Experimental Study on Partial Replacement of Aggregate with Waste Plastic in Concrete

Amit Kumar Pandey[1], Swati Chaudhary[2]

[1]*M. Tech (Structural Engineering) Student, Radha Govind Engineering College, Meerut, Uttar Pradesh, India*
[2]*Assistant Professor, Department of Civil Engineering, Radha Govind Engineering College, Meerut, Uttar Pradesh, India*

---***---

Abstract - *Safe disposal of waste plastic is a serious environmental concern which needs to be mitigate. Being a non-biodegradable material, it does not decay over time and even if dumped in landfills, finds its way back in the environment through air and water erosion, can choke the drains and drainage channels, can be eaten by unsuspecting grazing animals causing them illness and death, can contaminate the construction fill, etc. The use of plastic shall be refused as much as possible. This paper investigates the effect to fusing waste plastic materials on the concrete. Waste plastic used in this study were collected from home which are almost available in our homes. The plastic can be used as filler material in concrete as well as it can be used to improve the mechanical properties of concrete. Concrete is a composite material which comprises Cement, Coarse Aggregate, Fine Aggregate, Water and Admixtures. In this project, M25 grade of concrete with W/C 0.46 is adopted and the percentage of waste plastic added as 0%, 2%, 4%, 6%, 8% and 10% to study the strength of concrete. High compressive strength was found with 8% of waste plastic added in the concrete.*

***Key Words*: Waste plastic, Concrete, OPC, Aggregate**

1. INTRODUCTION

Concrete is the second most widely used material on the planet, after water. The manufacturing of concrete generates about 4.5 percent of the world's human-induced carbon dioxide emissions. Replacing even a small portion of concrete with irradiated plastic could thus help reduce the global carbon footprint. The plastic industry is amongst the fastest growing markets; this is attributable to its use in a variety of sectors. In India, about 80% of the total plastic consumption is discarded as waste, at least 40% of which is uncollected. Plastic is an organic hydrocarbon-based material, its high calorific value can be used for incineration or in other high temperature processes. But, burning of plastics releases varieties of poisonous gases which contaminates the air. However, the versatile behavior of plastic (it is lightweight, flexible, strong, moisture-resistant, and cheap) can make it a replacement of aggregates in making concrete.

1.1 Scope

Aggregates are natural materials of great demand, and they are the most mined materials. They are directly used for construction or as constituents of ready-mixed concrete or asphalt products, and they appear as an index of the economic activity of a country. Distance between quarries and demand points controls the price of high place-value products such as aggregates. Their potential exploitation depends on factors such as geology, environmental and heritage protection laws, or even on social rejection near populated areas. These factors are forcing quarries to move away from demand areas and make the aggregates to be transported for longer distances, with associated economic, environmental, and safety issues. To mitigate this issue, this work has focused on the usage of waste materials that were also adversely affecting the environment. Some of these are already in use such as Iron slag, Crusher Dust, etc. and many others are under research. Hence, usage of these waste materials helping in dual role by minimizing the usage of raw material of concrete and by using the waste materials that are affecting the environment. Its beneficial properties which include (i) Low density extreme versatility; (ii) Lighter weight without sacrificing strength; (iii) Durability and longevity; (iv) Resistance to chemicals, water, and impact; (v) Unique ability to combine with other materials and (vi) Highly weatherable and low maintenance.

1.2 Literature Review

T. Bragadeeshwaran, A.S. Kiruthika Devi, D. Manju Shree, R Pakya Sree in 2021 performed a study on Partial Replacement of Coarse Aggregate with Waste Plastic in Concrete. They used high strength of concrete w/c 0.35 and the percentage of waste plastic replaced by 3, 6, 9, 12, 15 and 18% of cement, coarse aggregate in concrete. They concluded that the use of waste plastic in cement-based composite can significantly reduce cost of construction through full or partial replacement of aggregates. The use of waste plastics in constructions will grossly reduce rate of solid waste accumulation in the environment and income will be generated from its utilization.

Azad Khajuria, Puneet Sharma in 2019 performed study on use of plastic aggregates in concrete. They performed study to test the mechanical properties of the concrete with plastic coarse aggregates. Concrete was prepared using plastic coarse aggregates in varying proportions of 0, 2.5, 5, 7.5 and 10%. It was observed while experiment that the compressive strength of concrete initially increases at 2.5% PCA but further addition of PCA shows reduction in strength. They concluded that the optimum compressive strength was obtained at 2.5% PCA and the Flexural Strength shown similar result to that of compressive strength.

