International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Volume 54, Issue 02 and Publication Date: 1st June, 2025
An Indexed, Referred and Peer Reviewed Journal with ISSN (Online): 2319-6564
www.ijesonline.com

A Research Study of Recycled Plastic in Concrete as Replacement of Fine Aggregate

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Abstract- The increasing pollution of land, water, and air has sparked concerns about the serious challenges surrounding the disposal of plastic trash. Only a small portion of solid waste gets recycled because solid waste management systems aren't working properly, which frequently leads to ecological disruption, risks to human health, and harm to animals and marine life. Natural sand, which has been heavily extracted from riverbeds in recent years, is one of the most sought-after commodities in the construction sector.

This has not only led to ecological issues but also to issues like sand scarcity, increased sand prices, and consequently stricter sand mining laws. An environmentally friendly way to solve these issues is to use plastic trash in place of natural sand. Numerous studies have examined the strength characteristics of concrete by substituting plastic trash for aggregate.

This study examines the strength and durability characteristics of concrete by substituting recycled plastic waste in the form of granules for sand (fine aggregate). According to the study's findings, the concrete that was created in this way satisfies the IS code's requirements for strength and durability while also having the potential to reduce costs by utilizing recycled plastic.

KEY WORDS: durability, plastic use, concrete, and sand scarcity.

1. INTRODUCTION-

India produces 15 million tonnes of plastic garbage annually. Only 25% of it is recycled because solid waste management systems aren't working properly. Landfills are burdened as a result. (1) The United Nations Environment Programme recently released a research stating that 400 million tonnes of single-use plastic (SUP) garbage are produced worldwide each year, accounting for 47% of all plastic waste. Only about 9% of plastic is thought to be recycled globally. It's interesting to note that while the majority of plastic garbage produced in India is recycled, the remainder ends up in the environment.

(2) A British science journal article claims that plastics can harm both people and the environment in a number of ways. Human bodies absorb chemicals found in plastics, some of which have the ability to alter the structure of hormones.(3) It is known that around 200 animal species consume plastic waste. It has been noted that eating plastic can cause an animal's stomach to get clogged. (4) A study that was published in Environmental Science and Technology claims that soil contamination by micro plastics is endangering earthworm growth.(5) According to a study in the journal Nature Communications, more than 8 million tons of plastic waste end up in the world's oceans annually. According to a study, there will be as many plastic entities in the world by 2050 as there are fish.

(7) Burning plastic garbage to reduce its volume is one method of disposal. However, since burning plastics releases poisonous gasses, it is not a practical substitute. Toxins from plastic waste and litter can contaminate groundwater, which people drink on a daily basis.

(8) After the US and China, India has the third-largest building industry in the world. Flyovers, offices, homes, and shopping canters have grown up everywhere. Higher construction speeds are currently needed to fulfil the growing needs of the construction sector and begin the operation of significant infrastructure projects early on given the nation's progress. Concrete is the foundation of all construction activities in the country, regardless of location, magnitude, or type. In actuality, each individual on the earth uses around three tons of concrete each year, making it the second most utilized material behind water.

(9 However, the real estate and building industries are always complaining about the severe lack of natural sand. Around the world, beaches and riverbeds are being stripped naked due to the extreme increase in demand for sand. However, imports by themselves won't be enough until laws are effectively implemented and alternative building materials are promoted.

(10) The usage of "manufactured sand" or "artificially crushed stone sand" has increased significantly in recent years as a result of regulatory prohibitions on the mining of river sands. However, the strength and workability of the concrete are impacted since manufactured sand often has a high percentage of micro fine particles as a result of its production process.
(11) It is imperative to give careful thought to the ecological risks posed by careless sand mining and plastic waste. The aforementioned conversations have necessitated the investigation of the viability of substituting recycled plastic for sand in concrete. The strength and durability characteristics of concrete made from recycled plastic are the main focus of this study. Concrete containing plastic aggregate is evaluated for workability, compressive strength, and durability (water permeability). The results show that the concrete produced in this way only meets the requirements of the IS Code.

