A Review: Impact of Static and Impact Load on the Mechanical Properties of Plastic Concrete

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Abstract

This review search seeks to know how the replacement effect on concrete is by replacing aggregate (coarse or fine) with plastic granules. Plastic does not dissolve in the climate and provides an early warning for collapses when mixed with concrete to give it more flexibility, making it more crucial to resist tensile stresses, increasing its strength, and seeking to make it more durable. The use of plastic is expanding day by day because of the rapid population increase and their constant demand. Every day, this causes a considerable amount of rubbish, which is harmful and causes pollution and plastic materials to take hundreds of years to dissolve. Solid waste management is currently a difficulty in any country, and the large-scale depletion of resources is causing environmental issues. For the concrete business, an alternative or alternative product must be produced. Plastic waste is the most challenging problem in solid waste management globally. In many countries, concrete has been one of the most excellent solutions for construction materials. It has hastened the pollution of the environment. It would be worthwhile to use plastic waste in concrete to solve the dual problems of a lack of raw materials and the safe disposal of plastic trash. This research aims to see if waste plastic can be used as a fine aggregate in concrete.

1. Introduction

1.1 Background

Nowadays, structure and infrastructure development practices are becoming widespread due to industrialization and urbanization. Consequently, humankind has been confronted with questions about addressing the issues resulting from this expansion. There is a severe lack of construction supplies and increased garbage dumping. Therefore, waste products should be used as construction materials. Plastic usage has increased dramatically worldwide, resulting in massive amounts of plastic-based garbage. The disposal of waste plastic is a serious issue in today's world because plastic production is constantly increasing, and it takes hundreds of years for plastic materials to decompose. When burned, plastic emits a variety of harmful gases. As a result, a viable method for recycling and reusing plastic must be devised. Otherwise, it will be highly destructive to our long-term environmental sustainability.

Plastic material is known to be non-degradable or melting, and disposal of it leads to environmental problems. Burning plastic damages, the earth's atmosphere, and burying plastic causes damage to plants and species that live underground. Over the past sixty years, the plastic output has expanded dramatically. Around 4% of global oil and gas production, nonrenewable resources, are used as plastic feedstock, with nearly 3–4% used to provide energy for their production. There are only a few methods of dealing with plastic, re-using it, and disseminating it randomly. Using these wastes in concrete mixtures will significantly contribute to resolving the environmental problem and decrease the waste's harmful effects.

Crushed plastics have become more popular as a partial replacement for aggregate in construction works. The mixing of waste in concrete grows as an additional benefit in environmental and possibly economic considerations. If material recycling is not an option, plastic can be burnt with energy recovery. Because of waste burning, air pollution can create acid rain. Abrasion resistance, impact resistance, flexibility, absorbency, and thermal transfer have all improved when waste plastic is partially replaced with aggregate in concrete. Moreover, adding plastic to concrete enhances the mechanical characteristics of the concrete, such as compressive strength, split tensile strength, and flexural strength. Concerns regarding how to dispose of the waste generated have grown as people have become more aware of global issues, one of the world's most critical environmental challenges in solid waste management, due to the scarcity of landfill space and the rising disposal expense. Waste materials are already being looked into for usage in concrete. Waste includes abandoned wheels and plastic. Both new and cured concrete benefit from the addition of waste materials. Concrete made from waste materials not only saves money but also helps to solve disposal difficulties.

Concrete is a multi-function civil engineering construction material. The lack of construction supplies is a severe issue in the construction sector. In today's resource-scarce world, sustainable concrete has gotten significant attention. Various attempts have been undertaken to limit the usage of non-renewable fine aggregate, coarse aggregate, and other concrete elements. Thus, to offer a new concept called waste plastic mix concrete, research for new construction materials and the means to dispose of plastic trash is required. According to a previous study, abrasion resistance, impact resistance, flexibility, shock absorption, and thermal conductivity are all attributes that can be improved by partially replacing concrete aggregate with waste plastic. According to research, adding plastic to regular concrete boosts the mechanical properties of the mix.

1.2 Plastic Waste

Most of the waste plastic comprises synthetic and semi-synthetic organic compounds. Humans, wildlife, and other living things in the ecosystem are all harmed by plastic products. Plastic bag garbage litters the landscape, creating an unsightly and unsanitary scene. Littering reduces the amount of rainwater that falls on the ground, resulting in low water levels across the board. The number of bottles and jars sold in the United States has increased by 16 % over the last two decades. Natural bottles, such as high-density polyethylene, create 4.9 % more than other product materials (HDPE). India dumps 0.24 million tons of plastic into the sea annually. Every year, 0.6 million tons of waste plastic are produced. In 2014, the amount of plastic floating in the ocean was estimated to be 270000 tons. As a consequence, the plastics must be carefully recycled. Plastic shells will be lowered by 0.5% if used in buildings. This is another option for properly disposing of plastic waste.

There is a serious waste disposal issue in the current situation, which has become costly due to overburdened landfills. Non-biodegradable materials such as waste plastics, scrap metal, and other non-biodegradable materials may contaminate the soil and groundwater. Waste plastic materials such as low-density polyethylene, high-density polyethylene, polystyrene foam wastes, polyethylene terephthalate, and other plastic materials have been researched to be utilized in concrete to modify, improve, and reduce the cost of the material.

2. Problem Statement

The challenge is that the plastic substance is non-degradable or melting, is present in considerable quantities in our society, keeps it locked in place, and is confined and constrained, such as pipes and tanks. On the other hand, concrete has a limited lifespan and cannot withstand high tensile and concussion loads. Most aggregates are obtained via quarrying and crushing stones. Crushing releases dust particles into the environment, just as quarrying of stones changes the geological characteristics of the area. As a result, there is a double negative impact on the ecosystem. To reduce this, researchers concentrated on the utilization of waste items that had a negative impact on the environment. Some of these, such as iron slag and crusher dust, are already used, while others are still being researched. As a result, using these waste materials serves a dual purpose. It reduces raw concrete components while also utilizing waste elements harmful to the environment. Another advantage of using these waste materials is that they help to improve concrete properties. Plastic was the waste material that we employed in the research, plastic harms the environment, yet it can be used in concrete due to its specific properties.

3. purpose of the study

The study highlights the characteristics of concrete that can be changed with plastic through the review of several studies. The characteristics include:

a) Compressive Strength.

b) Split Tensile Strength.

c) Flexural Strength.

4. Literature Review

4.1 Use of Plastic in A Concrete to Improve Its Properties

The paper is focused on the impact of plastic on the strength qualities of concrete. The investigator used pieces of polyethylene bags in varying percentages of 0.2, 0.4, 0.6, 0.8, and 1 percent to evaluate concrete's compressive strength and split tensile strength qualities. The study's findings show that when the percentage of plastic particles in concrete grows, the compressive strength of the concrete decreases. However, the rate of compression strength drop is determined to be relatively low. With the addition of 1% plastic fragments, the material's compressive strength was reduced by up to 20%. In contrast, the split tensile strength appears to be increasing, though at a slow rate. According to the findings, the tensile strength of concrete can be improved by adding more plastic particles to it [1].

Compressive strength

Tests were performed on 150mm X150mm X150mm, with three cubes manufactured for each mix. After 3, 7, and 28 days, the strength of each cube was determined. Figure 1 shows the results of the compressive strength test.

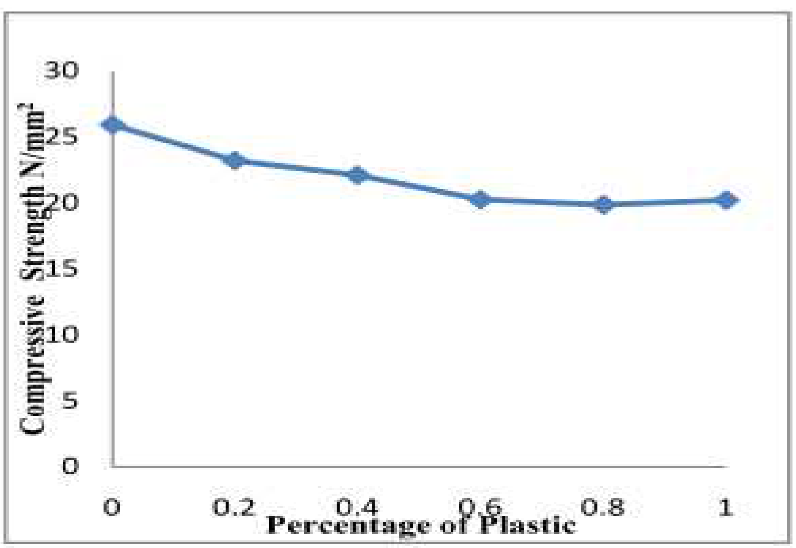


Figure 1 Variation in 28-day compressive strength with different plastic percentages

Tensile strength

Concrete has the advantage of performing well in compression but badly in tension, which is one of its disadvantages. A cylindrical sample with 150 mm and 300 m was used to test split tensile strength. The pieces should be re-tested after 3, 7, and 28 days. The split tensile test is depicted in Figure 2.

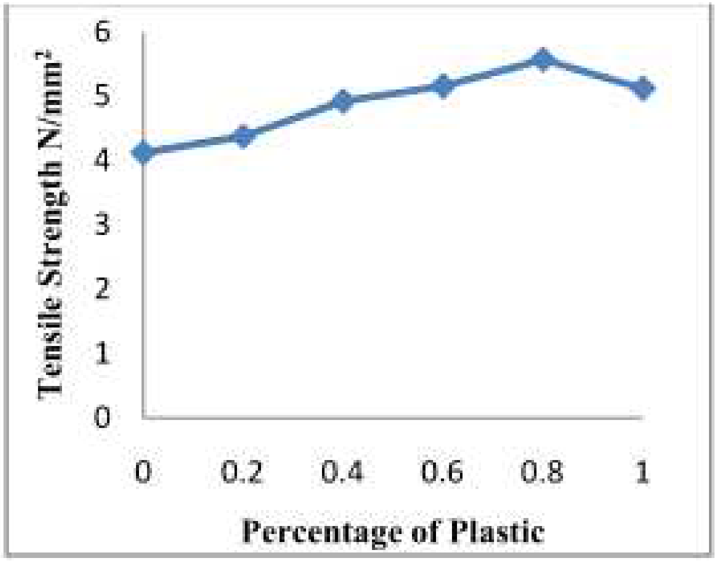


Figure 2 Variation in 28-day tensile strength with different plastic percentages

4.2 Use of Plastics in Concrete as Coarse Aggregate

This study highlights the results of replacing coarse aggregate with plastic to modify the mechanical characteristics of concrete. The plastic aggregate must be melted between 150 and 1800 degrees Celsius, then hardened and crushed to the required size. The concrete with the highest compressive strength contains 20% plastic aggregate. However, it is 2% less than nominal concrete. With 15% replacement and 30% less concrete than nominal, the split tensile strength test's maximum tensile strength is achieved. Concrete's tensile strength is significantly impacted by plastic aggregate but not compressive strength. The findings show that utilizing an optimum of 15% plastic aggregate as a replacement for coarse aggregate without altering the mechanical qualities of the concrete can effectively use plastic waste [2].

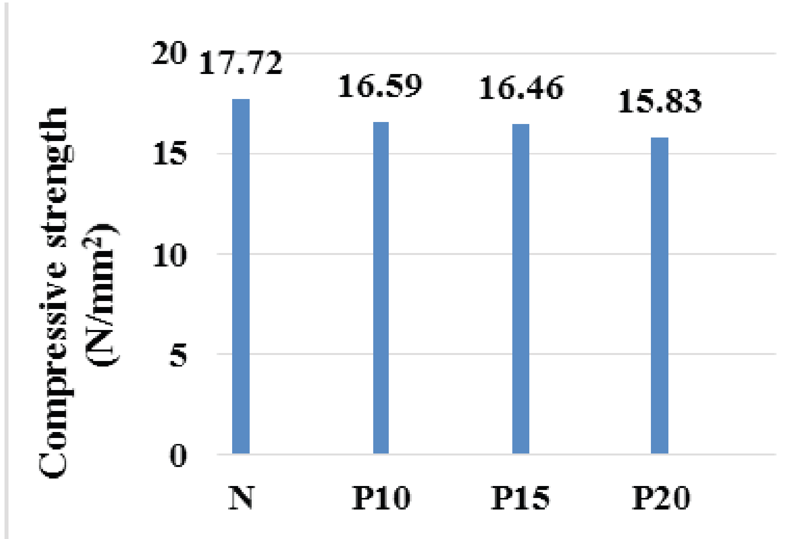


Figure 3 Compressive strength on the 7th day

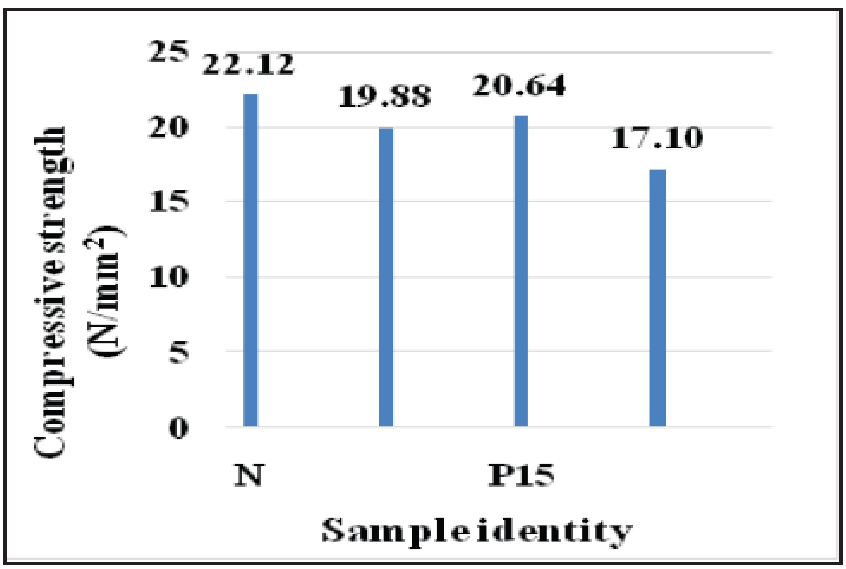


Figure 4 Compressive strength on the 14th day

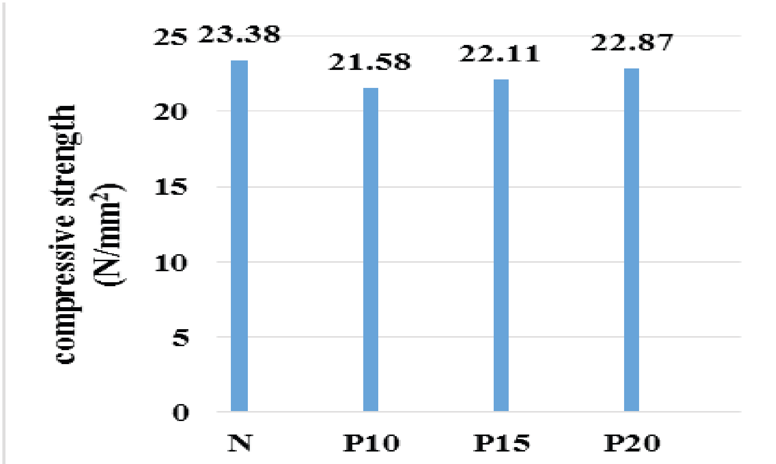


Figure 5 Compressive strength on the 28th day

For all percentage replacements and curing periods, the split tensile strength of plastic substituted concrete was lower than that of nominal concrete. The best value was in split tensile strength for concrete with a 15% percentage replacement, which increases with each curing period. At 28 days, however, it is still 30% less than the nominal concrete strength, as shown in Figures 6,7, and 8.