Elango A and Ashok Kumar A in 2018 performed study concrete with plastic fine aggregates. They used OPC 53 grade, River sand and crushed aggregates. They used plastic in place of fine aggregates in proportion of 10%, 20% and 30%. They test mechanical and durability properties on their concrete samples. They found the decrease in strength of concrete. But found that the concrete shows good results against acid attacks and increase in elasticity. So, they concluded that the plastic aggregate concrete can be used in place where we need less compressive strength but more durability.

Lhakpa Wangmo Thingh Tamanget. al. in 2017 performed experiment on Plastics in Concrete as Coarse Aggregate. They performed the testing of mechanical properties of concrete containing Plastic aggregates. They use plastic aggregates in proportion of 10%, 15%, and 20%. They found marginal reduction in strength and suggested the optimum result as 15% replacement.

B Jaivignesh and **A Sofi** in 2017 performed Study Properties of Concrete with Plastic Waste as Aggregate. They replace coarse aggregates in proportion of 5%, 10% and 20%. They found that the concrete was lighter in weight. But the compressive strength was lesser than that of conventional concrete. They also found that the concrete with 10% plastic aggregates shows strength nearly similar to the conventional concrete. So, the optimum result was 10% plastic aggregates.

M Mahesh, B Venkat Narsimha Rao, CH. Satya Sri in 2016, performed work on Re-Use of Polyethylene Plastic Waste in Concrete. They prepared concrete with 2%, 4%, 6% pulverized/non pulverized polyethylene material after doing the mix design. They concluded that waste plastic can be effectively re-used without affecting the mechanical properties considerably (5-10%). With increase in the percentage of plastic there was a sudden decrease in early strength, but the strength developed to the value as that of the conventional M25 concrete when 28-day tests were performed. For less percentage addition (2-4%) of plastic, there was no considerable variation in 7, 14 and 28 days compression strength and split tensile strength.

Praveen Mathew et. al. in 2013 study the use of Recycled Plastics as Coarse Aggregate for Structural Concrete. They performed test on concrete with various proportions of plastic aggregates in replacement of coarse aggregates and found the optimum result at 22% replacement of coarse aggregates with plastic aggregates. They further performed the test for other properties on concrete with 22% plastic aggregates and found that concrete with plastic aggregates was weaker in fire resistance.

S. Vanitha et al. in 2015 performed studies on use of waste plastic in Concrete Blocks. Paver Blocks and Solid Blocks of size 200 mm X 150 mm X 60 mm and 200 mm X 100mm X 65 mm were casted for M20 grade of concrete and tested for 7, 14 and 28 days strength. Plastic was added to a proportion of 2%, 4%, 6%, 8% and 10% in equal replacement of aggregates. They found the optimum result for paver block at 4% replacement of aggregates with plastic aggregates. And 2% of plastic in case of solid blocks.

Daniel Yaw Osei in 2014 performed experiments on plastics aggregate in concrete. He replaces the coarse aggregates in concrete of ratio 1:2:4 by 25%, 50%, 75% and 100% with plastic. He found that there was reduction in strength of concrete as well as density of concrete. They suggested that replacement of aggregates more than 36% is not suitable for structural concrete. They also suggested plastic as a medium for production of light weight concrete.

T.Subramani and **V.K.Pugal** in 2015 performed an experiments on plastic waste as coarse aggregates in concrete. They prepared the concrete with 5%, 10% and 15% replacement of aggregates in concrete with plastic. They found the optimum results at 10% replacement of aggregates with plastic. Further increase in plastic content decreases the strength of concrete.

Amalu.R.Get. al. in 2016 performed the study the use of waste plastic as fine aggregate in concrete. They use plastic as substitute of fine aggregates in proportion of 10%, 15%, 20% and 25%. They found reduction in strength of concrete but support the use of plastic in non-structural concrete for the reason it shows higher workability and reduce environmental waste.

Manhal A Jibrael and **Farah Peter** in 2016 studies the Strength and Behaviour of Concrete Contains Waste Plastic. They replace fine aggregates in concrete with plastic bottles and plastic bags in varying proportions from 0% to 5%. They concluded the results to use the plastic in concrete for non-structural purposes as it reduces the strength in both cases.

2. METHODOLOGY

The methodology adopted for this experimental study is as under:

a) Literature study was carried out based on data available on use of waste plastic in concrete.

b) Waste plastic was collected, cleaned, dried and shredded.

c) Test related to properties of cement and aggregates are performed.

d) Proportion of plastic coarse aggregates (PCA) in different mixes is selected based on available literature.

e) Mix design for different proportions of concrete is prepared and tests are conducted to obtain the mechanical properties of different mixes.

f) Based on the literature survey and optimum quantities of plastic, the following combinations are adopted.