2. LITERATURE REVIEW

Raghtate A. (12) conducted the study and examined how the use of plastic in concrete affected its compressive and split tensile strengths. In order to conduct the study, different percentages of polyethylene bag pieces were added in increments of 0.2%, 0.4%, 0.6%, 0.8%, and 1%. The compressive strength was affected by an increase in the percentage of plastic, however the pace at which strength was lost was determined to be slower. With 1% plastic, a 20% decrease in compressive strength was noted. Additionally, it was discovered that adding plastic to the concrete somewhat boosted its split tensile strength. The researcher found that while adding more plastic to concrete increases its tensile strength, it has an impact on its compressive strength.

Researchers Mahesh M. et al. (13) investigated the use of polyethylene plastic fibers in concrete. Different proportions of plastic fibers in the concrete—2%, 4%, and 6%—were used in the study. Compressive strength and split tensile strength tests were performed on concrete specimens that had been cured for 7, 14, and 28 days. According to the test results, the proportion of plastic fibers in concrete decreased its compressive and split tensile strengths, but the rate of strength loss was minimal. Concrete's self-weight was found to have decreased. It has been determined that adding plastic fibers to concrete can alter its mechanical qualities by 5% to 10%.

Tamang L. and others (14) the researchers conducted a thorough investigation to look at how using plastic as coarse aggregate affected the mechanical qualities of concrete. Melting the plastic at 150–1800 degrees Celsius allowed it to solidify and crush to the desired size, creating the plastic aggregate. Although 20% plastic aggregate concrete had a good compressive strength, it was 2% less than nominal concrete. According to split tensile strength test results, concrete containing 15% plastic aggregate had a good tensile strength, although it was 30% less than nominal concrete. According to the study's findings, the use of plastic aggregate in concrete maintained its compressive strength while significantly reducing its tensile strength.

Chien C. and associates (15) the study's foundation was the examination of concrete's characteristics using HDPE plastic fine aggregate. The findings of the workability test indicated that concrete's workability decreases as the percentage of HDPE plastic fine aggregate increases. After replacing 10% of the fine aggregate with HDPE plastic aggregate, the workability of the concrete decreased significantly, but the compressive strength and heat absorption of the concrete improved, according to the results of the split tensile strength and compressive strength tests conducted on cylindrical specimens measuring 100 mm in diameter by 200 mm in height and 305 x 305 x 25 mm slabs.

P. Mathews and associates (16) the impact of substituting plastic coarse aggregate (PCA) for natural coarse aggregate (NCA) on the mechanical characteristics of concrete was examined by the researchers. The findings of the workability test indicate that because the PCA does not absorb water, the workability of concrete containing 20% PCA is higher than that of nominal concrete. When concrete specimens with different percentages of NCA to PCA substitution were evaluated for compressive strength, it was discovered that a 22% replacement of NCA with PCA significantly increased the concrete's compressive strength.

Das S. et al. (17) Investigating the impact of employing plastic trash as fine aggregate on the mechanical qualities of concrete was the goal of the study. In concrete, the plastic was ground and substituted for fine aggregate in different proportions: 2%, 4%, 6%, 8%, and 10%. Concrete's mechanical qualities, such as its compressive strength, tensile strength, and post-heating compressive strength, were assessed using an ACI mix of M28 in a series of tests. According to the findings, 6% was the ideal proportion for replacing fine aggregate in concrete with plastic aggregate. Concrete's mechanical qualities improved by up to 6% when fine aggregate was substituted with plastic aggregate; nevertheless, strength decreased as the amount of plastic aggregate increased.

Youcef G. *et al*(18) The investigation of replacing fine aggregate in concrete with waste plastic bags serves as the foundation for this research report. Compressive strength, flexural strength, and ultrasonic pulse velocity tests were performed on concrete specimens containing 10%, 20%, 30%, and 40% plastic aggregate. According to test results, using plastic aggregate increased workability. Because the plastic aggregate's smooth surface lessens grain bondage in the concrete, the density of the concrete decreased, according to the ultrasonic pulse velocity measurements. The authors came to the conclusion that the concrete with flexible aggregate had significantly lost its mechanical qualities.

Manikandan P. et al (19) the use of crushed plastic as coarse aggregate and scraped plastic as fine aggregate in concrete was investigated, along with the implications on the concrete's characteristics. Compressive strength tests were performed on concrete specimens that had fine and coarse aggregate replaced with plastic trash at percentages of 5%, 7%, and 9%. According to the findings, the compressive strength of concrete significantly increased as the proportion of plastic in the concrete increased. According to the findings, the compressive strength of concrete including scraped plastic as fine aggregate was higher than that of concrete containing crushed plastic as coarse aggregate.