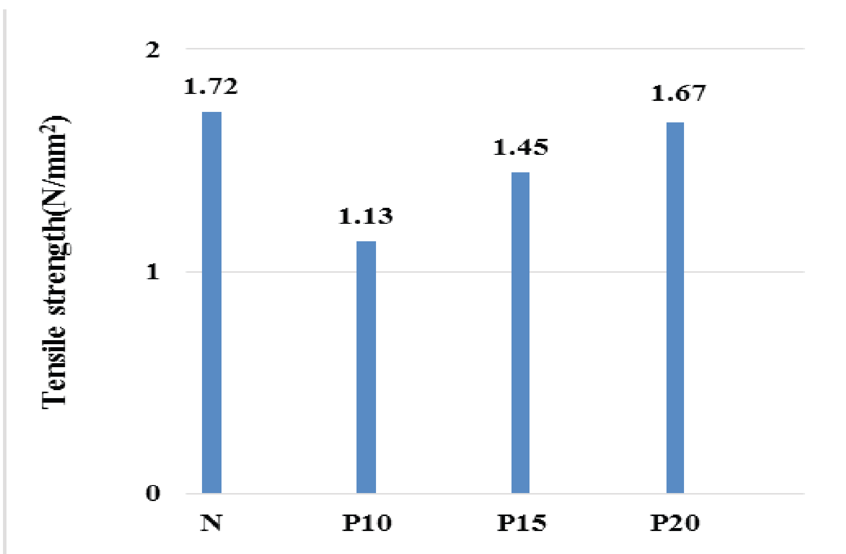


Figure 6 Split Tensile Strength on the 7th day

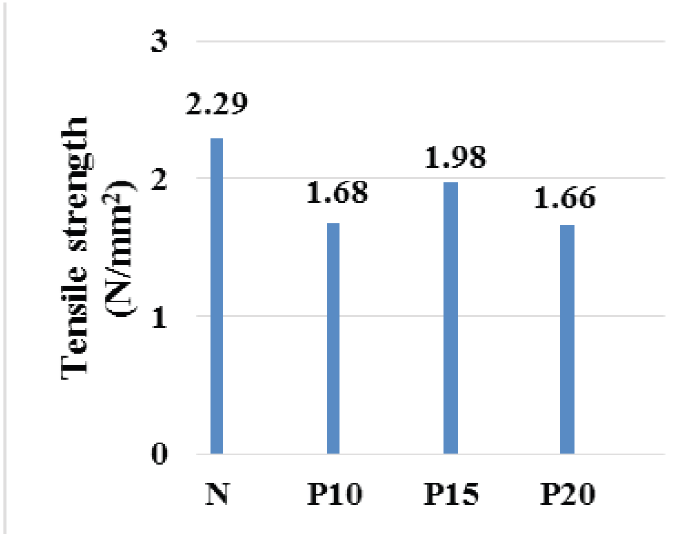


Figure 7 Split Tensile Strength on the 14th day

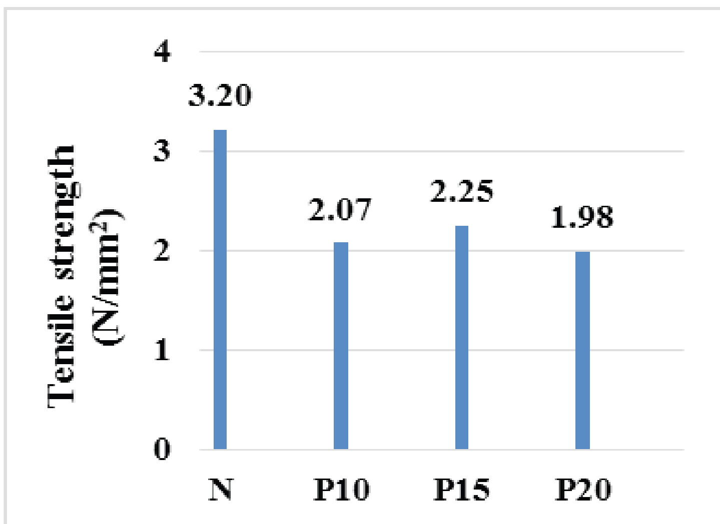


Figure 8 Split Tensile Strength on the 28th day

4.3 Compressive Strength of Concrete using Plastic Waste

The purpose of this research is to assess the compressive strength of concrete when fine particles are replaced with scraped plastics and coarse aggregates are replaced with crushed plastic. Plastic trash with a density of 0.93 to 0.97 g/cm3 was employed as a 5%, 7%, and 9% replacement for fine and coarse aggregate, respectively. Compressive strength tests performed after 7 and 28 days revealed that increasing the proportion of plastic aggregate in concrete increases compressive strength. According to the findings, the compressive strength of concrete with scraped plastic as an acceptable aggregate replacement is higher than that of concrete with crushed plastic as a coarse aggregate replacement [3].

There are two waste plastics used, scraped plastics, and crushed plastics, that have a considerable density to know the compressive strength of concrete cube by adding an extra replacement of 5%, 7%, and 9%, as shown below in figures 9, and 10.

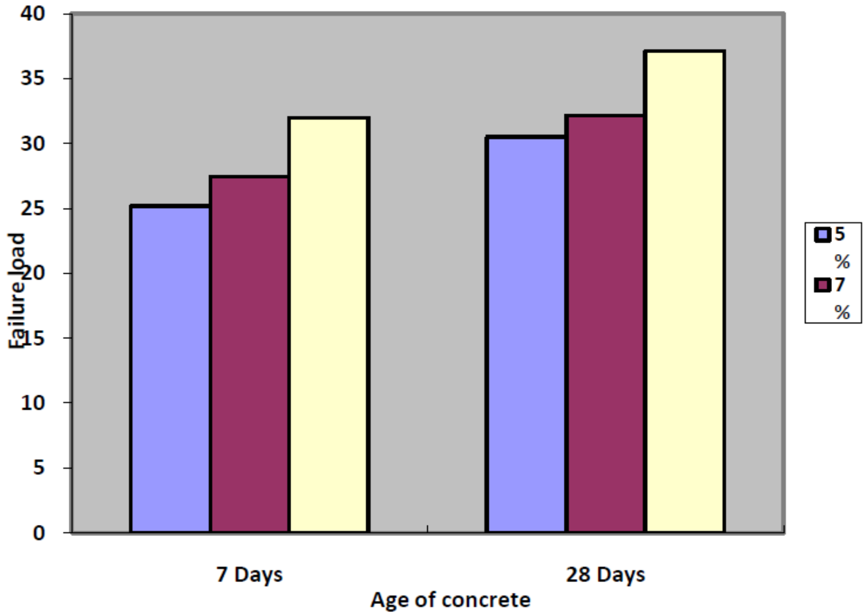


Figure 9 Concrete Failure Load with scraped plastics

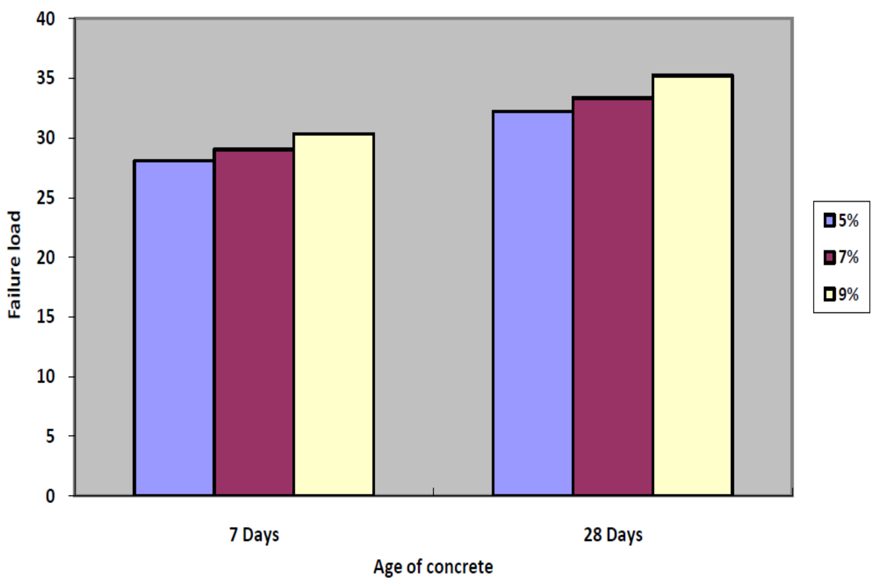


Figure 10 Concrete failure loads with scraped plastics

4.4 Concrete Mixture with Plastic as Fine Aggregate Replacement

This research report examines the effectiveness of employing high-density polyethylene plastic waste as a suitable aggregate replacement in concrete. According to the workability tests, the slump lowers as the fraction of fine aggregate substituted with high-density polyethylene plastic aggregate increases. This test is performed on concrete with high-density polyethylene plastic as an acceptable aggregate replacement, which has a non-stable shape and produces incorrect slump counts. Split tensile strength, compression strength, and heat absorption tests were performed on cylindrical specimens measuring 100mm in diameter, 200mm in height, and a slab of 305mm*305mm*25mm. The study's outcomes indicated that replacing fine aggregate in concrete with high-density polyethylene plastic waste results in a significant loss of workability, higher compressive strength, and a significant rise in heat absorption [4].

The test specimen's compressive strength and loss are shown in Tables 1 and 2. The concrete samples' strengths varied significantly, according to the results. The compressive strength of the concrete dropped as the percentage of plastic replacing sand raised. The strength of the concrete was reduced by about 15% when 10% of the fine aggregate was replaced with high-density polyethylene plastic. Similarly, with 20% replacement, the concrete's compressive strength was reduced by more than 30%. The 50% and 100% replacement samples lost cohesiveness and compressive strength significantly [4].
Furthermore, both samples were discovered to be late. This was because of the high air content and the unique form of the high-density polyethylene aggregate. The 30 percent plastic replacement sample's 28-day compressive strengths were found to be exceptionally low. It would be pretty unusual for the 28-day compressive strength of a batch of concrete to be lower than the 7 days and 14-day compressive values. The cause of this aberration remained unknown and therefore necessitated additional inquiry. The most plausible reason is that the cylinders that failed at 28 days were improperly compacted or otherwise faulty, causing the cylinders to shatter early due to intrinsic faults.

Table 1 Concrete compressive strength

Replacement	Compressive Strength		
	7 days (Mpa)	14 days (Mpa)	28 days (Mpa)
0	26.7	37.3	41.2
10	22.9	32.5	35.2
20	18.3	24.8	28
30	12.1	18.2	8.1
50	6.2	9.8	9.5
100	0.8	0.9	1.1

Table 2 Loss in compressive strength

Replacement	strength loss VS control		
	7 days (Mpa)	14 days (Mpa)	28 days (Mpa)
0	0	0	0
10	14.2	12.9	14.6
20	31.5	33.5	32
30	54.7	51.2	80.3
50	76.8	73.7	76.9
100	97	97.6	97.3

4.5 Use of Recycled Plastic Waste as Partial Replacement for Fine Aggregate in Concrete

The study goal was to examine the various mechanical properties of concrete that included plastic garbage. Plastic aggregate is used to substitute fine aggregate in a range of percentages of 5%, 6%, 8%, 10%, 15%, and 20% of the concrete. The well-performing mix, concrete with 15% acceptable aggregate substitution with plastic aggregate, is made using varying amounts of silica fume as a binding ingredient. The concrete's compressive strength, flexural strength, and direct tensile strength were determined through various testing. The test revealed that as the plastic component of the concrete grows, the workability of the concrete increases as well, owing to the smooth surface and low water absorption of the plastic aggregate. The authors find that when cement is combined with silica fume, the strength qualities of concrete using plastic waste as a fine aggregate substitute increase. The use of silica fume in conjunction with plastic-infused cement in concrete also prevents the production of microcracks [5].

Compressive strength

Table 3 shows the compressive strength results for the waste plastic concrete mixtures at 7 and 28 days. The results demonstrated decreased compressive strength as the waste plastic to fine aggregate ratio increased because of a lack of adhesive strength between the waste plastic's surface and the cement paste.

Table 3 Concrete compressive strength after 7 and 28 days

Mix No.	Compressive strength for 7 days N\mm2	Compressive strength for 28 days N\mm2
H1	28.2	47
H2	27.66	46.1
H3	27.6	46
H4	27.24	45.4
H5	26.52	44.2
H6	25.26	42.1
H7	24	40

Tensile strength

The tensile strength of the concrete specimens was examined under a split tensile test to comprehend the effects of the replacement ratio of fine aggregate with plastic aggregate on the tensile behavior of concrete at 7 and 28 days. The experimental findings are provided in Table 4.

Table 4 Concrete tensile strength after 7 and 28 days

Mix No.	Tensile strength for 7 days (N\mm2)	Tensile strength for 28 days (N\mm2)
H1	1.8	3
H2	1.833	3.055
H3	1.962	3.027
H4	1.782	2.97
H5	1.74	2.9
H6	1.71	2.85
H7	1.68	2.8

4.6 Use of Recycled Plastic in Concrete as Replacement of Fine Aggregate

The workability of concrete was increased by 7% compared to the control mix by replacing 10% of the fine aggregate with plastic granules, according to the test study work being carried out for creating the concrete by using plastic granules to replace fine aggregate. The mixes A1 and B1 with a 10% acceptable aggregate replacement produced superior results. The compressive strength decreases by enhancing the number of plastic granules in it. When compared to the strength of the control mixture, the compressive strength of the mixtures is found to be 15% lower. When evaluating the durability of mixes with 10% acceptable aggregate replacement by plastic granules to a control mix, Mix A1 is shown to have significant resistance to water penetration. Plastic grade A was graded similarly to the fine aggregate used during the control mix [6].

Workability

Figure 11 represents the results of the slump cone test. Mix2A and Mix2B, with slump values of 78mm and 75mm, respectively, supplied the requisite workability of 75mm - 100mm. The outcomes of concrete mix (Mix 1A and Mix 3B) with slump values of 67mm and 72mm differed by 21% and 10% from the control mix, respectively. The workability of the concrete is observed to improve as the fraction of fine aggregate replaced with plastic granules increases. Plastic has a hydrophobic feature, which means it absorbs lower water. The concrete mixes with 10% plastic differed just 6.5 % from the control mix in terms of workability. High variation was discovered in the mixes with 7.5 percent and 12.5% plastic substitution [6].

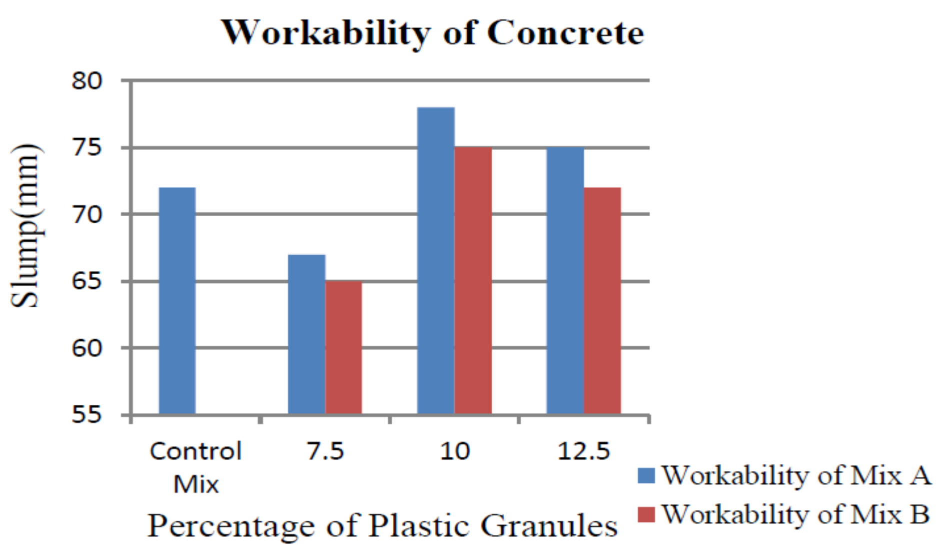


Figure 11 Workability of concrete

Compressive strength

Figure 12 shows a chart of concrete compressive strength test values. Mixes Mix 1A and Mix 1B outperformed other mixes in the compressive strength test, with 25.45 N/mm2 and 24.5 N, respectively. The control mix had a strength of 27.2 N/mm2, while the concrete mixtures with plastic had less than that. Compared to the control mix, Mix2A and Mix2B found just a 15% drop in compressive strength. The compressive strength of the concrete was diminished as the fraction of fine aggregate replaced with plastic granules increased.

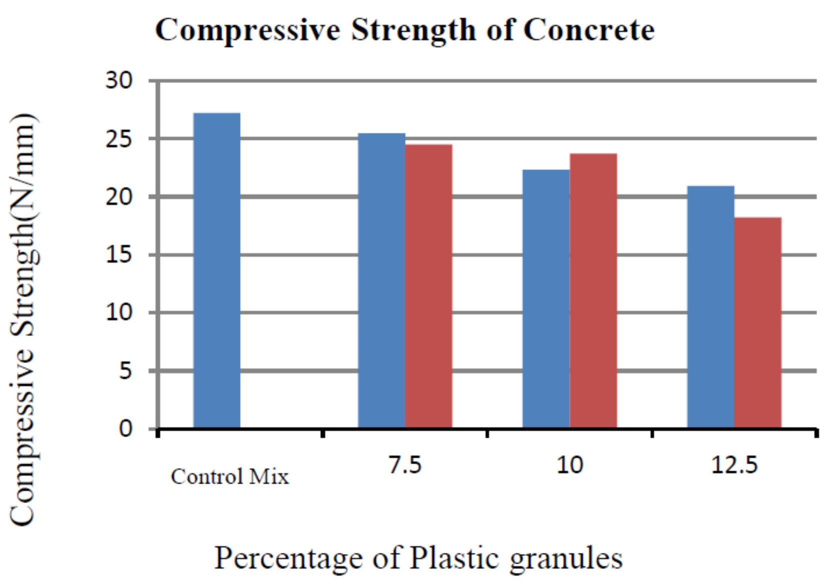


Figure 12 Compressive strength

4.7 Study on Mechanical Properties of Concrete Using Plastic Waste as an Aggregate

The report shows the study results that used steel fibers in concrete to improve the mechanical properties of a mixture of plastic waste and concrete. Fine material was replaced with plastic fines in the concrete, while coarse aggregate was replaced with coarse plastic aggregate. Steel fibers with 0.3% cement are employed in the concrete. The concrete with plastic granule and steel fiber's compressive strength, split tensile strength, and flexural strength were measured and found to be lower than that of controlled mix concrete. According to the findings, plastic in concrete influences compressive strength, split tensile strength, and flexural strength. It is concluded that the weak link between plastic aggregate and cement, caused by the hydrophobic nature of plastic, impacts the concrete's mechanical qualities. The concrete's steel fibers are still useless [7].

