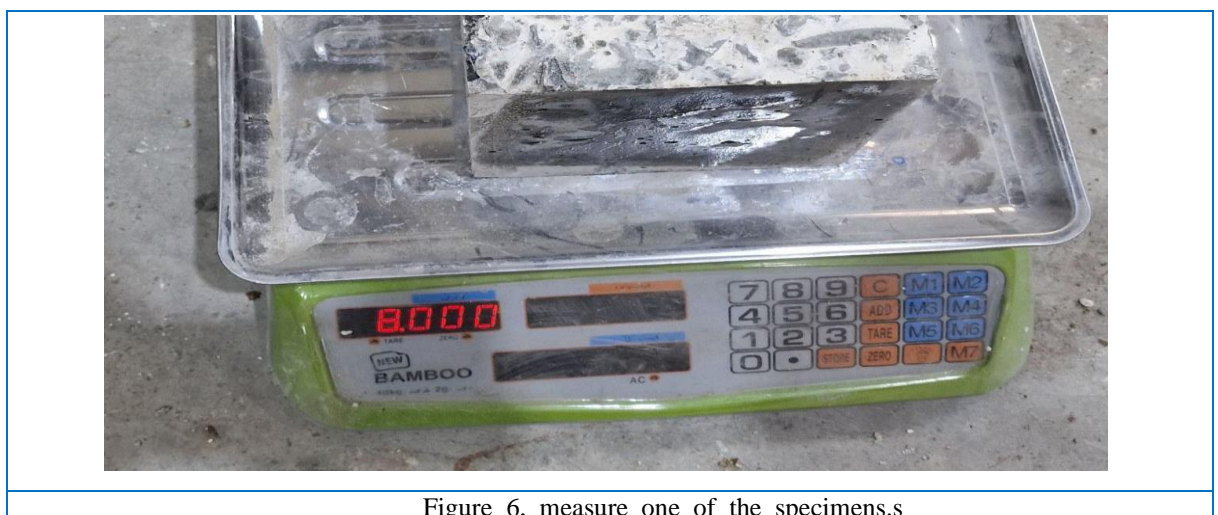
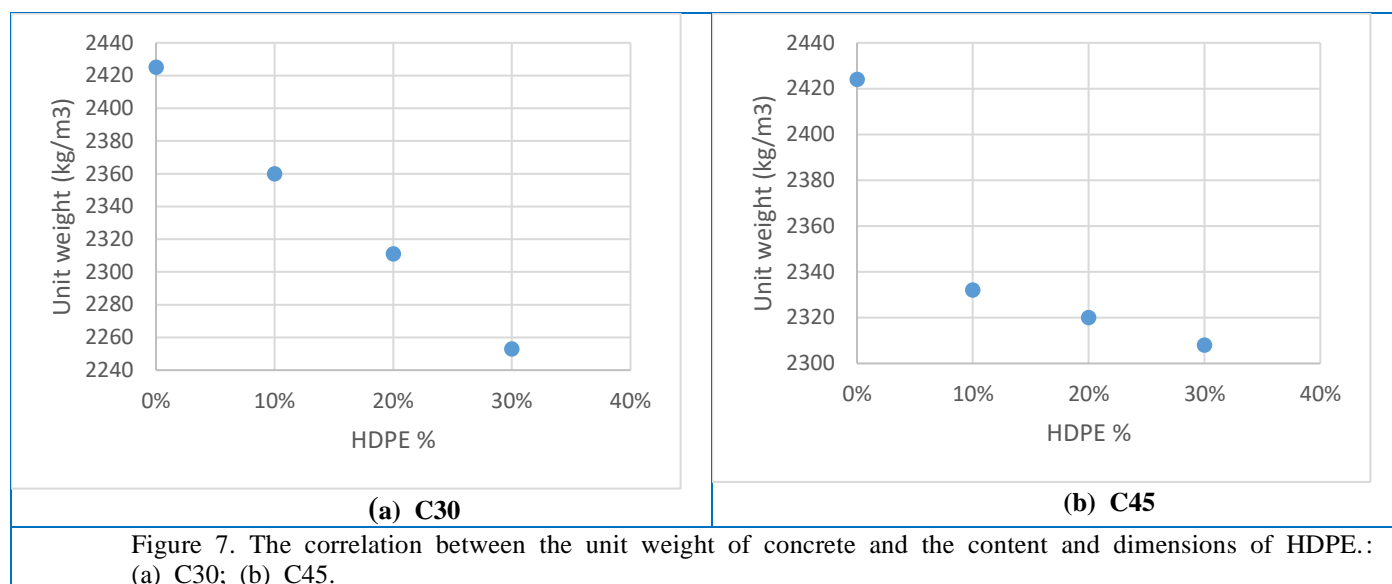


Figure 6, measure one of the specimens.