3. MATERIAL USED AND THEIR PROPERTIES

Cement: Ordinary Portland Cement (43 grade) with 29% normal consistency conforming to IS: 8112-1989 is used. The specific gravity and fineness modulus of cement are 3.15.

Coarse Aggregate: Natural **c**rushed stone conforming to the IS 383-2016 is used. The shape of coarse aggregate is angular, water absorption capacity is 0.5%, fineness modulus is 4.50 and specific gravity is 2.68.

Fine Aggregate: Uncrushed natural river sand is used as fine aggregate. In accordance with IS 383-2016 tests were conducted and concluded that the fine aggregate falls in Zone-II. The water absorption capacity is 1%, fineness modulus is 2.60 and specific gravity is 2.62.

Water: Water is an important ingredient of concrete as it is actively participates in chemical reactions with cement therefore clean potable water conforming to IS 456-2000 is used for the preparation of concrete mixture.

Plastic: Studies have revealed that waste plastics have great potential for use in concrete as its addition in small doses, about 6-12%, by weight of aggregates helps in substantially improving the strength of concrete. The waste plastic used in this study conforms to the size passing 2.36 mm sieve and retained on 600-micron sieve. Dust and other impurities shall be removed and not be more than 1%. Plastics used in this study and sources are given in table 1 below-

Table- 1: Plastics used and sources

Waste Plastic	Origin
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Low Density Polyethylene (LDPE)	Carry bags, milk pouches, and other packaged household items pouches like detergent, salt, tea etc.
Polyethylene Terephthalate (PET)	Drinking water bottles, soft drink water bottles etc.

4. MIX PROPORTION

The mix design is prepared in accordance with the IS 10262-2009 and mix proportions of ingredients are shown in Table 2 below-

Table- 2: Mix proportion

Unit of batch	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)		Water (kg)	Admixture (kg)
			10mm (40 %)	20mm (60 %)		
1 cum. Content	370	809	430	645	170	3.7
Ratio	1	2.2	1.2	1.7	0.46	0.01

Further mixes are prepared partially replacing waste plastic to coarse aggregate of percentage 0%, 2%, 4%, 6%, 8% and 10 %.

Table- 3: Percentage of waste plastic adopted for replacement

Concrete Trial No.	Natural Coarse Aggregate (%)	Waste Plastic (%)
1	100	0
2	98	2
3	96	4
4	94	6
5	92	8
6	90	10

Fig. 1: Mixing of shredded waste plastic with concrete

5. RESULT AND DISCUSSION

(i) Workability: Slump test was performed to measure the workability of concrete. Workability of concrete is defined as the ease to do work with it, without segregation. Workability of concrete is an important property of fresh concrete. Concrete should have good workability. The result of slump test shows that there was firstly increase in slump up to 4% addition of plastic and then it starts reducing. The slump test results are shown in table 4 below.

Table- 4: Workability of concrete

Percentage replacement of aggregate	Slump (in mm)
0	**88**
2	**85**
4	**89**
6	**93**
8	**91**
10	**87**

(ii) Compressive strength test: This test is performed on hardened concrete, to check the strength of concrete in accordance with the IS 516-1959. Test results are shown in Table 5 below. It is noted from the results obtained that the strength of concrete achieved at 7 & 28 days using 0% of waste plastic and 10% are almost similar. It is also noted that addition of waste plastic content at 2%, 4%, 6% and 8% strengthened the concrete and 8% provided optimum strength value.

Table- 5: Compressive strength of concrete

Concrete Trial No.	7 days strength (N/mm^2)	14 days strength (N/mm^2)	28 days strength (N/mm^2)
1	24.10	30.50	34.26
2	24.65	30.98	34.96
3	25.08	31.32	35.66
4	25.98	31.89	36.46
5	26.46	33.12	37.88
6	25.02	31.00	36.12