Compressive strength

Concrete specimens are taken down from the curing tank and allowed to dry completely before being placed in the compression testing equipment. The load was applied to the sample till it failed, and the ultimate load of each specimen was determined. The compressive strength of concrete was obtained, and the average of three specimen compressive strengths was calculated for all concrete compositions at various curing ages. The graph was drawn using the results of Figures 13 and14. The addition of plastic to waste plastic used concrete reduced the compressive strength. The reduction is estimated to be between 9 and 17%. The weak binding strength between plastic particles and concrete may be blamed for this loss [7].

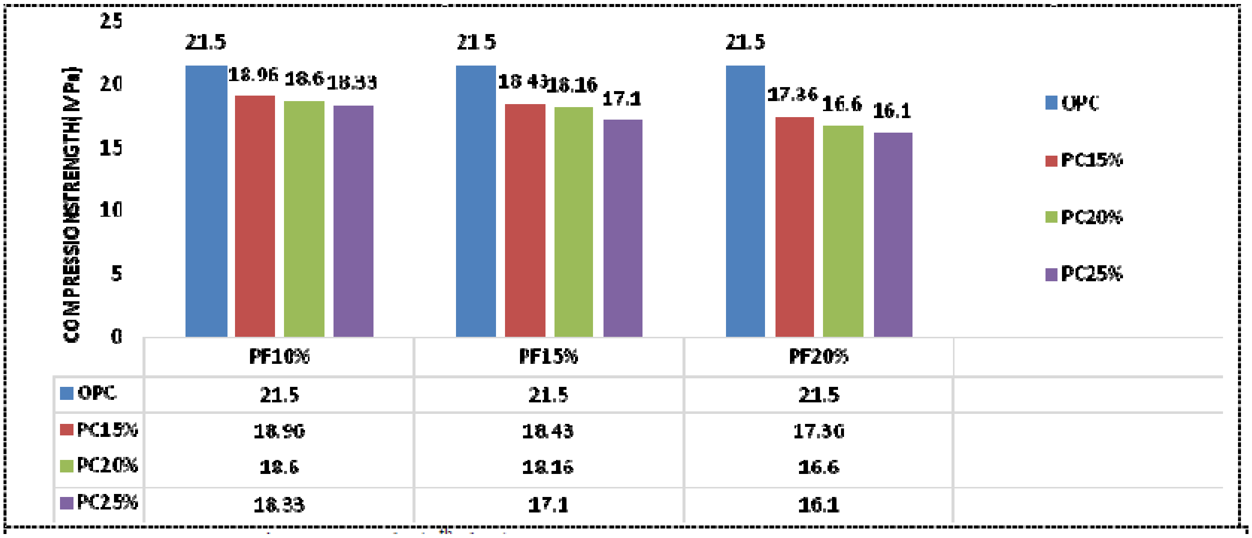


Figure 13 Compressive strength on the 7th day

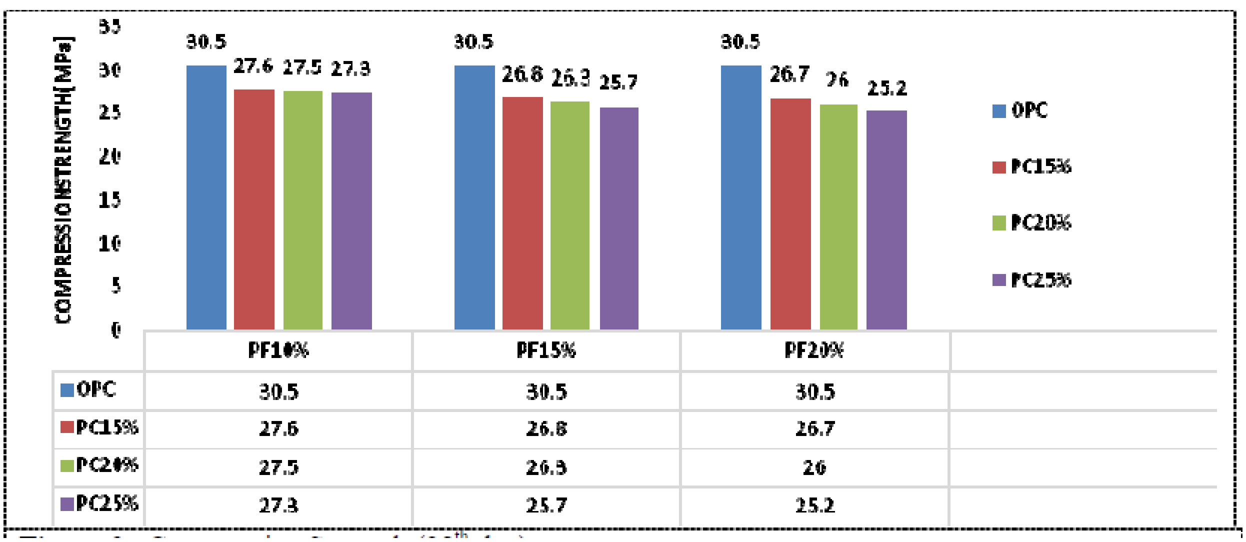


Figure 14 Compressive strength on the 28th day

Tensile strength

In tension, the concrete is brittle. The splitting tensile strength of concrete cannot be determined directly. As a result, cylinders with a diameter of 100mm and a depth of 200mm were cast and cured in portable water for 7 and 28 days, respectively. After drying the surface wetness, the specimens are held longitudinally in the compression testing machine. The ultimate load at which the sample may crack is determined by applying a load to the specimen's longitudinal surface. Figures 15 and 16 illustrate graphs created from the acquired results.

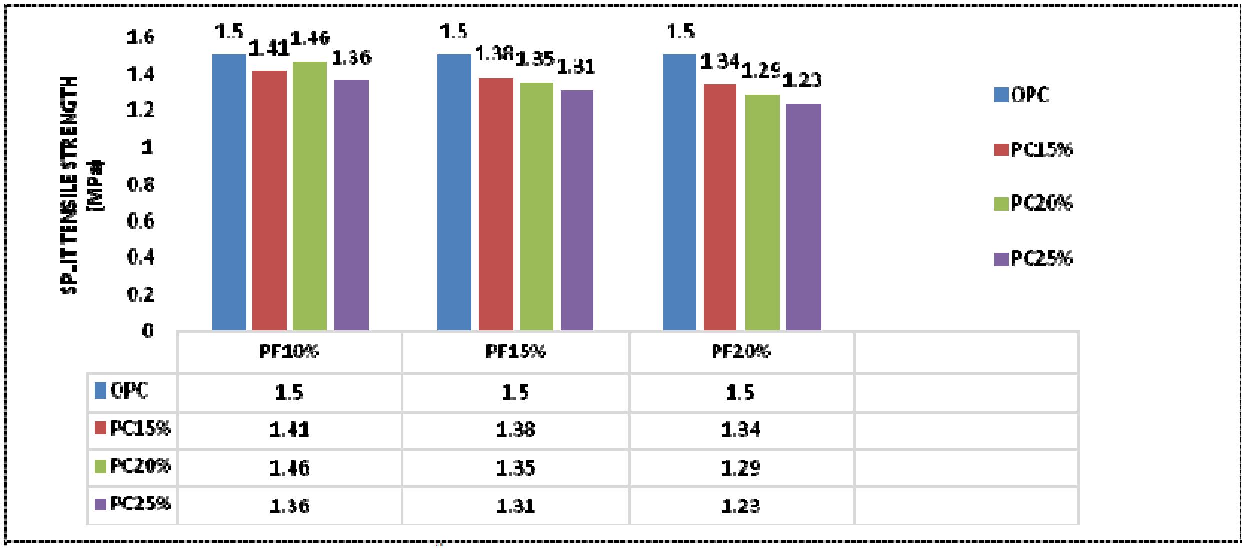


Figure 15 Split Tensile Strength on the 7th day

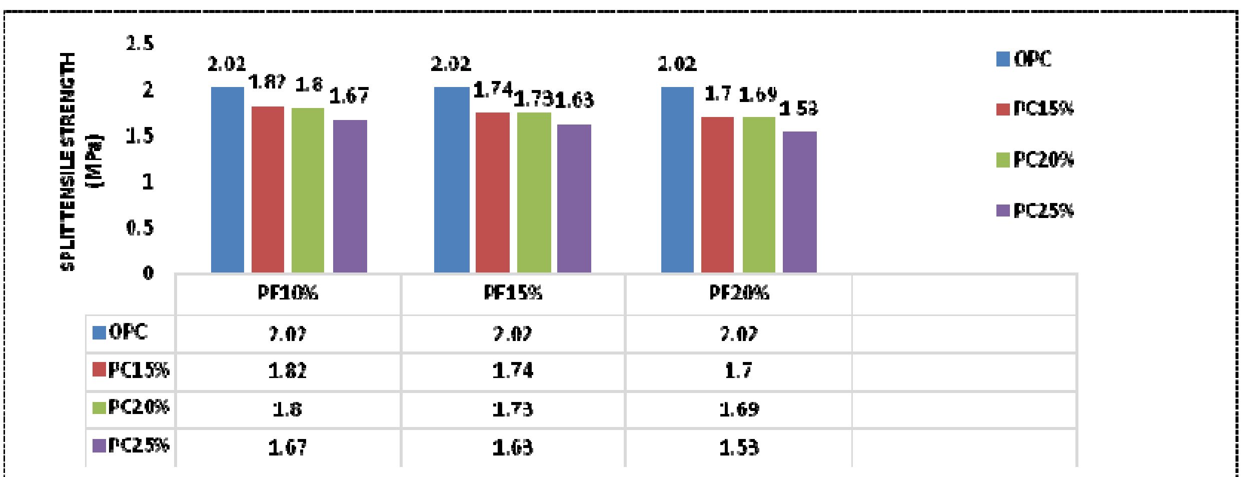
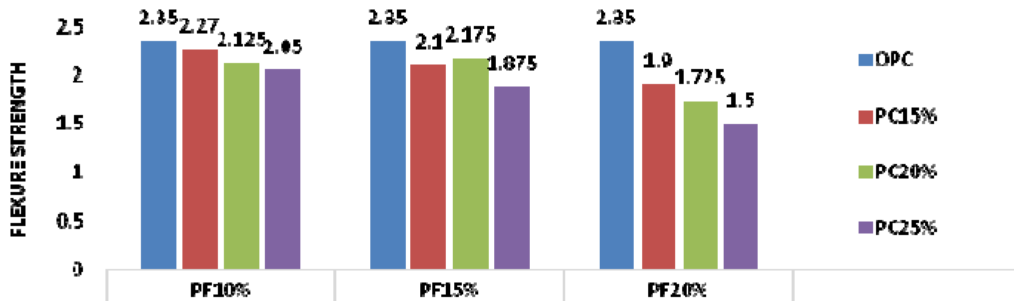


Figure 16 Split Tensile Strength on the 28th day

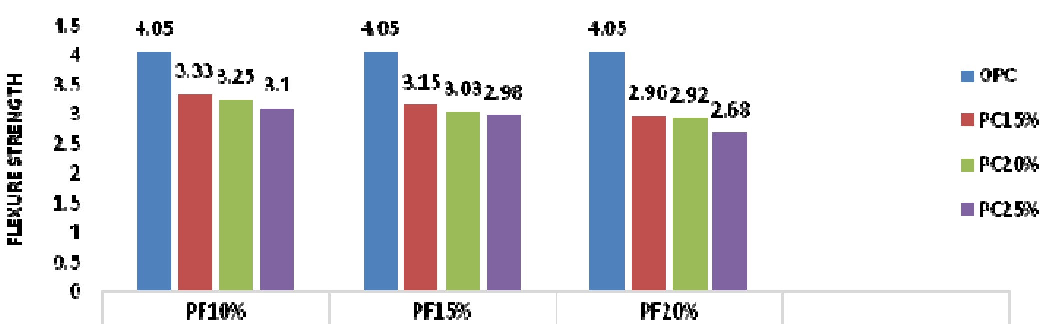
Flexural strength

To determine the behavior of beams, flexural strength testing was conducted on prisms of size 100×100×500 mm at 7 and 28 days of age. The specimen was put on the universal testing equipment, and hydraulically applied two-point loading was raised until failure. Figures 17 and 18 are graphs created from the results acquired.



	PF10%	PF15%	PF20%
OPC	2.35	2.35	2.35
PC15%	2.27	2.1	1.9
PC20%	2.125	2.175	1.725
PC25%	2.05	1.875	1.5

Figure 17 Flexural strength on the 7th day



	PF10%	PF15%	PF20%
OPC	4.05	4.05	4.05
PC15%	3.33	3.15	2.96
PC20%	3.25	3.03	2.92
PC25%	3.1	2.98	2.68

Figure 18 Flexural strength on the 28th day

4.8 Practical Study on the Effect of Partial Replacement of Coarse Aggregate with Plastic Waste on some Normal Concrete Properties

Plastic trash was used to substitute gravel in the concrete mixture in three proportions: 2.5, 5, and 10%. A total of 14 concrete cylinders measuring 150x300 mm were cast. The benchmark reference was 10 concrete cylinders with a water/cement ratio of 0.48 and mixing ratios of 1:1.5:3 that were cast with a water/cement ratio of 0.48 and mixing ratios of 1:1.5:3. A total of 10 concrete cylinders were made with a 2.5% coarse aggregate substitution. Another 10 concrete cylinders were produced with a 5% coarse aggregate partial replacement. The final 10 concrete cylinders were made with a 10% coarse gravel partial replacement [8].

According to the studies, increasing the amount of plastic waste in the concrete mixture decreased the compressive strength. Due to the light weight of the plastic material, concrete density reduces as the content of waste plastic components increases. As the findings of compressive strength were reasonable and proved that the concrete could be utilized in loaded structural sections, the best ratios of partial substitution of aggregates with plastic wastes were 2.5% and 5%. The quantity of compressive strength reduced to 14Mpa when the percentage was 10% replacement. As a result, the concrete can be applied in non-loaded structural sections in this instance [8].

Compression strength

After 28 days of hardening, the concrete samples were tested for compression strength. A total of four groups were studied, each with a mean of ten examples. Iron cylinders with dimensions of 150x300 mm were used to test compression resistance in accordance with ASTM standards 86 and C39. Compared to the reference concrete samples, the compressive strength was reduced by 12 %, 29 %, and 47 % when the coarse material was replaced by 2.5 %, 5 %, and 10% of the plastic waste, respectively, as shown in Figure 19.

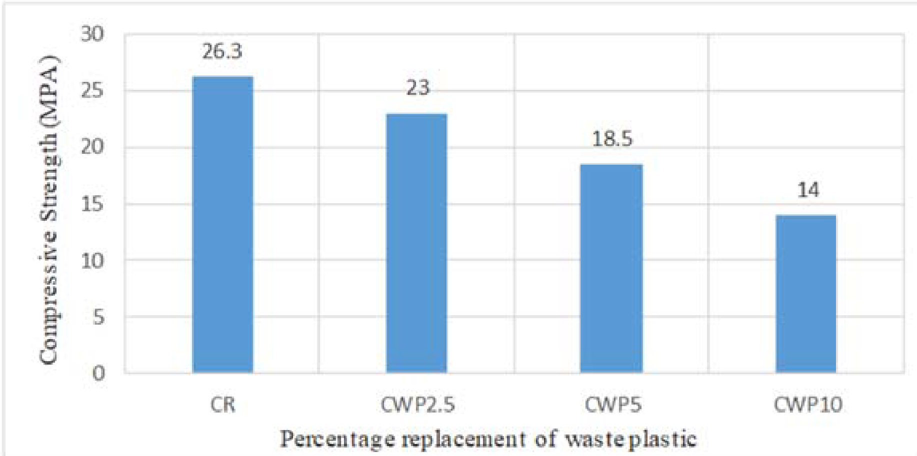


Figure 19 Compressive strength on the 28th day

Figure 20 shows the relationship between time and load. According to the study, the drop in strength is attributable to the plastic waste's lower qualities when compared to coarse aggregate. The specific weight and density of the plastic garbage were approximately 1.38 and 1381 Kg/m3, respectively. In contrast, the particular weight and density of the gravel as a reference sample were about 2.61 and 2610 Kg/m3, respectively.

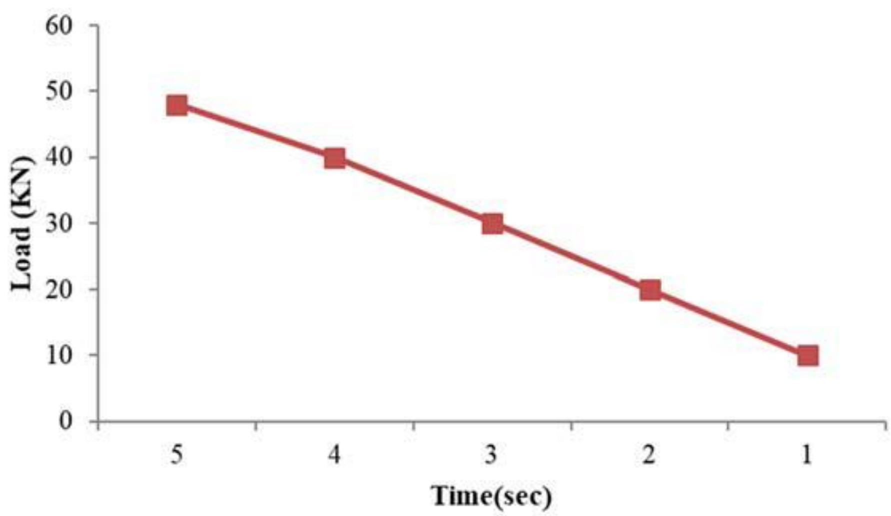


Figure 20 The relationship between time and loads

4.9 Strength Characteristics of Concrete using Solid Waste an Experimental Investigation

Testing specimens for compressive, split tensile, and flexural strengths are part of the current experimental examination of High-Density Polyethylene fiber. Samples are made with a design mix including varying percentages of High-Density Polyethylene ranging from 0 to 6% by volume of concrete. Cubes 150 x 150 x 150 mm dimensions, cylinders with 150 x 300 mm, and beams with 100 x 100 x 500 mm are constructed. For curing, the samples were placed in a slump. According to the experiment, solid waste can be included in concrete for strength and disposal. The use of solid waste fibers increases the concrete's force-carrying capacity. A max of 2% of fibers can be utilized for strength purposes, while up to 6% can be used for disposal purposes. The flexural strength, the split tensile strength, and the compressive strength are 39.85, 4.35, and 4.12 M Pa [9].