### 4.3 Compressive Strength Test

Figures 8 and 9 for C30 and C45 show the concrete compressive strength results for curing times of 7 and 28 days, along with HDPE waste replacement at varying percentages. Figure 8 shows the compressive strengths (fcu) of the eight combinations at 7 and 28 days after curing. The image shows that compressive strength declined when recyclable plastic rubbish replaced it. By around 11, 15, and 18% as well as 10, 20, and 30% for C30 in 28 days, and similarly reduced by roughly 8, 18, and 27% as well as 10, 20, and 30% for C45 in 28 days when recycled plastic trash was used in place of natural gravel. The concrete showed the same declining trend after 7 days of curing (for C30 & C45), but at slower rates. Figure 9 shows the test compressive strength of cubes with dimensions 15 x 15 x 15 cm. The decline in compressive strength with increased HDPE substitution is primarily attributed to poor bonding with other concrete particles, as HDPE has a smooth, non-porous surface that inhibits robust adhesion to cement paste. Moreover, HDPE exhibits lower stiffness and strength than natural aggregates, and its lack of water absorption results in excessive free water, increased porosity, and diminished concrete integrity. The density discrepancy and inadequate compaction exacerbate micro-void formation, whereas HDPE's plasticity permits deformation under stress rather than resisting it. These factors jointly elucidate the persistent decline in compressive strength. This experience aligns with prior studies (Rao, M. M., & Ravula, R. G. (2018)[8], Lopez, N., Collado, E., Diacos, L. A., & Morente, H. D. (2019)[9] and Radhi, M. M., Khalil, W. I., & Shafeeq, S. (2022)[13].

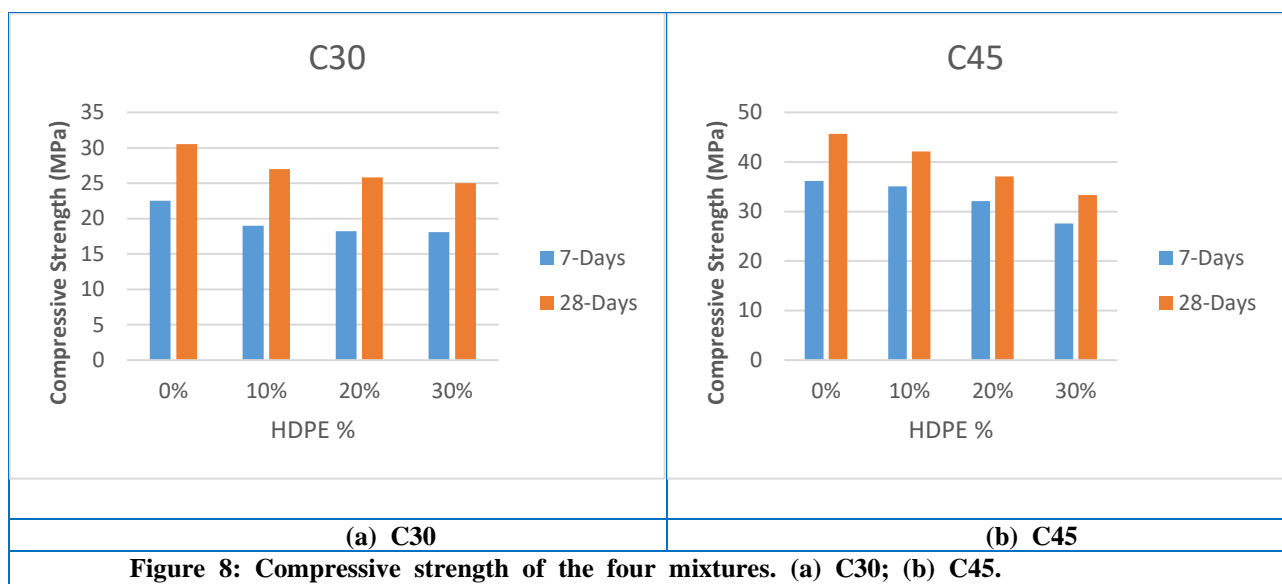


Figure 8: Compressive strength of the four mixtures. (a) C30; (b) C45.