Amalu R. et al (20) the utilization of discarded plastic as a substitute for fine aggregate in concrete was the foundation of the study. The proportion of recycled plastic trash used to substitute fine aggregate ranged from 10% to 25%. Workability, compressive strength, and flexural strength tests were performed on the concrete specimens. According to the test results, the concrete specimen's flexural and compressive strengths decreased as the percentage of recycled plastic trash used to replace the fine aggregate increased. However, as the amount of plastic aggregate in concrete increased, the workability of the concrete improved because of decreased water absorption.

Shyam S. *et al* (22)The performance of M20 concrete with the inclusion of E plastic trash as coarse aggregate was experimentally studied by the researchers. Between 0% and 30% of coarse aggregate was substituted with E plastic waste. Up to 20% waste plastic replacement in the concrete did not significantly lower the concrete's flexural or compressive strengths. The findings of the ultrasonic pulse velocity test conducted on concrete specimens containing fly ash and E plastic trash showed minor departures from the designated limits after 7 and 14 days, but within acceptable bounds after 28 days. It was determined that the concrete using E plastic waste had good strength development properties when fly ash was added.

Rai B. et al. (23) Using different proportions of discarded plastic flakes in the concrete, the researchers investigated the mechanical properties of the material. Workability, compressive strength, and flexural strength tests were performed on the concrete mix with and without plasticizer. It was discovered that the workability of concrete mixes without plasticizer decreased as the amount of plastic waste flakes increased, while concrete mixes with plasticizer exhibited less workability deviation. The addition of plasticizer to concrete had no discernible effect on its flexural strength. Adding discarded plastic flakes to concrete reduced its strength by a maximum of 15%.

A. Research Gaps

The following research gaps are found from the literature review:

• When employing plastic as an aggregate substitute, the researchers have only focused on the concrete's strength characteristics. Furthermore, the endurance qualities of concrete are not highlighted.
• There are no reports of the use of plastics in granular form in various grades in the literature.

To close this gap, the current study considered using waste plastic to create concrete of at least M20 grade in order to evaluate its strength and durability characteristics in accordance with IS standards.

B. Objectives

The following are the research's goals:

• To replace the fine aggregate content (crushed sand) in the production of M20 grade concrete, the ideal amount of waste plastic (i.e., tightly graded granular form) should be varied between 7.5% and 12.5%.

• To create M20 grade concrete by substituting a desired amount of waste plastic in tightly graded granular form for fine aggregate.

- To research the created concrete's workability, strength, and durability.

2. EXPERIMENTAL PROGRAM

As advised by IS 10262:1982, thirty M20 grade cubes containing three distinct percentages of plastic grade A and plastic grade B (0%, 7.5%, 10%, and 12.5%) were cast and allowed to cure for 28 days.

A. Materials-

a. Cement: Ordinary Portland cement (OPC) grade 53 was utilized in the design of the concrete mix. Table 1 lists the physical characteristics of the cement that were assessed in a lab setting following the standard procedures outlined in IS 4031: 1968.

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Table 1- Physical properties of cement

Physical Property	Test Results
Consistency	31%
Specific Gravity	3.15
Initial Setting Time	165 min.
Final Setting Time	250 min.
Soundness	1.5mm
Compressive strength at 28 days	56N/mm^2

b. Aggregate: Table 2 lists the physical characteristics of coarse and fine aggregate as established in the lab:

Table 2- Physical properties of aggregate

Physical Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.73	2.76
Water Absorption	1.59%	1.45%
Fineness Modulus	5.61	4.4
Grading of Aggregate (Confirming to IS 383:1970)	< 20 mm	Zone II

c. Water: All of the concrete mixes were prepared using potable water.