Compressive strength and split tensile strength

The compressive strength, and split tensile strength of concrete at 7 and 28 days, with fiber percentages ranging from 0% to 6%. Concrete compressive strength and split tensile strength rise as the fiber percentage increases up to 3.5 percent, but strength decreases as the fiber concentration increases from 3.5 to 6%. The results are shown in Figures 21 and 22.

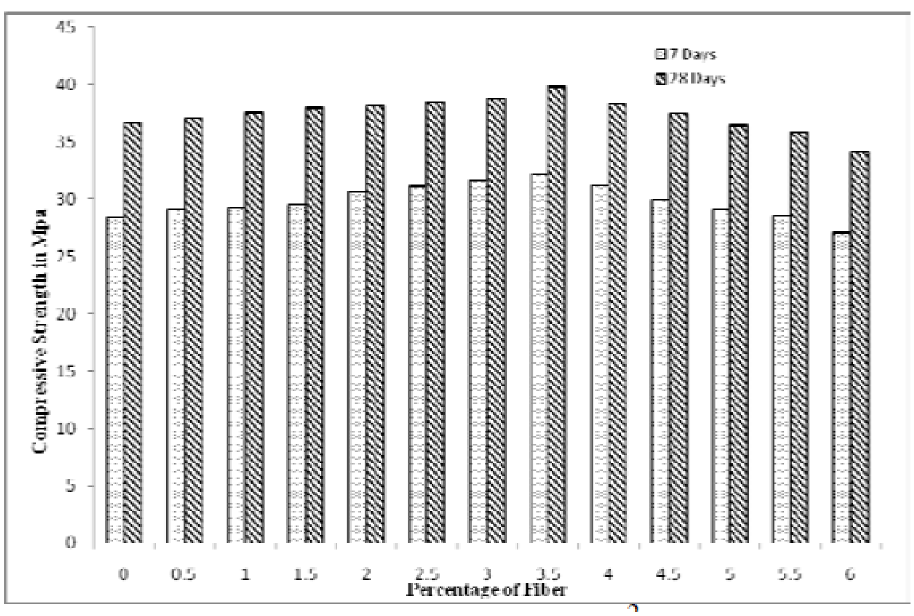


Figure 21 Compressive strength on the 7 and 28 days

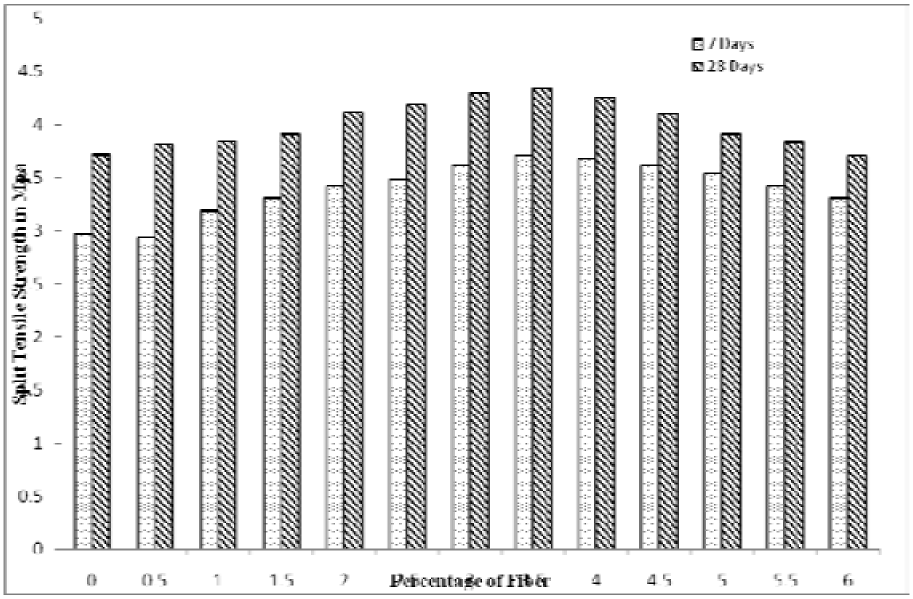


Figure 22 Tensile Strength on the 7 and 28 days

4.10 Compressive Strength and Tensile Strength of Granite Waste, Plastic Waste Concrete by Replacing Partially

The study aims to explore compressive strength and split tensile strength. This study compares regular cement concrete mixes with Plastic Waste Concrete using a single standard grade. This study partially used recycled plastic aggregates to replace natural coarse aggregate in concrete. Different amounts of recycled plastic coarse aggregates were intended, ranging from 0% to 2%, 3%, and 5%. Each sample's compressive strength was measured and compared to a standard concrete mix [10].

Compressive strength

As 2% plastic waste is replaced with coarse aggregates, 7-day strength is reduced by 14%, and 28-day strength is reduced by 12.58 % when relative to 0% replacement. When 3 % plastic waste is replaced with coarse aggregates, 7-day strength is reduced by 16.8%, and 28-day strength is reduced by 13% relative to 0% replacement. When coarse aggregates replace 5% of plastic waste, 7-day strength reduces by 17.8%, and 28-day strength decreases by 13.5 % relative to 0% replacement.

Table 5 Compressive strength with 0% replacement of plastic

No.	Number of days	Compressive strength N/mm2
1	7	32.58
2	14	38
3	28	48.88

Table 6 Compressive strength with 2% replacement of plastic

No.	Number of days	Compressive strength N/mm2
1	7	18.8
2	14	24.3
3	28	36.22

Table 7 Compressive strength with 3% replacement of plastic

No.	Number of days	Compressive strength N/mm2
1	7	16
2	14	24
3	28	35.7

Table 8 Compressive strength with 5% replacement of plastic

No.	Number of days	Compressive strength N/mm2
1	7	15
2	14	23
3	28	35.33

The compression strength of M40 grade concrete with 0%, 2%, 3%, and 5% replacement of plastic waste in coarse aggregate at 7,14,28 days of curing is shown in the tables above.

Tensile strength

When 2% plastic waste is replaced with coarse aggregates, the 7-day strength drops by 2.72%, and the 28-day strength drops by 3.2% relative to 0% replacement. When 3% plastic waste is replaced with coarse aggregates, 7-day strength drops by 2.8%, and 28-day strength drops by 3.28% relative to 0% replacement. When coarse aggregates replace 5% of plastic waste, 7-day strength drops by 2.9%, and 28-day strength drops by 3.41% relative to 0% replacement. In plastic waste concrete, greater strength was attained at 2% replacement close to 2%, 3%, and 5% replacements.

Table 9 Tensile strength with 0% replacement of plastic

No.	Number of days	Weight of cylinder Kg	Tensile strength N/mm2
1	7	13.3	4.64
2	14	13.4	4.94
3	28	13.3	5.4

Table 10 Tensile strength with 2% replacement of plastic

No.	Number of days	Weight of cylinder Kg	Tensile strength N/mm2
1	7	12.9	1.92
2	14	12.92	2.09
3	28	12.92	2.2

Table 11 Tensile strength with 3% replacement of plastic

No.	Number of days	Weight of cylinder Kg	Tensile strength N/mm2
1	7	12.81	1.84
2	14	12.84	2
3	28	12.89	2.12

Table 12 Tensile strength with 5% replacement of plastic

No.	Number of days	Weight of cylinder Kg	Tensile strength N/mm2
1	7	12.75	1.72
2	14	12.8	1.88
3	28	12.78	1.99

The tensile strength of M40 grade concrete with 0%, 2%, 3%, and 5% replacement of plastic waste in coarse aggregate at 7,14,28 days of curing is shown in the tables above.

4.11 Recycled Plastics as Coarse Aggregate for Structural Concrete

The objective of this study was to figure out what percentage of natural coarse aggregate should be replaced with coarse plastic aggregate in concrete to improve the concrete's mechanical strength capabilities. Mechanical strength tests were conducted after replacing various percentages of natural coarse aggregate with coarse plastic aggregate. The results revealed that replacing 22% of the natural coarse aggregate with coarse plastic aggregate improved the concrete's compressive strength. It was discovered that the workability of 20% plastic coarse aggregate concrete is much better than that of natural coarse aggregate concrete, owing to plastic aggregates' reduced water absorption rate [11].

Figure 23 shows the compressive strength of a 15 x 15 x 15 cm cube at various percentages. At the end of the 28-day curing, it can be shown that 20% substitution produced stronger concrete than natural coarse aggregate concrete. After 28 days, all testing on concrete specimens for the M20 mix to verify its hardened qualities was completed. The optimum percentage substitution was calculated using the curve in figure 30, and the other structural parameters were computed using this optimum value [11].

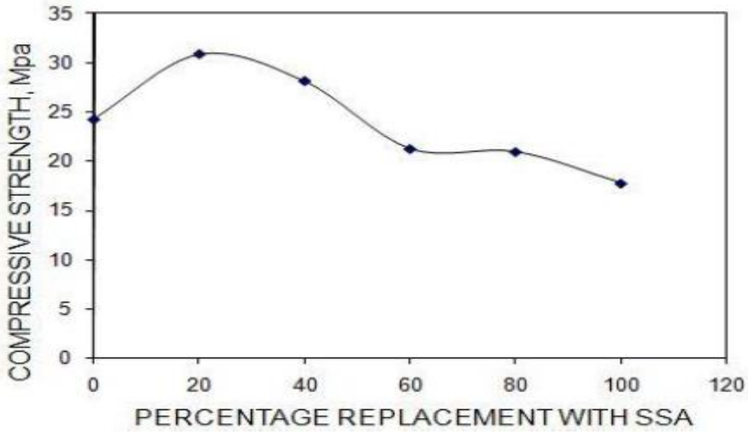


Figure 23 Curve of Compressive Strength

Table 13 lists the results of tests to determine the cylinder compressive strength, split tensile strength, and modulus of elasticity on specimens measuring 150 mm x 300 mm. Although plastic coarse aggregate concrete has a 28% higher compressive strength than conventional concrete, it has a lower split tensile strength and modulus of elasticity. It may be deduced that poor bonding between the coarse plastic aggregate and the matrix contributes to the lower values. The introduction of appropriate admixtures to improve binding strength could reduce these concerns.

Table 13 The properties of concrete structure

Particulars	Cylinder compressive strength in Mpa	Splitting tensile strength in Mpa	Modulus of elasticity in Mpa
NCA	11.8	2.45	16290
22%PCA	16.27	1.91	12686

Figure 24 shows the stress-strain curves for both natural coarse aggregate and plastic coarse aggregate concrete. A flexural strength test was also performed on a 100 x 100 x 500 mm specimen to assess tensile strength. Natural coarse aggregate concrete had a strength of 4.4 Mpa, while plastic coarse aggregate concrete had a 4.24 Mpa. Even though plastic coarse aggregate concrete has a little lower strength than natural coarse aggregate concrete, the values are well within the acceptable limit.

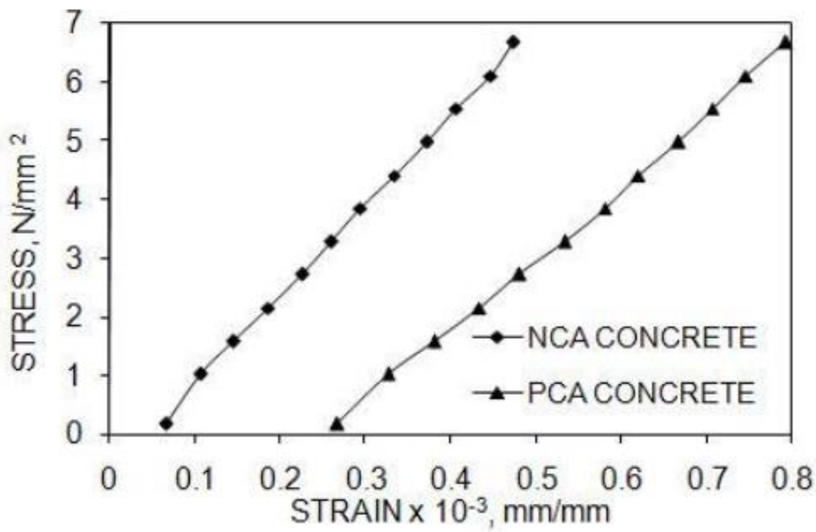


Figure 24 Stress-strain curves

4.12 Effects on Flexural Strength of Concrete Beams Using Waste Polythene Bags as Partial Fine Aggregate Replacement

According to the study, shredded polythene bags can replace fine aggregate in concrete up to 10% in grade 20 concrete. The grade 20 concrete mixture outperforms the grade 30 concrete mix design for shredded polythene bag replacements. The mixed concrete's optimal flexural strength for grade 20 concrete was 5.2980 N/mm2 after 28 days of curing, a 14.1% improvement over the control concrete. According to the gradual decline in flexural strength of mixed concrete beams at 5% and 10% fine aggregate replacement with shredded polythene bags, Grade 30 mix design concrete was not acceptable for the mixed concrete [12].

The load-deflection curve of concrete incorporating shredded polythene bags indicated that small cracks were stopped, which could be helpful in places requiring significant toughness.

The concrete beams were subjected to flexural strength testing according to ASTM C78 (2018) technique. Table 14 and Table 15 demonstrate that the flexural strength of the shredded polythene bag's concrete beams enhanced from 0% to 10% after 7 days and 28 days of curing for concrete grade 20 and decreased for concrete grade 30 after 7 days and 28 days of curing [12].

Table 14 Flexural Strength of Concrete by grade 20

Days of curing	Average flexural strength of beams (N/mm2)		
	0% SPB	5% SPB	10% SPB
7	2.886	2.9445	3.6765
14	3.5331	4.7145	3.855
28	4.6425	5.0625	5.298

Table 15 Flexural Strength of Concrete by grade 30

Days of curing	Average flexural strength of beams (N/mm2)		
	0% SPB	5% SPB	10% SPB
7	2.415	2.475	2.475
14	4.86	8.307	3.126
28	5.871	5.7015	5.484

4.13 Use of Recycled Plastic as Replacement of Fine Aggregate in Structural Concrete

The study has investigated Plastic aggregates. Plastic can be used to replace traditional aggregates with success and effectiveness. Using plastic material in concrete as a fine aggregate replacement is beneficial. The use of plastic in concrete increases compressive strength for a short period of to 4%, after which it begins to decline. The compressive strength of normal and plastic-used concrete for 7 days, 14 days, and 28 days is shown in tables 16 and 17 [13].

Due to the lightweight nature of the plastic, the unit weight of concrete reduced as the percent replacement increased. The concrete compressive strength declined as the percent replacement rose. The use of plastic as a fine aggregate substitute significantly impacts concrete density. The density of concrete decreases as the percentage of plastic increases. As a result, this is ideal for high-rise constructions to lower the structural eelement’sself-weight. Even with its lightweight nature, the plastic element separates from the concrete mass during the vibratory compacting of blended plastic concrete. As a result, significant caution should be used when utilizing the vibrator to compact concrete [13].

Table 16 Compressive Strength of Concrete

Replacement of aggregate %	Compressive strength after days (Mpa)	
	7 Days	28 Days
0%	14.8	24.9
1%	14.92	24.96
2%	14.98	25.1
3%	15.2	25.22
4%	15.31	25.4
5%	15.39	25.5
10%	15.4	25.52
11%	14.9	24.3
12%	13.4	23.4
13%	12.1	21.8

Table 17 Tensile Strength of Concrete

Percentage of plastic added	Tensile strength of concrete (Mpa)	
	7 Days	28 Days
0	3	3.25
1	3.2	4.12
2	3.31	4.33
3	3.5	4.4

4.14 Utilization of Plastic Waste in Concrete as A Partial Replacement Of Fine Aggregate

The study's main objective is to see how fine aggregate replacement with plastic waste affects the mechanical qualities of concrete. Plastic waste has been used as a fine aggregate replacement in an ACI mix of M28. The plastic is crushed to the desired size and then utilized as fine aggregate in concrete with 2%, 4%, 6%, 8%, and 10% fine aggregate percentages. Compressive strength, tensile strength, and post-heating compressive strength are determined through various testing. According to the results, the strength characteristics of concrete using plastic aggregate as a fine aggregate substitute improve by up to 6% before decreasing with the addition of plastic aggregate [14].