Figure.9 One of the specimens on testing

#### 4.4 Splitting Tensile Strength Test

Figure 10 demonstrates that an increase in the fraction of gravel replaced by shredded plastic box particles correlates with an enhancement in splitting tensile strength. The reference specimen (0%) had the lowest splitting strength among the two mixes (C30 and C45). As a result, in C30, there was an increase of around 11.25% at 10%, 26% at 20%, and 30% showed no growth. The augmentation in splitting strength was commensurate with the replacement ratio. Additionally, C45 increased, albeit at a different rate, as seen in Figure 10. Figure 11 shows the splitting tensile strength test of a cylinder measuring 15 x 30 cm. The enhancement of tensile strength arises from HDPE molecules functioning as fiber-like inclusions within the concrete matrix, absorbing stress and restricting the spread of microcracks, hence improving tensile strength despite a reduction in compressive strength. This experience aligns with prior studies (Rao, M. M., & Ravula, R. G., 2018)[8] and Punitha, V.,

Sakthieswaran, N., & Babu, O. G., 2021) [10].

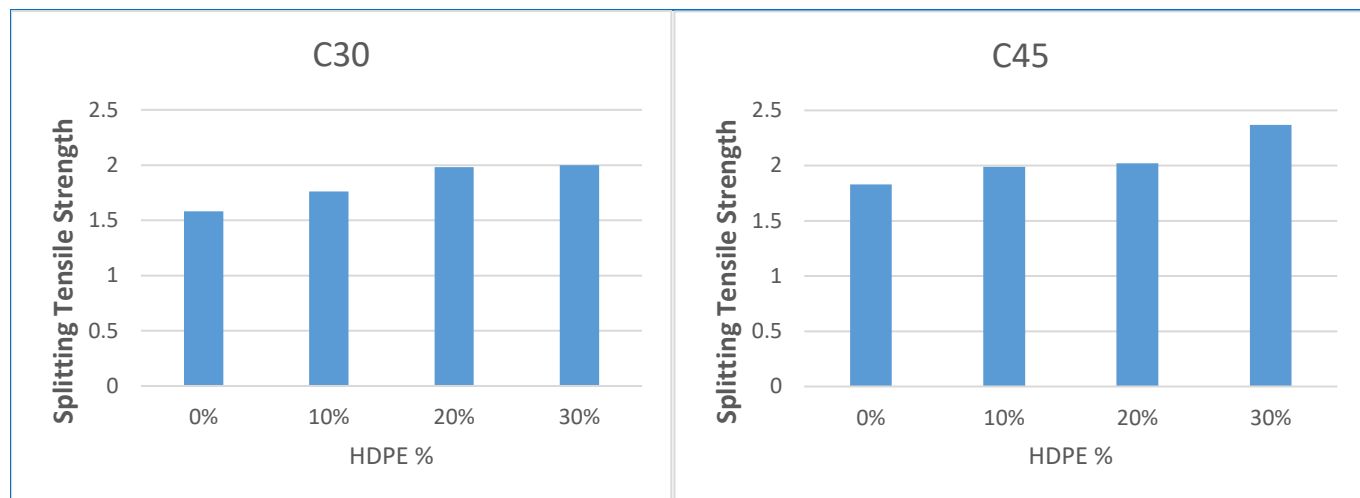


Figure 10. Splitting tensile strength for eight mixtures.



Figure.11 One of the specimens on testing

#### 4.5 Flexural Test C78

Figure 12 shows that the modulus of rupture for both combinations, C30 and C45, follows a similar trend to that of the splitting test. Strength rises when crushed recycled plastic particles replace natural coarse aggregate. Specific stresses created during each test may reduce compressive strength and enhance splitting tensile strength and rupture modulus. A concrete prism undergoes compressive strength under concentric compression loading; hence, the crushing strengths of both the concrete and the aggregate are crucial. The strength continuously decreased as the number of plastic particles increased, since real gravel has a far higher crushing strength than these particles. However, tensile stresses are in control during splitting and flexural testing. Due to their superior ductility, the irregularly shaped HDPE plastic coarse aggregate particles, which adhere well to the concrete, reduce internal tensile stresses. This slows the widening of tensile fractures and delays specimen failure. Figure 13 illustrates the modulus of

rupture test beam, a 30 cm x 10 cm specimen. This experience corresponds with previous research (Rao, M. M., & Ravula, R. G. (2018)[8], Lopez, N., Collado, E., Diacos, L. A., & Morente, H. D. (2019)[9], Punitha, V., Sakthieswaran, N., & Babu, O. G., 2021) [10] and Radhi, M. M., Khalil, W. I., & Shafeeq, S. (2022)[13].