Table 4 - Mix Proportion

Material	**Control mix**	**Mix 1A**	**Mix 1B**	**Mix 2A**	**Mix 2B**	**Mix 3A**	**Mix 3B**
Cement(kg)/m^3)	350	350	350	350	350	350	350
Water (kg/m)	190	190	190	190	190	190	190
Fine Aggregate (kg/m^3)	784.25	724.36	745.38	706.71	706.73	687.59	687.57
Coarse Aggregate (kg/m^3)	1212	1212	1212	1212	1212	1212	1212
Plastic Grade A (kg/m^3)	-	16.836	7.216	22.268	9.543	28.242	12.10
Plastic Grade B (kg/m^3)	-	8.125	18.96	10.747	25.07	13.63	31.80
% Replacement	0	7.5	7.5	10	10	12.5	12.5

d. Plastic Granules: To replace fine aggregate in concrete, two grades of low density polyethylene (LDPE) plastic granules were utilized. The physical property test results for the plastic granules are displayed in Table 3 below:

Table 3- Physical properties of Plastic Granules

Physical Property	Plastic A	Plastic B
Specific Gravity	1.11	1.25
Grain Size	1.18mm-2.30mm	2.40mm-3.80mm

e.To improve plastic grading, these two plastics were combined in 70:30 and 30:70 ratios to create Plastic Grade A and Plastic Grade B, respectively.

B. Concrete Mix Design:

IS10262: 1982 and IS456:2000 criteria were followed in the preparation and testing of the concrete mix. Thirty cubes of M20 grade concrete, each measuring 150 mm by 150 mm by 150 mm, were formed using three distinct percentages of plastic grades. They were then allowed to cure for 28 days. A standard control mix of concrete was used to cast six cubes. Table 4 provides the specifics of the material quantities (proportions) as determined during the mix design process.

Table 5 –Proportion of plastic granules in mix

Designation	% Replacement of FA with Plastic	Plastic grade A		Plastic grade B	
		%	Weight (kg)	%	Weight (kg)
Mix1A	7.5	70	16.836	30	8.125
Mix1B	7.5	30	7.216	70	18.96
Mix2A	10	70	22.267	30	10.746
Mix2B	10	30	9.543	70	25.07
Mix3A	12.5	70	28.242	30	13.62
Mix 3B	12.5	30	12.10	70	31.80

3. PRELIMINARY TRIALS

Compressive strength of trial mixes:

To achieve the required workability and compressive strength, trials were conducted on a control mix. Once the water concentration was adjusted to account for water absorption, the mix's required workability was achieved. Trials were also conducted to achieve the required compressive strength.

Finding the desired content of plastic granules:

Experiments with varying percentages of plastic granules were conducted in order to ascertain the desired content of plastic granules. A range of 7.5% to 12.5% FA replacement was deemed adequate based on these experiments. The control mix was formed into cubes using two grades of plastic in place of FA at 7.5%, 10%, and 12.5%.

Mixture Types:

Details regarding each blend and its plastic proportion are provided in Table 5 below.

These mixtures were made and poured into cube-shaped molds that measured 150 mm by 150 mm by 150 mm. After 24 hours, these cubes were taken out of the molds and allowed to cure for 28 days in water.

Concrete tests include:

1. Workability:

Workability provides insight into how easy it is to place concrete. The workability of concrete mixes was assessed using the slump cone test in accordance with IS 456:2000 criteria.

2. Compressive Strength:

After 28 days of curing, the concrete cubes were put through a CTM test. Each blend was tested on three cubes, and the average of the results indicates the mix's compressive strength.

3. Durability:

The water permeability test is the most precise method of evaluating all significant durability. Testing the permeability of a mix can reveal its durability because of the correlation between permeability and durability. A water permeability test was conducted to determine the durability of the mixtures in accordance with DIN 1048-Part 5.

5. OUTCOME AND CONVERSATION

The following sections report the findings of many tests conducted on concrete cubes made with a desired amount of plastic granules:

Concrete workability: Figure 1 displays the findings of the slump cone test. The required workability, or 75mm–100mm, was achieved by the mixes Mix2A and Mix2B with slump values of 78mm and 75mm. With slump values of 67 mm and 72 mm, the concrete mixes Mix 1A and Mix 3B produced results that were 21% and 10% different from the control mix, respectively. As the amount of fine aggregate replaced with plastic granules increases, the concrete's workability is shown to rise as well. Plastic's hydrophobic qualities reduce the amount of water that is absorbed.

The concrete mixes containing 10% plastic only showed a 6.5% divergence in workability when compared to the control mix; in contrast, the mixes with 7.5% and 12.5% plastic substitution showed a considerable deviation.