A mixed design of 28 MPa concrete was used to create the testing specimen. Three cylindrical models of 6-inch and 12-inch length were cast with varying water-cement ratios for the design strength test. They were cured in fresh water for 28 days. They were put through a compressive strength test after a 28-day curing period. The test specimens were cast using three different water ratios of 0.40, 0.45, and 0.50. According to the test results, the 0.40 water-cement ratios provided the needed strength for the design test specimen. To cast the concrete cube specimen, we used a 0.40 w/c ratio [14].

Table 18 Compressive Strength as a Function of Water Cement Ratio

Water Cement Ratio	Specimen No.	Applied Load (KN)	Average Applied load (KN)	Average compressive strength (Mpa)
0.4	1	50	51.67	28.41
	2	52		
	3	53		
0.45	1	49	49	26.8
	2	48		
	3	50		
0.5	1	48	47.33	25.79
	2	48		
	3	46		

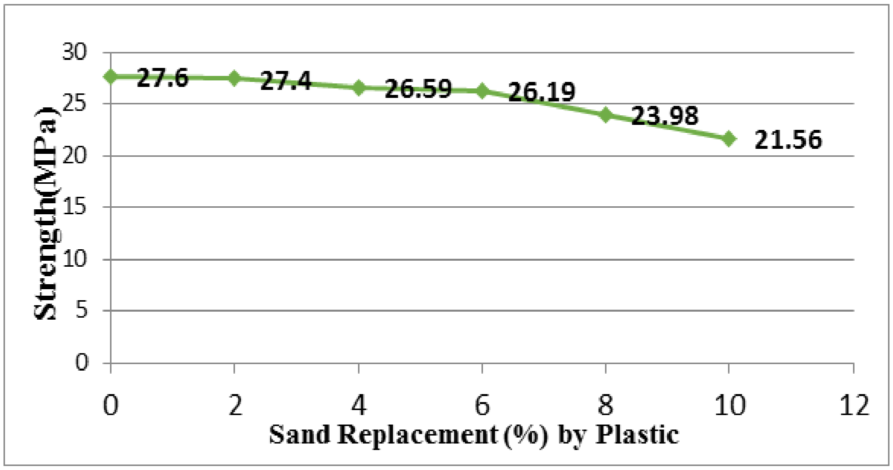


Figure 25 Compressive Strength of Concrete on the 7th day

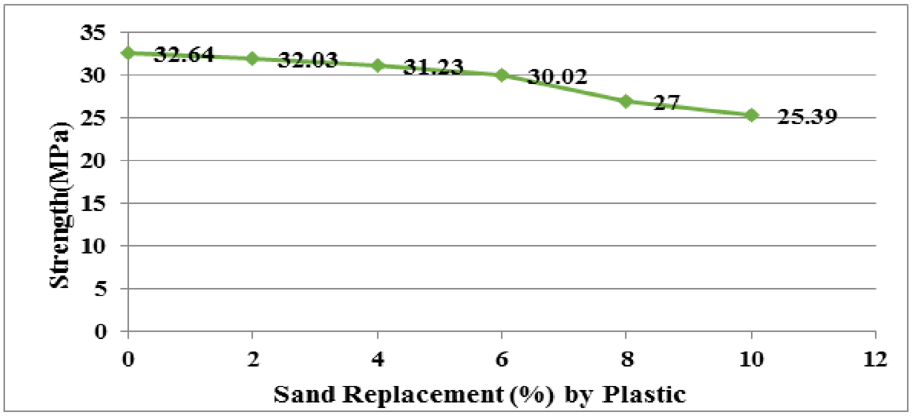


Figure 26 Compressive Strength of Concrete on the 28th day

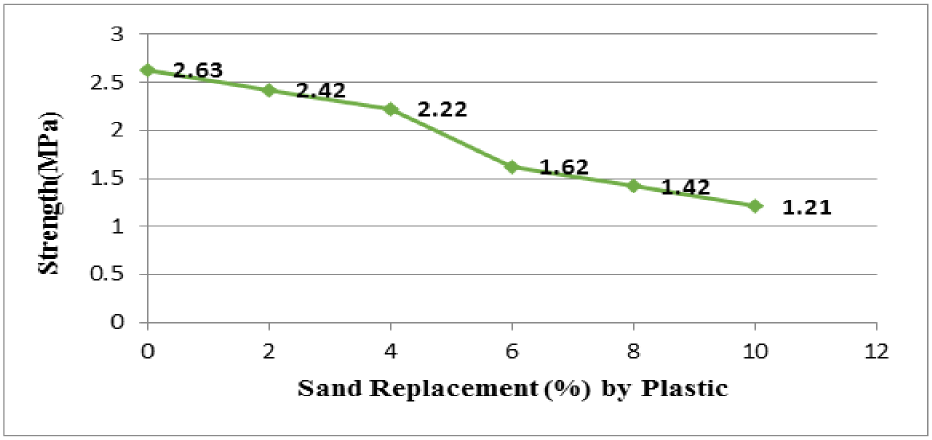


Figure 27 Tensile Strength on the 7th day

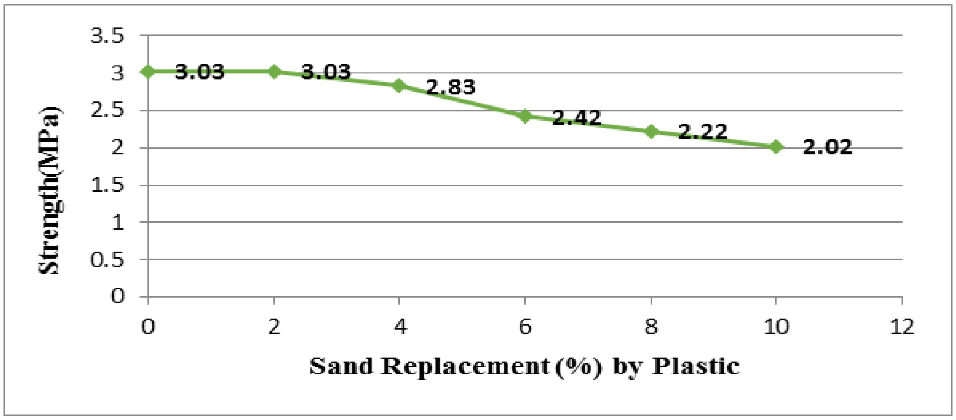


Figure 28 Tensile Strength on the 28th day

4.15 Crushed Plastic Waste in Concrete

The structural characteristics of concrete, the exposure circumstances, and the concrete process are all aspects to consider while creating the mix. The researchers used crushed plastic wastes to partially replace natural coarse aggregate in concrete to measure the material's performance on a mechanical properties scale. M40 grade concrete is produced with plastic waste replacing 10, 20, and 40% of the crushed stone aggregate, and several tests are made to measure the specimen's workability, compressive strength, and flexural strength. The experiments show that concrete with 10% plastic aggregate replacingces coarse aggregate has compressive strength approximately equivalent to normal concrete, but the flexural strength of the concrete decreases due to the waste plastic's low bonding ability. Table 19 compares the compressive strength of 7 days and 28 days in various replacement percentages [15].

Table 19 Compressive Strength of Concrete

% Of Waste Plastics (Replacement for Coarse Aggregates)	7 days (N/mm2)	28 days (N/mm2)
0	34.76	53.14
10	29.65	48.84
20	27.41	45.32
30	24.57	42.18

The stress of the material before it yields in a flexure test is defined as flexural strength, also known as the modulus of rupture. Table 20 compares the flexural strength of 7 days and 28 days in various replacement percentages.

Table 20 Flexural Strength of Concrete

% Of Waste Plastics (Replacement for Coarse Aggregates)	7 days (N/mm2)	28 days (N/mm2)
0	3.58	5.26
10	3.47	5.12
20	3.23	4.89
30	3.17	4.26

4.16 Evaluation of Strength and Durability of Waste Plastic Mix Concrete

Mechanical parameters such as the compressive strength of cubes and cylinders, split tensile strength, and flexural strength was studied. The design mix for M20, M25, and M30 grade concrete was created according to IS 10262:2009, based on experimental mixtures with varying constituents. The shredded plastic trash is added to the concrete at a rate of 15% by volume, which would be the optimum amount without causing significant strength loss. The different specimens were cast according to the test requirements. The specimens were tested after 28 days of curing. For each test, three examples were cast, and the average results were recorded. Three samples should be tested in each category [16].

The strength and durability properties of waste plastic mixed concrete with and without fibers were examined. The tested durability properties were within the code-mandated limitations for typical concrete. The addition of polypropylene fibers could somewhat compensate for the drop in compressive strength caused by waste plastic in conventional concrete. This research indicates that plastic waste mix concrete could be a valuable cementitious compound with superior durability to regular concrete [16].

Compressive strength

The compressive strength of normal concrete (NC), waste plastic mix concrete (WPC), and polypropylene fiber reinforced waste plastic mix concrete (PFR-WPC) parts were tested to see how they behaved in compression. The samples were prepared and tested by IS 516-1959. The specimens, which were 150 150 150 mm in size and cured for 28 days compressive strength, were cast using the specified mix proportions. The test was carried out using a compression testing machine loaded at an 11 kN/sec rate. The force was gradually increased, and the maximum load applied to the specimen was recorded. The compressive strength of the sample was calculated by dividing the most significant load by the cross-sectional area of the sample. The compressive strengths of conventional concrete, waste plastic mix concrete, and polypropylene fiber reinforced waste plastic mix concrete are shown in Figure 29.

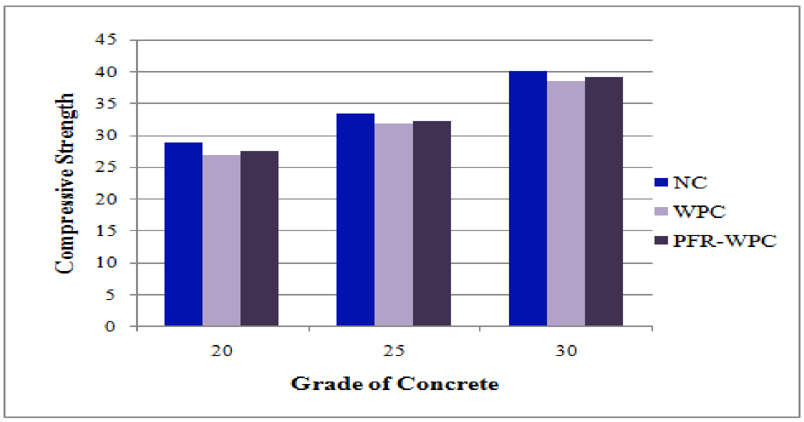


Figure 29 Compressive strengths

Tensile strength

This test was used to investigate the behavior of normal concrete (NC), waste plastic mix concrete (WPC), and polypropylene fiber reinforced waste plastic mix concrete (PFR-WPC) elements in tension tests. At 28 days, the split tensile strength test was performed on cylinders measuring 150Φ x 300mm, checking IS 5816-1970. The sample was placed on the compression testing machine testing platform. At the top and bottom, two packing strips of 3 mm thick metal wire are placed. The load was applied consistently until it broke, and the load was recorded. The split tensile strength of NC, WPC, and PFRWPC is shown in Figure 30.

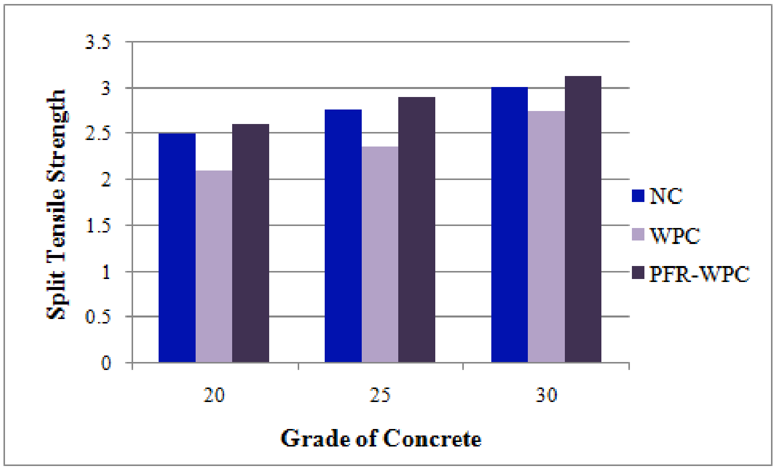


Figure 30 Tensile strength

Flexural strength

To understand the changes of beams and other flexural members after cast with normal concrete (NC), waste plastic mix concrete (WPC), and polypropylene fiber reinforced waste plastic mix concrete (PFR-WPC), flexural strength tests were performed on prisms of size 100 × 100 × 500 mm at the age of 28 days. The sample was put on the international testing equipment, and hydraulically two-point loading was applied, increasing till collapse. The flexural strength of (NC), (WPC), and (PFR-WPC) is shown in Figure 31.

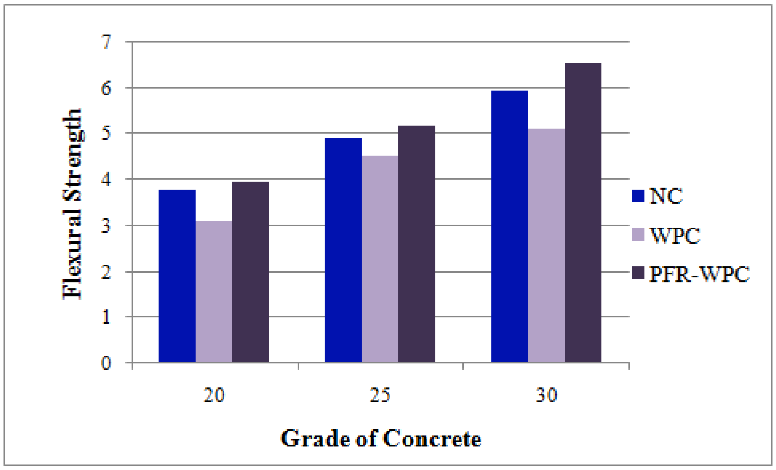


Figure 31 Flexural strength

4.17 Study of Strength Properties of Waste Plastic Fiber Reinforced Concrete

The strength qualities of concrete when waste plastic fibers are added in various percentages are studied. When waste plastic fibers are added to different ratios of cement, such as 0%, 1%, 2%, and 3%, concrete strength attributes such as compressive strength, tensile strength, and flexural strength have been discovered. Locally accessible fine and coarse aggregates were employed in the test. The waste fibers are chopped into strips with a width of 3 mm and around 5 mm. The actual ratio was set at 35. The proportions of the concrete mix were 1:1.5:3 [17].

A direct split tensile test was performed on a tensile strength sample with 150mm dia and 300mm length. The compressive strength samples were 150mm X 150mm X 150 mm in volume. The example for flexural strength was 100mm X 100mm X 500mm in volume. During the experiment, two points loading was applied for 400 mm [17].

The concrete elements, namely cement, sand, and coarse aggregates, were mixed in dry form in the proportions of 1:1.5:3. The mix was homogeneously blended after the needed amount of water was supplied. The concrete mixture was poured into the mold layer by layer, and adequate compaction was achieved using both a hand and a table vibrator. During the experiment, two points loading was applied for 400 mm. The molds and samples were placed in a curing tank after 24 hours and kept curing for 28 days. These samples were put to the test after 28 days of curing.

Table 21 Test of compressive strength

% Of waste fibers	Compressive strength Mpa
0	22.21
1	23.11
2	24
3	25.03

Table 22 Test of tensile strength

% Of waste fibers	Tensile strength Mpa
0	4.24
1	4.95

2	5.37
3	5.8

Table 23 Test of flexural strength

% Of waste fibers	Flexural strength Mpa
0	5
1	5.8
2	7
3	8.24

Compared to normal concrete, the compressive strength rises by roughly 13%. As the ratio of waste plastic fibers in normal concrete increases, tensile and flexural strength improves by 38 and 65 %, significantly.

4.18 Use of Plastic Aggregates in Concrete

Following 7, 14, and 28 days of cure, samples were evaluated after casting. The procedure used to test samples for different attributes such as compressive strength, split tensile strength, and flexure strength was discussed in this study. The IS:10262-2009 standard has been used to produce the concrete mix. A design mix for M25 grade and concrete was created, and trial mixes to test the mix design and alter the additive and water-cement ratio. The combined proportions were used to cast all the samples. The relevant amounts were calculated and then blended for these mixed proportions. The cement content was increased by 10% by weight [18].

Plastic was added to concrete in proportions of 0, 2.5, 5, 7.5, and 10% in place of coarse particles. On the research-based results of this investigation, When the flexural strength of the beam was tested, it was discovered that it collapsed in the loading span between its two supports. Hence the formula utilized was 3PL/4bd2. During the experiment, it was found that adding 2.5 % plastic coarse particles to concrete improves compressive strength initially, but that adding more plastic coarse aggregates reduces strength. At 2.5 % plastic coarse aggregates, the best compressive strength is achieved. Compared to other strengths, the cylinder's tensile strength provides higher outcomes. The outcome of flexural strength is comparable to that of compressive strength [18].

Compressive strength

The experiment was carried out on conventional cubes measuring 150mmX150mmX150mm. A mix of concrete in various quantities was produced and poured into a cube mold. The initial configuration was then left for 24 hours. Nine samples were prepared for each mix proportion, with three samples for every 7 days, 14 days, and 28 days of testing. The samples were evaluated using Compression testing equipment once the curing phase was completed. A constant loading rate of 5.2 KN/sec was used, as shown in the table below.