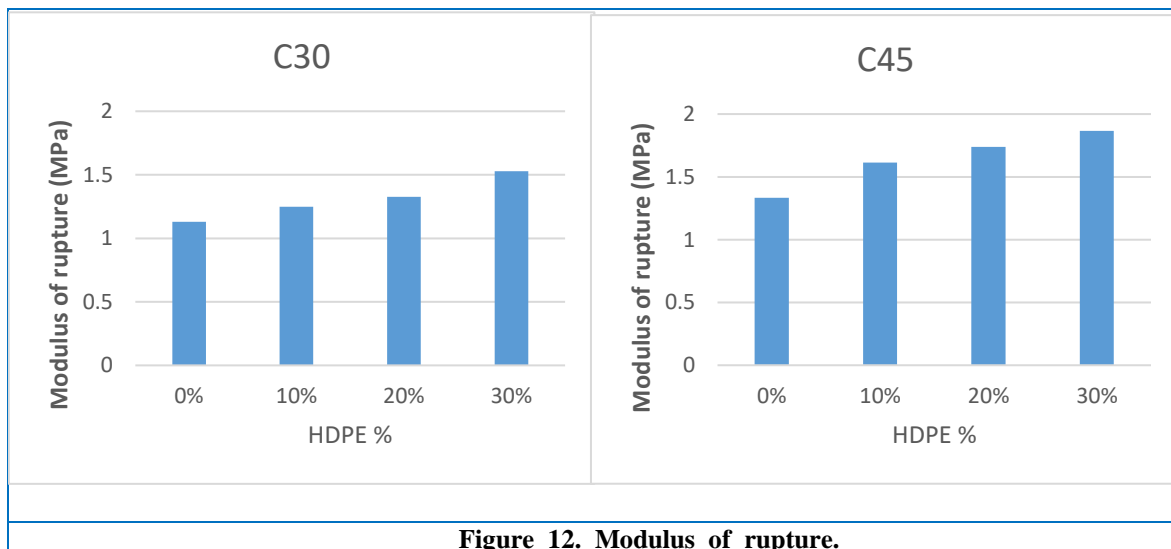


Figure 12. Modulus of rupture.



Figure.13 One of the specimens on testing

## 5. Conclusion

Using HDPE plastic as a partial gravel replacement in concrete reduces trash disposal issues. The project's results suggest the following:

- The slump in value decreases with an increase in HDPE percentage
- The results of the unit weight proved that recycled plastic has a role in reducing the unit weight of concrete
- Compressive strength reduced as the percentage of plastic waste increases, and a 10% replacement ratio is the closest indicator to the reference concrete in regular concrete.
- The modulus of rupture and splitting tensile strength demonstrated an improvement in strength with a higher proportion of gravel replaced by shredded plastic box particles.

- Not appropriate for structural applications when replacement ratios are elevated, as compressive strength is markedly diminished, a characteristic vital for load-bearing structural components (columns, beams, and slabs). Any flaw in this property jeopardizes the building's integrity.
- Most appropriate for non-structural applications, such as lightweight concrete blocks, pavements, non-load-bearing floor slabs, or components where low weight and thermal insulation are prioritized over strength.
- Concrete contains recycled materials. Plastic can be incorporated into concrete as a substitute for 10% of the coarse aggregate.

## 6. Suggestions for Further Research

Future research should focus on the following subjects to better understand the Mechanical Properties of Concrete Mixture:

- Further experimental study is needed to understand recycled plastic's mechanical characteristics and find ways to improve them when it replaces coarse aggregate.
- Modulus of elasticity and Poisson's ratio are important in finite element analysis and recycled plastic concrete performance; thus, they need additional investigation to be accurate.
- Evaluating the impact of recycled plastic on the shear strength of reinforced concrete deep beams with different aspect ratios.
- Future research should evaluate recycled plastic concrete's heat, sound, and fire resistance experimentally.

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