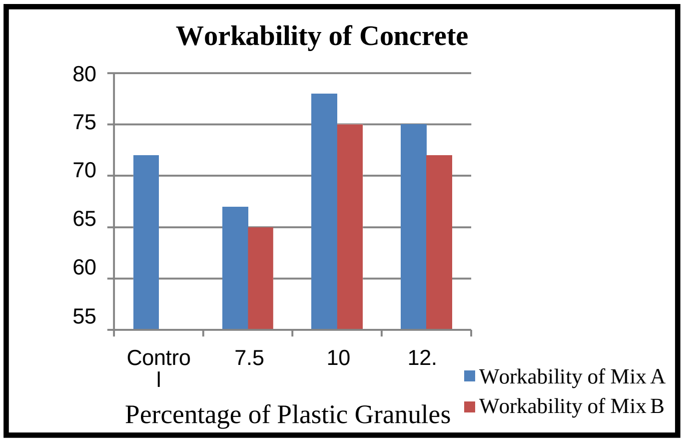

FIGURE-1

Compressive Strength of Concrete: Mixes 1A and 1B outperformed the other mixes in the compressive strength test, achieving 25.45 N/mm2 and 24.5 N/mm2, respectively. The findings of every concrete mix including plastic stayed below the control mix's strength of 27.2N/mm2. When compared to the control mix, Mixes 2A and 2B showed a mere 15% decrease in compressive strength.

Growing proportion: The concrete's compressive strength decreased when plastic granules were substituted for F.A. Figure 2 displays the graph of the concrete's compressive strength test results.

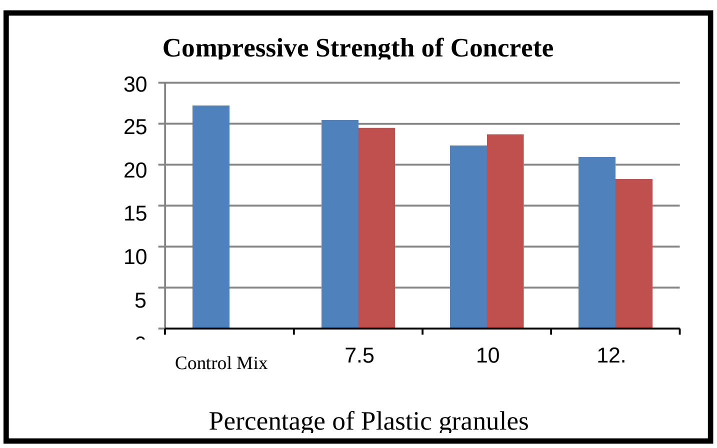

FIGURE-2

Durability of Concrete: We discovered that concrete specimens with 10% FA replacement by plastic grade perform better than other specimens based on the workability and compressive strength tests. Thus, the water permeability of the Mix 2A and Mix 2B specimens is investigated.

Test of water permeability -
Table- 6 displays the findings from the specimens' water permeability test:

Table 6-Depth of Penetration of water into concrete

Designation	Depth of Penetration (mm)
Control Mix	12
Mix 2A	27
Mix 2B	34

According to the results of the water permeability test, adding plastic granules to the concrete decreased the concrete's density. Concrete Mix 2A demonstrated superior resistance to water penetration, despite the fact that the findings showed that concrete containing plastic exceeded the typical depth of penetration value. Mix2A's penetration depth is +2 mm greater than the normal value of 25 mm.

6. CONCLUSIONS

The following inferences can be made from the experimental research done to create the concrete using plastic grains in place of FA:

• It has been discovered that adding plastic granules to 10% of the fine aggregate in concrete improves its workability by 7% when compared to the control mix.
• As the percentage of plastic granules increases, the compressive strength decreases. Better results were obtained with mixes 2A and 2B that had 10% fine aggregate replacement. When compared to the strength of the control mix, the mixes' compressive strength is determined to be 15% lower.
• Mix 2A exhibits good resistance to water penetration when compared to the control mix and mixes that have 10% of the fine aggregate replaced with plastic granules.

Plastic grade A received the same grade as the fine aggregate in the control mix.

7. FUTURE SCOPE

• Since it has been discovered that grading plastic granules enhances the qualities of concrete, extensive effort must be made to improve plastic granule grading so that it is comparable to grading fine aggregate.
• Using mineral admixtures, such as fly ash or silica fume, can be a better way to increase the concrete's density. The concrete with plastic may become more durable as a result.

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