Table 24 Compressive strength after 7, 14, and 28 days

	Compressive Strength test of concrete (N/mm2)		
NO. of mix	7 days	14 days	28 days
1	21.23	27.61	30.57
2	22.57	27.93	30.63
3	20.42	27.1	29.86
4	19.68	26.4	29.07
5	18.84	25.98	28.74

Tensile strength

The tensile strength is determined by placing it in a compressive test machine with the compressive force acting horizontally. Because of the tension created in the lateral direction, the failure happens along the vertical axis. It was also tested for 7, 14, and 28 days. The loading rate was 2.1 KN/sec, as shown below.

Table 25 Tensile strength after 7, 14, and 28 days

	Tensile strength test of concrete (N/mm2)		
NO. of mix	7 days	14 days	28 days
1	2.01	2.72	2.98
2	2.47	2.86	3.12
3	2.51	2.91	3.19

4	2.33	2.79	3.04
5	2.1	2.68	2.97

Flexure strength

The beams are subjected to a flexure strength test. A compressive test machine was used to put the beams through their paces. It has a four-point load configuration, with two on the bottom and two on the top. The loading rate was 0.1 KN/sec.

Table 26 Flexure strength after 7, 14, and 28 days

	Flexure strength test of concrete (N/mm2)		
NO. of mix	7 days	14 days	28 days
1	4.09	5.47	6.01
2	5.12	5.61	6.19
3	4.02	5.37	5.98
4	3.95	5.28	5.91
5	3.89	5.21	5.84

4.19 Properties of Concrete by the Addition of Plastic Solid Waste

This research aimed to observe partial replacement of aggregate with recycled plastic solid waste affected the characteristics of concrete. The highest packing density of aggregate is obtained by altering the sizes of recycled plastic aggregate, and different tests are conducted to establish the workability, compressive strength, tensile strength, and thermal analysis of the concrete. The research results of the experiments show that as the amount of plastic aggregate in concrete rises, the compressive strength of the concrete goes down, as does thermal conductivity, and the temperature of the concrete with plastic aggregate is lower than that of the nominal concrete. It has been discovered that as the water-cement ratio is increased, the workability of concrete improves, yet if the percentage of plastic aggregate grows, the workability of concrete decreases [19].

Concrete compressive strength is measured at different water-cement ratios, such as 0.4, 0.45, and 0.50. Three cubes are ready with concrete and plastic concrete should be created, and the average results should be taken. Figure 32 shows the compressive strength of control and plastic concrete for varying amounts of plastic.

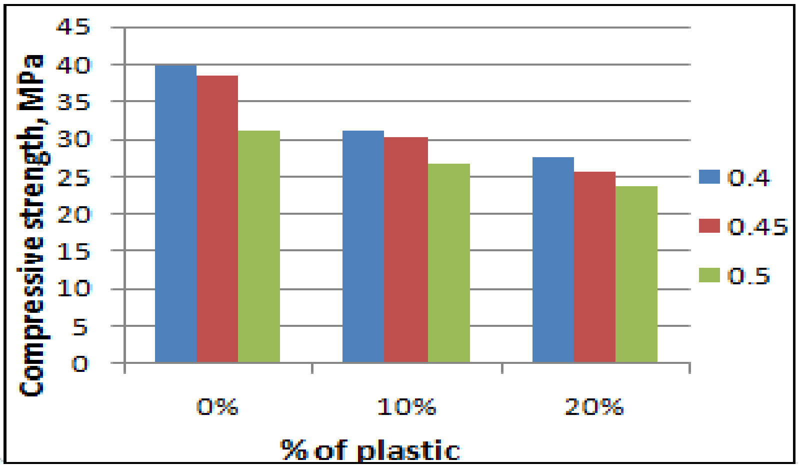


Figure 32 Compressive strengths on the 28th day

Testing the concrete specimen at 28 days showed the tensile strength for different amounts of plastic in control and plastic concrete. Figure 33 shows the tensile strength of management and plastic concrete for different amounts of plastic.

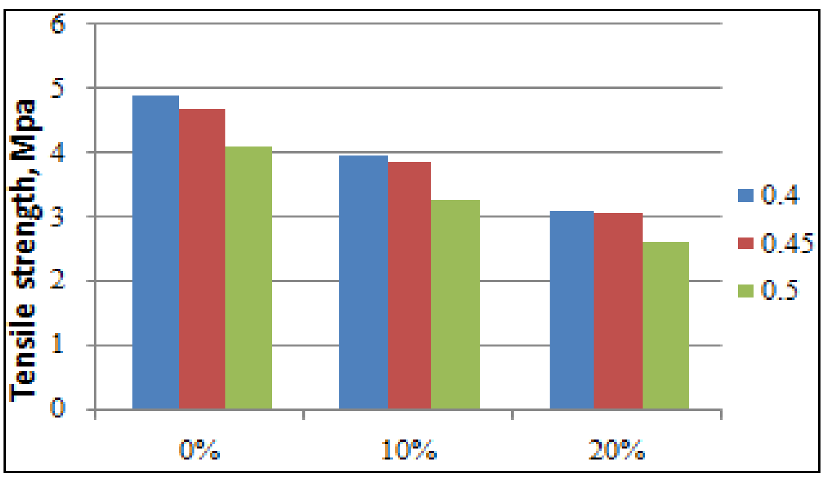


Figure 33 Tensile strength on the 28th day

4.20 Use of Recycled Plastic Bag Waste in The Concrete

The researchers conducted experiments to see if recycled plastic bag wastes are used as a fine aggregate replacement in concrete. The compressive strength, flexural strength, and ultrasonic pulse velocity of concrete specimens prepared with 10%, 20%, 30%, and 40% replacement of fine aggregate with recycled plastic aggregate are examined. The findings revealed that adding plastic sand to concrete improved its workability. In addition, the ultrasonic pulse velocity test demonstrated that when plastic aggregate is used to substitute fine aggregate in concrete, the density of the concrete reduces [20].

The research finds that using plastic aggregate waste as a fine aggregate substitute in concrete results in a considerable reduction in mechanical strength development. The study focuses on two possible reasons for reducing concrete strength properties. The low roughness of plastic aggregate reduces bonding between grains and cement paste. Its circular shape increases void volume in the mortar, reducing concrete density, and plastic has a lower load-carrying capacity than natural sand.

The circular shape of waste increases the void volume in the mortar, reducing compactness. At 28 days, the flexural strength and compressive strength are tested. Each mechanical property value in the following article is the average of three tests performed on three different specimens. Figures 41 and 42 show the improvement of concrete's compressive and flexural strengths, respectively. The observes a decrease in mechanical strength in response to an increase in the ratio of plastic bag waste in the concrete to remains consistently near to this last for the cases of 10% and 20% when compressive strength falls by roughly 10% and 24%, respectively at 28 days. In this study, concrete replacing natural aggregate at a replacement level of 20% showed up to 72% losses in compressive strength compared to control mixes [20].

The decrease in concrete compressive strength could be attributable to either a poor bond between the cement pastes and the plastic bag wastes or the plastic waste’s low strength. The low roughness of waste returns adhesion between the grains and cement paste, and the circular shape of waste increases the void volume in the mortar, reducing compactness. The fracture surface of concrete prismatic, on the other hand, revealed that most of the plastic wastes are not removed and remain lodged in the specimens.

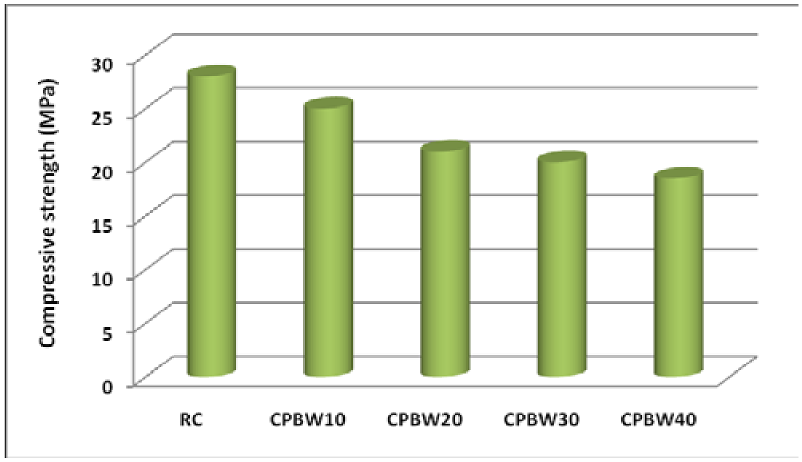


Figure 34 Compressive strength as a function of plastic bag waste content

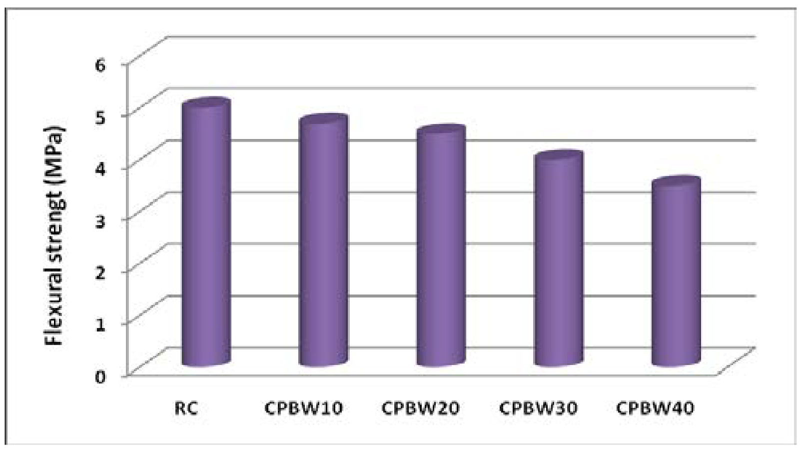


Figure 35 Flexural strength as a function of plastic bag waste content

4.21 Effect of Mix Parameters on the Strength Performance of Waste Plastics Incorporated Concrete Mixes

The researchers seek to see how the partial replacement of coarse aggregates with waste plastics affected the mechanical qualities of different concrete mixes. Compressive strength, split tensile strength, workability, and flexural strength qualities of concrete with plastic are made and tested for 10 percent, 20 percent, and 30 percent substitution of coarse aggregate by waste plastic. The results show that concrete mixtures using up to 30% plastic waste as coarse aggregate are acceptable. The workability tests revealed that when the proportion of plastic in the concrete increases, the water demand of the mix increases by 1.5 percent for every 10% increase in plastic content [21].

Figure 36 shows the results of compression experiments. For equivalent strength values for 150mm cube specimens, the strength values of 100mm cube specimens were rectified by multiplying with a factor of 0.9. Another result was acquired empirically. With an increase in the amount of waste plastic replacement, the compressive strengths of these combinations tend to decrease. For 10, 20, and 30% replacement of waste plastic, the average percentage drop in strength is 2.3, 7.8, and 13.6%, respectively. Even though there is a continuous strength loss, all the mixes have achieved appropriate compressive strengths ranging from 30 to 35 MPa. The distribution of waste plastic particles was visually evaluated on the rupture surfaces of all test specimens after failure under compression testing. The plastic particles were found to be evenly dispersed throughout the concrete matrix. The cubes failed in a trapezoidal pattern, typical of trapezoidal failure.

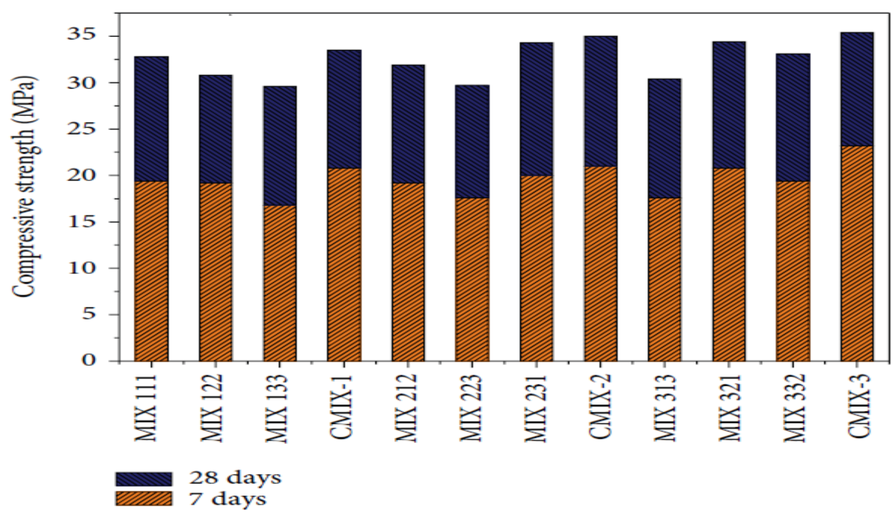


Figure 36 Different mixtures have different compressive strengths

Figure 37 shows the split tensile and flexural strengths of waste plastics integrated concrete mixes. These mixes have lower flexural and split tensile strengths as expected, compared to equivalent blends with crushed granite rock chips aggregates only. Flexural strength losses are less significant than split tensile strength declines. The loose binding qualities of waste plastic coarse aggregates with the cement paste account for the reduced tensile strength. Low strengths could also be due to a weak transition zone in waste plastic coarse aggregates.

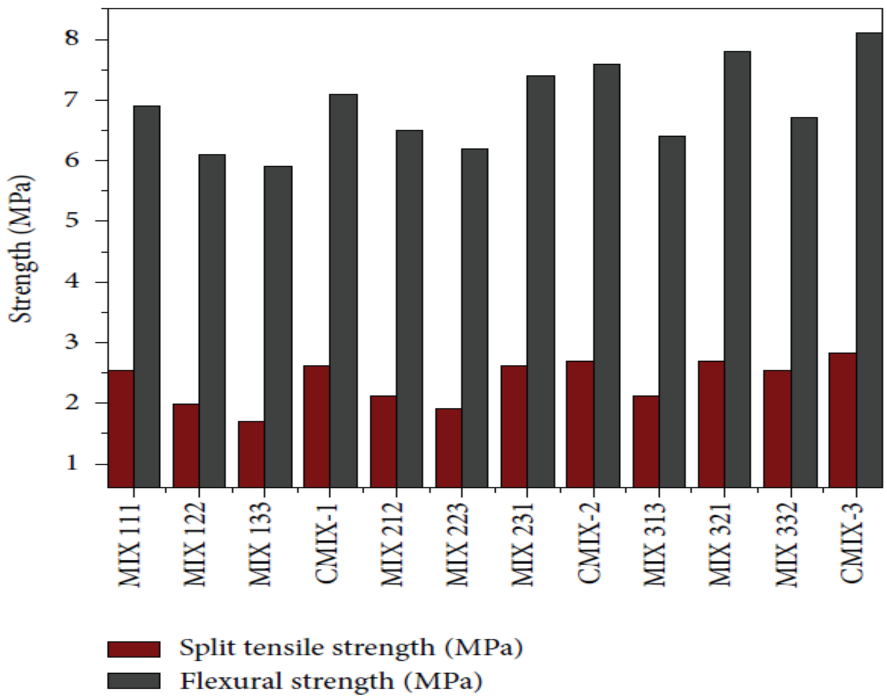


Figure 37 Split tensile and flexural strengths

For each mixture, the total reductions in various strengths were calculated. Table 32 summarizes the percentage decreases in compression strengths, split tensile strengths, and flexural strengths of the mixtures. The strengths of each of the three mixes are compared to the control mix. The strengths of the first set of mixes, MIX 111, MIX 122, and MIX 133, for example, are compared to CMIX-1 as a benchmark. Similarly, CMIX-2 and CMIX-3 are used to compare the second and third sets of mixes, respectively.

Table 27 Strength decreases as a percentage

	% Reduction in strength at 28 days of testing		
Mix designation	Compressive strength	Flexural strength	Split tensile strength
MIX 111	2.1	2.3	2.76
MIX 122	8.1	14.6	24.37
MIX 133	11.6	16.4	35.17
MIX 212	8.9	14	21.07
MIX 223	15.1	18.4	28.97
MIX 231	2	2.6	2.66
MIX 313	14.1	21	24.98

MIX 321	2.8	3.7	14.97
MIX 332	6.5	18	4.97

4.22 Strength Analysis of Concrete by Using Plastic Waste

The cement qualities used in this inquiry and the Ordinary Portland Cement of Grade 43 were used in this experimental examination. This experiment was conducted with natural river sand. This goes entirely through a sieve with a 4.75 mm aperture size. Coarse aggregates with a 20 mm sieve size were employed in this investigation and are locally available. In this experiment, polyethylene terephthalate waste plastic was used. Plastic waste was collected from glucose and water bottles that were readily available in the area, and this plastic was used for packaging purposes [22].

In this experiment, cast concrete cubes are subjected to various tests to determine the strength and other qualities of the concrete. The main goal of the experimental analysis is to look at the concrete's developed strength on various testing days after curing. In general, appropriate concrete casting and curing will increase the concrete's strength. Each test is carried out with three samples for each mixing ratio and tested at the required curing time for this project. The average values are then used to conduct the investigations [22].

The compressive strength test shows that the concrete is weak in tension but strong in compression, indicating that the concrete must be strong to achieve high compression. The compressive strength test determined how much compressive load a concrete can withstand while staying below the fracture limit. Three samples of each mix were evaluated in this investigation, and the average strength was compared to the nominal mix of M25 Mix. Table 28 shows the results of compressive strength testing at the 7 days and 28 days.

Table 28 Compressive Strength of Concrete M25 Cubes

Percentage Replacement of Waste Plastic bottles	Compressive Strength (N/mm2)	
	7 Days	28 Days
0%	22.64	33.03
1%	23.28	33.98

2%	22.74	33.16
3%	21.99	31.87
4%	19.87	30.26
5%	18.16	28.73

The slump cone test is used to ensure that recently cast concrete is workable. This test was carried out independently on recently cast concrete with fine aggregates replaced with waste plastic bottles to determine workability. The slump is extremely useful for detecting differences in the consistency of a mix with given nominal proportions. Figure 38 shows the slump variations.

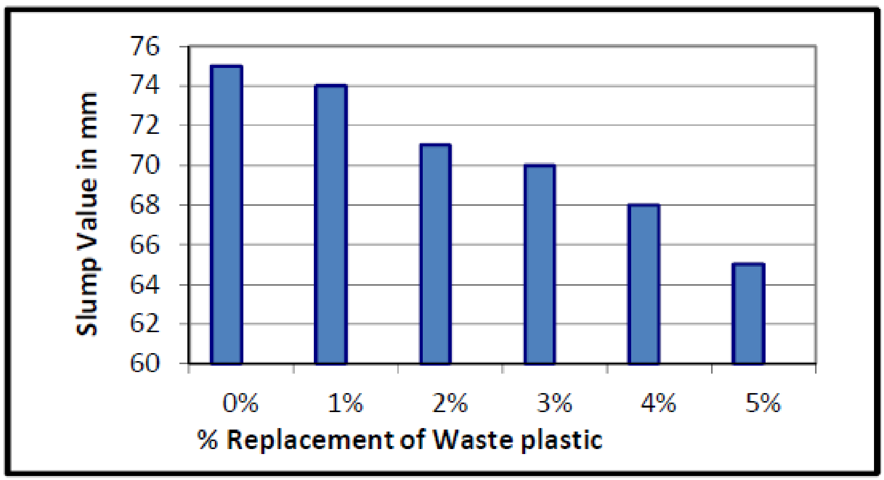


Figure 38 Slump test value

4.23 Experimental Investigation on Recycled Plastics as Aggregate in Concrete

The characteristics of various concrete mixes were evaluated to a control concrete mixture with a mass ratio of 1:2:4 and a water/cement ratio of 0.5. To make four more samples, recycled plastic was utilized to replace 25 %, 50 %, 75 %, and 100 % of crushed granite by capacity. Made steel molds measuring 150 mm x 150 mm x 150 mm was used to make concrete cubes. The compacting factor experiment, performed in trend with BS 1881, was used to determine the workability of fresh concrete [23].

On the 7, 14, 21, and 28 days of cure, a 1500 kN Matest compression machine evaluated the compressive strengths of concrete. The compressive strength of concrete goes down as the quantity of recycled plastic in the mix grows, although the workability of concrete did not vary appreciably.

Recycled plastic waste can theoretically replace less than 36% of crushed granite manufacturing reinforced concrete. Concrete completely replacing crushed granite with recycled plastic waste is not structurally sound. According to the study findings, recycled plastics can be utilized to replace granite up to 33% in the production of normal-weight concrete [23].

Compressive Strength

In Table 29, the results of the compressive strength tests are presented. The compressive strength of concrete was enhanced with each replacement as the concrete aged. Concrete's compressive strength decreased as the replacement increased at all ages. The excellent bond between the cement paste and the aggregates determines the strength to an incredible amount. The specific surface area grew as the percentage of recycled plastics grew. As a result, additional cement paste was needed to link with the recycled plastics. The bonding was insufficient to accommodate the increased surface since the cement content was kept the same. As the percentage of recycled plastics in the mix grew, the compressive strength decreased. The 28-day strengths of concrete with 50 %, 75 %, and 100 % crushed granite replaced by recycled plastic ranged from 5 to 19.5 Nmm–2.

Table 29 Compressive strength (Nmm-2)

% Of Replacement	days			
	7	14	21	28
0	22.3	23.36	23.97	24.64
25	19.53	21.12	21.36	21.39
50	13.4	14.3	14.57	15.21
75	6.62	6.79	7.26	7.34
100	5.34	5.41	5.59	5.74

Workability

Many factors affect the workability of concrete, such as water content, cement content, aggregate grading, and characteristics. The outcome of the compacting factor test is shown in Table 30. Table 30 shows that as the amount of granite replaced by recycled plastics grew, there was no noticeable decrease in workability.

Table 30 Compacting Factor Test

% Of Replacement	0	25	50	75	100
compacting Factor	0.87	0.84	0.84	0.81	0.84

4.24 Experimental Investigations on Concrete With E-Plastic Waste

The cement was utilized as standard Portland Cement-53 grade, which complied with IS:12269, 1987. As a coarse aggregate, crushed granite stone aggregate and e-plastic waste with a maximum size of 20 mm were employed. Fine aggregate was made from naturally accessible fine sand. According to the tests, the bulk density and specific gravity of e-plastic waste were around 4.58 and 2.54 times fewer than the natural coarse aggregate. The concrete mixture proportions were calculated according to IS: 10262:2009. Depending on several trail mixtures, a cement concentration of 380kg/m3 and a water-cement ratio of 0.53 were chosen to produce an intermediate degree of workability [24].

It was discovered that using E–Plastic waste as coarse aggregate has no significant impact on the workability of concrete. It could be because of the E-Plastic waste aggregate's clean surface and sliding textures, reducing the internal friction between the mortar and the e-plastic waste aggregate. The workability of concrete is unaffected by using e-plastic waste as coarse aggregate. Using e-plastic waste as coarse aggregate in the mix has no effect on concrete's compressive and tensile strength up to 10% substitution for a certain cement content w/c [24].

Compressive Strength

Figure 39 shows the compressive strength of concrete measured at 7 and 28 days. At different periods, the compressive strength achieved ranged between 16 MPa to 31 MPa. According to experimental reports, compressive strength grew significantly up to 10% of e-plastic waste and dropped to 20% of e-plastic waste. Compared to the standard mixture, the percentage drop in compressive strength was around 20% and 18% at 7 and 28 days. The above pattern was observed in people of all ages. The chemical nature of plastic waste, the effect of reducing water movement, and the significantly reduced bond strength between the surface of the plastic waste and the cement paste are two factors responsible for the minimum compressive strength of concrete.

The compressive strength of concrete containing 10% e-plastic waste aggregate matches the required strength values for M20 grade concrete. At the end of 28 days, the compressive strength of around 31 MPa was achieved using 10% e-plastic waste.

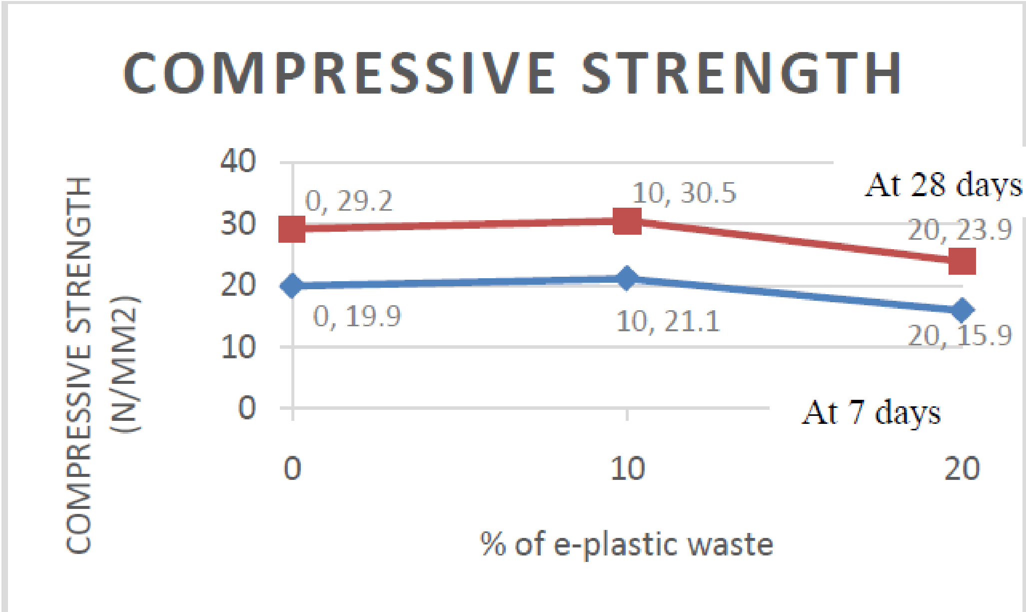


Figure 39 Compressive Strength Test

Tensile Strength

Figure 40 shows the split tensile strength of concrete with up to 20% e-plastic waste aggregate at 28 days. Concrete's splitting tensile strength ranges from 2.68 MPa to 3.43 MPa on average. The creation of e-plastic waste significantly improves the splitting tensile of concrete roughly to 10% and reduces it above 10%, equal to the characteristic of compressive strength. The factors that contributed to the drop in splitting tensile strength were comparable to those that reduced in compressive strength of plastic aggregate concrete. According to investigators, the properties of the interfacial changeover boundary affect the splitting tensile strength of concrete, so the shape of the plastic particles and free water gathered on the exterior of the plastic aggregate may result in a lower bonding among both the PVC granules and the cement paste.

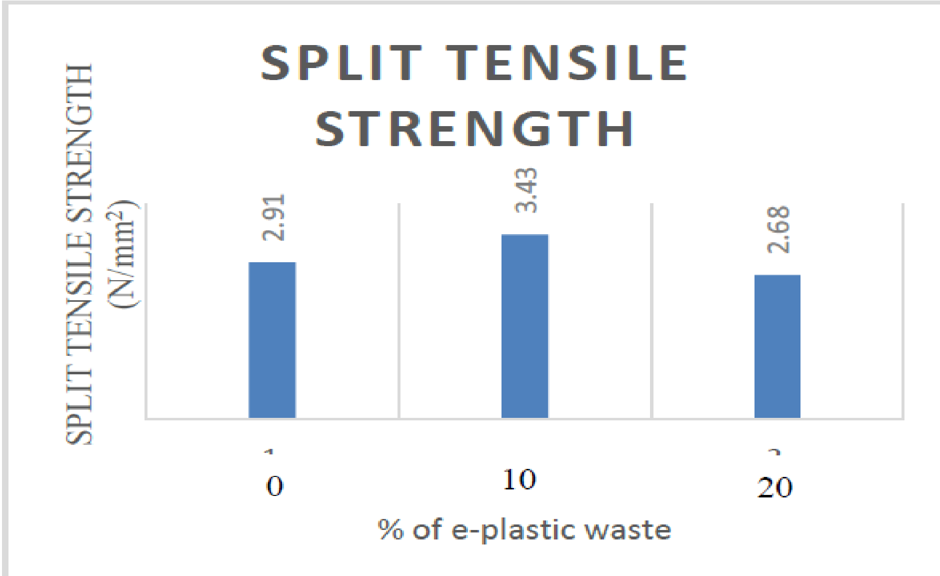


Figure 40 Tensile Strength for different replacement e-plastic waste

4.25 Strength Variations in Concrete by Using E-Waste as Coarse Aggregate

This research aimed to determine the most impactful methods for repurposing rigid plastic waste granules as coarse aggregate. In a traditional mix, the E-Waste content is estimated on a mass basis as coarse aggregate. 6.937 is the fineness modulus of coarse aggregate with various E-waste contents [25].

The granular sizes of the split granules are estimated to be around 10mm and 20mm. Therefore, the E-Waste granules can be used as a partial coarse aggregate substitution, with the whole mix ratio staying unchanged. The grade M30 concrete mix strength standards were investigated. The compressive strength tests were performed to analyze the strength improvement of concrete containing varying E-waste contents at 7, 14, and 28 days. Cylindrical specimens were also molded to determine the tensile strength of models after 7, 14, and 28 days for each mix specification, using normal test protocols [25].

Compressive Strength

When 15% of the coarse aggregate is replaced with E-Waste, the compressive strength of concrete is determined to be optimal. Further than that, the compressive strength starts to deteriorate. Figure 41 shows the differentiation of the strength.

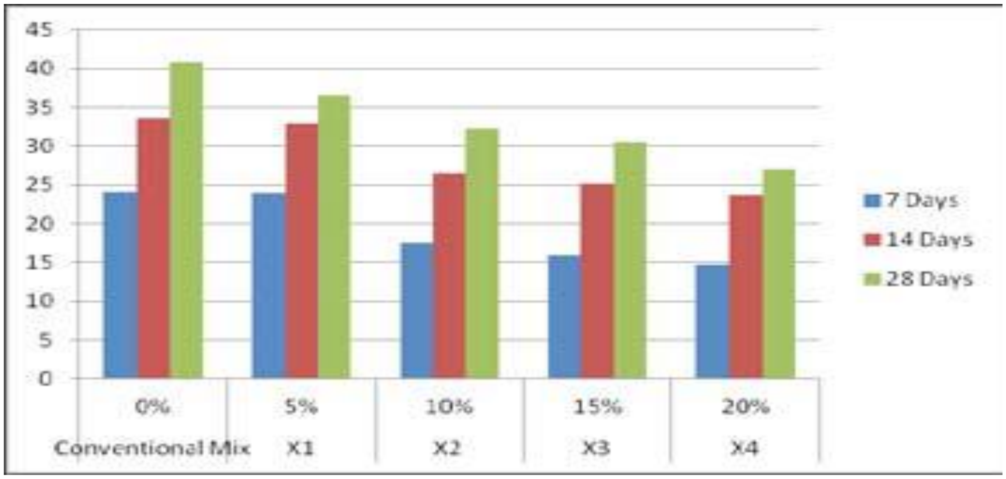


Figure 41 Compressive strength

Tensile Strength

When coarse aggregate is replaced with 20% E-waste, and the results are compared to conventional concrete at 28 days strength, it is discovered that the strength of the concrete is dropped by 33.7 %. Figure 42 explains this.

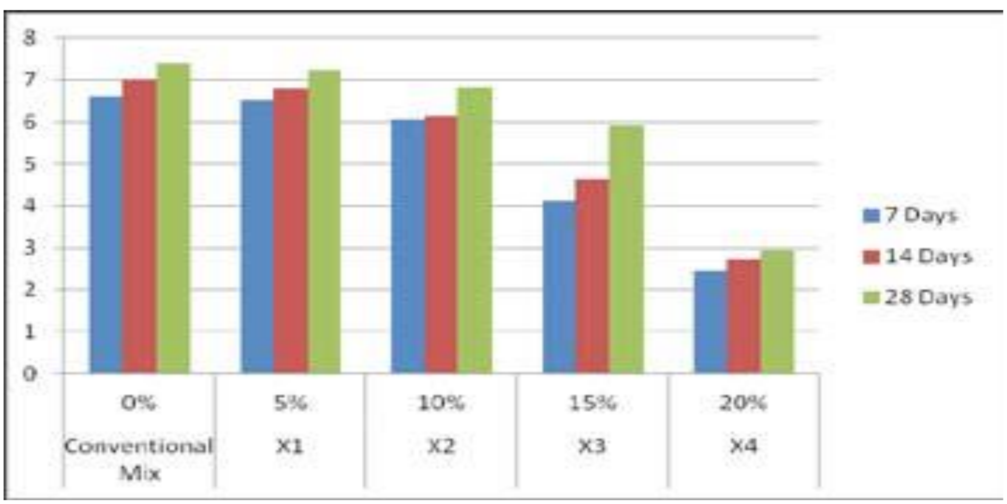


Figure 42 Tensile Strength Results

4.26 Experimental Investigation on The Properties of Concrete Containing Post-Consumer Plastic Waste as Coarse Aggregate Replacement

The research investigation discovered that replacing coarse aggregate with plastic waste substantially impacts concrete strength properties. Compared to control samples, the fresh unit weight of concrete samples with plastic waste was reduced by 4%. Many significant, concrete samples including plastic debris, had lower compressive strengths than the control sample. When compared to control concrete, the compressive strength of 10 % polyethylene terephthalate (PET), 10 % high-density polyethylene (HDPE), and 5 % PET + 5 % HDPE substituted concrete specimens was reduced by 35 %, 48 %, and 40 %, significantly [26].

According to the outcomes of the tests, polyethylene terephthalate (PET) plastic has a little stronger compressive strength over high-density polyethylene (HDPE). Furthermore, the splitting tensile strength values for 10 % HDPE and 5 % PET + 5 % HDPE substituted concrete test samples were reduced by 37% and 7%, correspondingly. In comparison, the test result for the 10 % polyethylene terephthalate (PET) concrete sample was raised by 21% compared to the control sample. According to the discoveries of the tests, it is recommended that polyethylene terephthalate (PET) plastic waste be used in concrete to increase the material's tensile properties [26].

Compressive Strength

The evaluation of compressive strength experiment results between the control sample and concrete with various percentages of plastic is shown in Figure 43. It shows that concrete composed of polyethylene terephthalate (PET) plastic is better during compression than concrete consisting of high-density polyethylene (HDPE). Compressive strength range for 10 % PET, 10 % HDPE, and 5 % PET +5 % HDPE substituted concrete samples were reduced by 35 %, 48 %, and 40 %, however, compared to control concrete shown in figure 50.

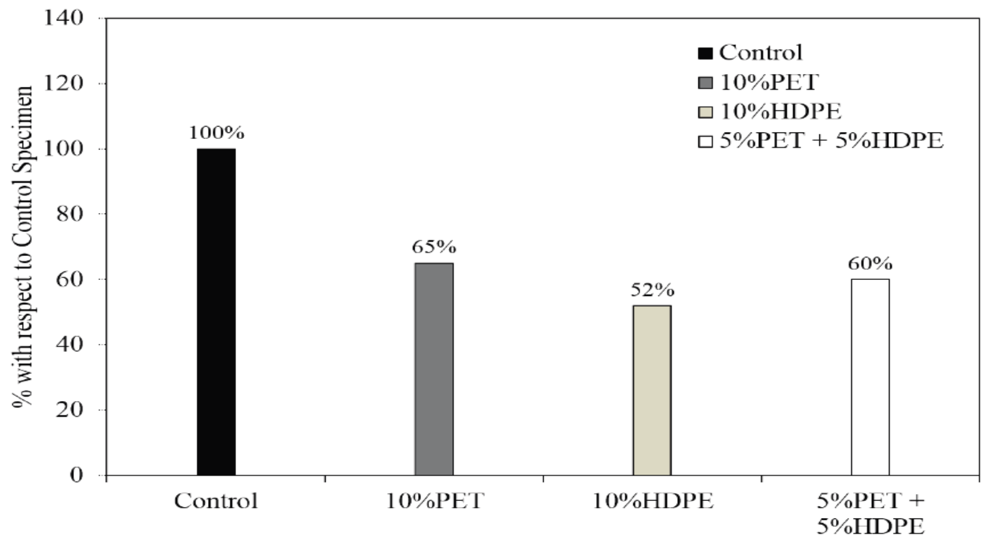


Figure 43 Compressive strength test values for samples

Tensile Strength

Since concrete is prone to tensile breaking because of many impacts and applied loads, tensile strength is important. Therefore, concrete tensile strength is relatively weak when matched to its compressive strength. Because applying uniaxial force to a concrete sample is challenging, the tensile strength of concrete could be evaluated using an indirect test method known as the Split tensile test, which was employed in this work to assess the tensile characteristics of concrete samples. Figure 44 depicts the sample split tensile strength test records after 28 days.

The relative evaluation of splitting tensile strength test results between the control sample and concrete containing various percentages of waste plastic is shown in Figure 45. It shows that polyethylene terephthalate (PET) plastic has a higher tensile strength than high-density polyethylene (HDPE) plastic. Figure 44 shows that the splitting tensile strength range for 10% high-density polyethylene (HDPE) and 5% PET +5% HDPE replaced concrete samples were reduced by 37% and 7%, in both. In comparison, the experiment results for the 10% polyethylene terephthalate (PET) concrete sample were improved by 21% compared to the control sample.

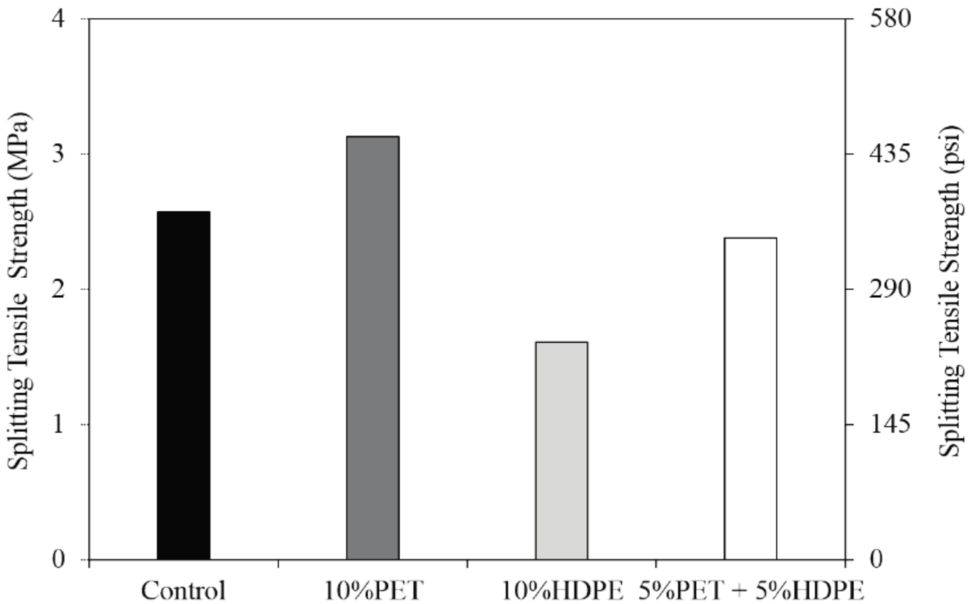


Figure 44 Tensile strength value for samples

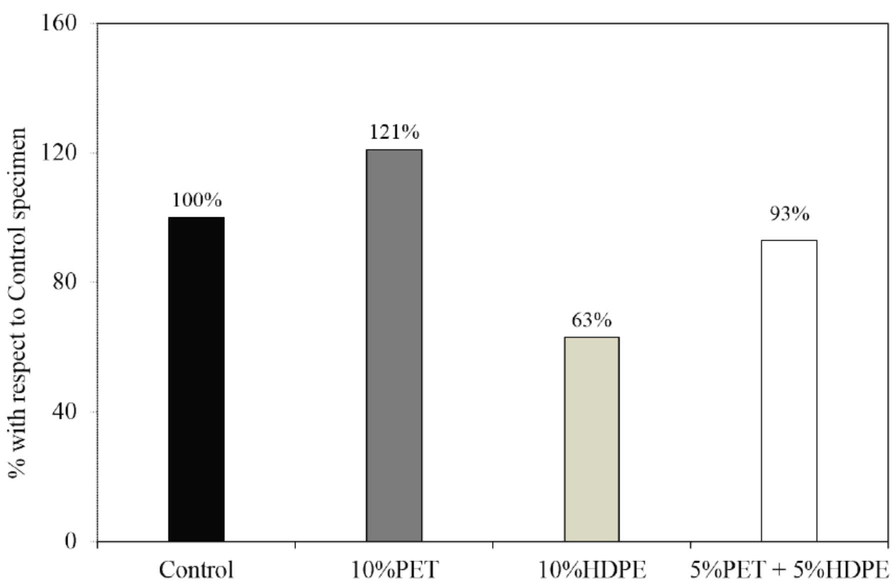


Figure 45 Comparison of tensile strength values for samples

4.27 Effect of Partial Replacement of Coarse Aggregates with E-Waste on Strength Properties of Concrete

According to the research results, E-waste decreases compressive strength at delayed ages but enhances flexural strength; the best replacement ratio of coarse aggregate by E-waste is 10%. The weight of concrete is reduced by 2.5 % for every 5% addition of E-waste. At 10% coarse aggregate replacement ratios, satisfying compressive strength results are obtained. At a replacement ratio of 10%, flexural strength is improved. If E-waste, including HDPE or metal particles, is employed, the compressive strength values may be enhanced. E-waste can be used in structural elements supporting modest tensile pressures since its flexural strength increases [27].

Compressive Strength

Table 31 shows the values of the compressive strength test after 7 days of curing. The control mixture of M30 has an average compressive strength of 24.263 MPa, as shown in Table 31. On the other hand, the mixture, including 10% E-waste, had the maximum strength, 2.93 % higher than the control mix. When E-waste is added over 10%, the product's strength drops. Table 32 shows the findings after 28 days of cure. Table 32 shows that the M30 control mixture has achieved the maximum compressive strength of 34.92 MPa. While 10% of E-waste is introduced, the strength is reduced by 15.29 %. Any addition of E-waste decreases the strength even more.

Table 31 Compressive strength at 7 days

Concrete mix	1	2	3	Average compressive strength (N/mm2)
Mix 0%	22.81	24.06	25.92	24.26
Mix 10%	26.67	20.47	27.78	24.97
Mix 15%	19.92	20.15	22.33	20.8
Mix 20%	17.88	17.99	16.86	17.58

Table 32 Compressive strength at 28 days

Concrete mix	1	2	3	Average compressive strength (N/mm2)
Mix 0%	34.27	36.38	34.12	34.92
Mix 10%	28.56	30.56	29.61	29.58
Mix 15%	26.4	25.92	26.33	26.22
Mix 20%	22.73	24.67	23.86	23.76

Flexural Strength

Table 33 shows the values of a flexural strength test after 7 days of concrete curing. The mixture, including 10% E-waste, has the maximum flexural strength, as shown in table 33. Flexural strength was kept up practically at the same level for mixtures including 10% and 15% E-waste but subsequently began to drop. As 10% coarse aggregate is replaced with E-waste, the strength of the mix improves by 8.25 % compared to the control mix. Table 34 shows the results of a flexural strength test performed after 28 days of concrete curing. Table 34 shows that 28 days of flexural strength is the strongest in the mix, followed by 10% E-waste. When E-waste is added over 15%, the strength begins to deteriorate. E-waste makes up 10% of concrete.

Table 33 Flexural strength at 7 days

Concrete mix	1	2	3	Average flexural strength (N/mm2)
Mix 0%	5.8	3.4	2.8	4
Mix 10%	5.8	3.2	4	4.33
Mix 15%	5	4.8	3	4.27
Mix 20%	3.8	3.6	1.6	3

Table 34 Flexural strength at 28 days

Concrete mix	1	2	3	Average flexural strength (N/mm2)
Mix 0%	4	4.6	5	4.53
Mix 10%	5.2	6	5.8	5.66

Mix 15%	5	4.6	5	4.87
Mix 20%	4.2	3.9	4.5	4.2

4.28 Study of Strength Characteristics of Concrete with E-Waste

Based on the research results, E-waste is an acceptable replacement material for sand in concrete that should be used for non-structural purposes. When the percentage of E-waste increases, the self-weight of concrete decreases. According to research, E-waste should be utilized in concrete when additional strength is unnecessary. The split tensile strength and the compressive strength of samples containing E-waste are 18%, 21%, and 33% lower than those of control mix concrete samples. As a result, lightweight concrete incorporating E-waste can be employed successfully [28].

Compressive Strength

The research provided in figure 46 indicates a systematic decrease in compressive strength as the number of E-waste increases. E10, E20, and E30 have lower 28-day compressive strengths than Control Mix by 7.6%, 21.47 %, and 26.11 %, respectively. On 7 days, the strength of Control Mix, E10, E20, and E30 concretes is 42 %, 35 %, 30 %, and 23 % of its 28-day compressive strength. However, as a result, as the amount of fine aggregate replaced by E-waste grows, the value of strength gains drops.

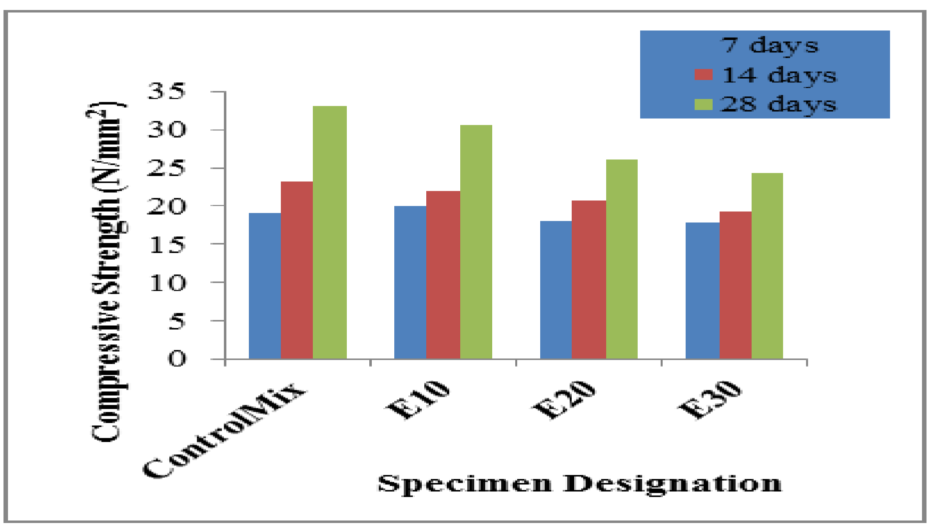


Figure 46 Compressive Strength

Tensile Strength

Figure 47 represents the split tensile strength of E10, E20, and E30 concretes is 1.67 %, 20.98 %, and 38.98 % lower than that of control mix concrete.

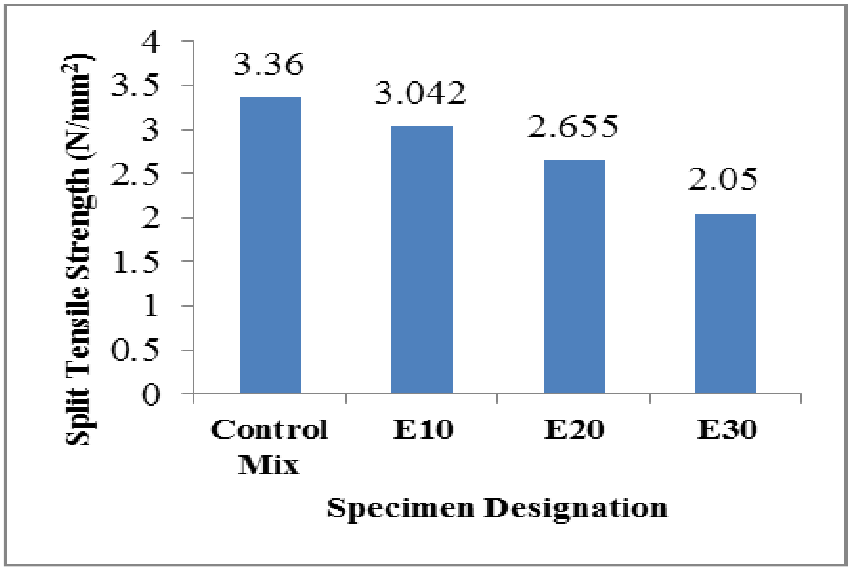


Figure 47 Tensile Strength

Flexural Strength

The flexural strength test determines the ability of an unreinforced beam to prevent bending collapse. It is determined by loading concrete beams measuring 150 mm x 150 mm x 700 mm. Point loading determines the flexural strength, given as the modulus of rupture in MPa. Control mix concrete has a modulus of rupture of 5.60 N/mm2, which becomes more significant than E10, E20, and E30 concretes by 16.67 %, 40.5 %, and 42.86 %, as shown in figure 48.

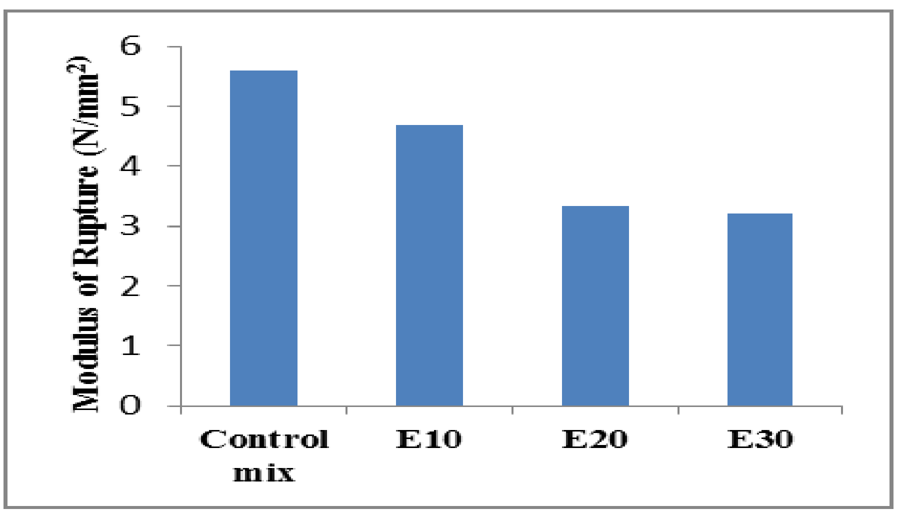


Figure 48 Flexural Strength Test

5. Conclusions and Recommendations

According to the researchers, plastic waste can partially replace normal aggregate. At all curing periods, the compressive strength of all waste plastic concrete combinations tends to fall, the results for the evaluation of concrete mixtures as the waste plastic percentage increases. The flexural strength at every curing period drops as the waste plastic to aggregate ratio increases. Most studies have concentrated on concrete strength features using plastic waste as an aggregate in concrete production. Furthermore, just a few research on the durability of concrete with plastic waste have already been published. It emphasizes the importance of researching concrete's durability qualities, including plastic waste. Among the essential durability variables to examine is the efficiency of the concrete in terms of fire resistance.

Since aggregate grading is so significant in concrete construction, it's necessary to think about how the size and grade of plastic waste affect the strength and durability of the material. Employing plastic waste in granules aggregate form with fine gradations improves concrete density. Thus, using plastic waste in granular aggregate form with acceptable gradations greatly enhances concrete qualities. Plastic waste quantity is growing, which is putting distress on our ecosystem. Because plastic is a nondegradable element, it must be disposed of largely or expensively. As a result, that may use plastic in building construction while reducing our environmental impact.

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