Case-I: 7 days compressive strength

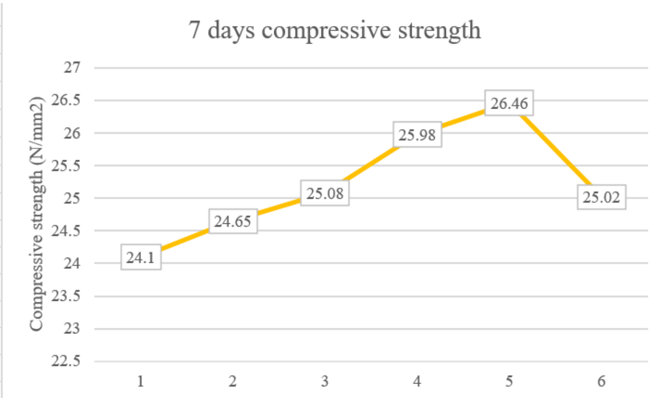

Chart- 1: Variation of compressive strength on concrete after 7 days

Case-II: 28 days compressive strength

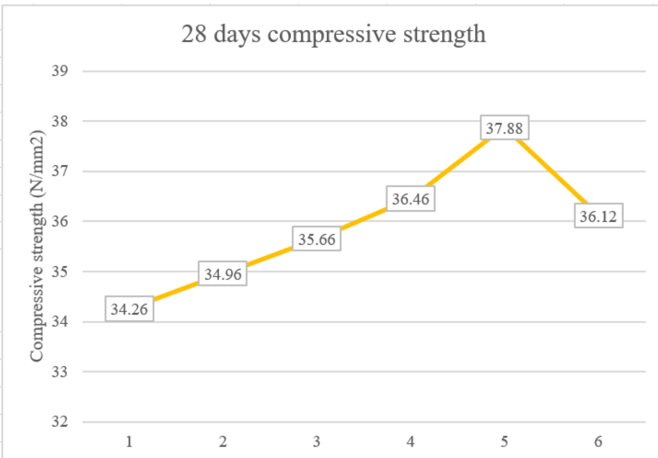

Chart- 2: Variation of compressive strength on concrete after 28 days

Comparison of compressive strength of concrete

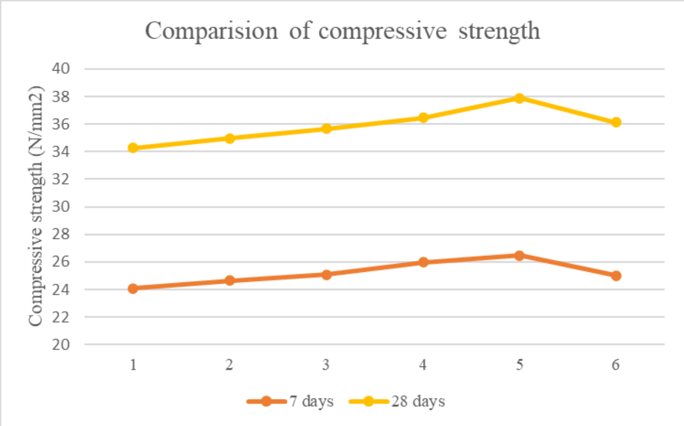

Chart- 3: Comparison of compressive strength of concrete at 7 and 28 days

(iii) Flexural Strength: The flexural strength test is conducted for the beams. Results of flexural strength of concrete are shown in table 6 below. It can be seen from the results that there is an increase while adding waste plastic however, after trial 5 there is a reduction in strength.

Table- 6: Flexural strength of concrete

Concrete Trial No.	7 days strength (N/mm^2)	28 days strength (N/mm^2)	Waste plastic content (%)
1	5.11	7.43	0
2	6.36	7.95	2
3	6.96	8.64	4
4	7.31	9.35	6
5	8.16	10.54	8
6	7.64	9.24	10

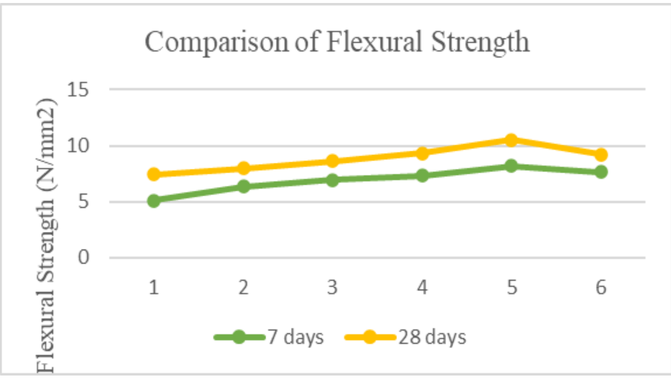

Chart- 4: Comparison of flexural strength of concrete at 7 and 28 days

(iv) Split Tensile Strength: The split tensile strength of concrete is evaluated at 7 and 28 days of cure. Results are shown in table 7 below. It is observed that tensile strength is increasing while we add waste plastic content on a similar line to compressive strength. The maximum tensile strength achieved at 8% of waste plastic content.

Table- 7: Split Tensile strength of concrete

Concrete Trial No.	7 days strength (N/mm2)	28 days strength (N/mm2)	Waste plastic content (%)
1	1.75	2.05	0
2	1.89	2.10	2
3	1.95	2.33	4
4	2.00	2.85	6
5	2.10	3.10	8
6	1.99	2.23	10

Comparison of split tensile strength of concrete

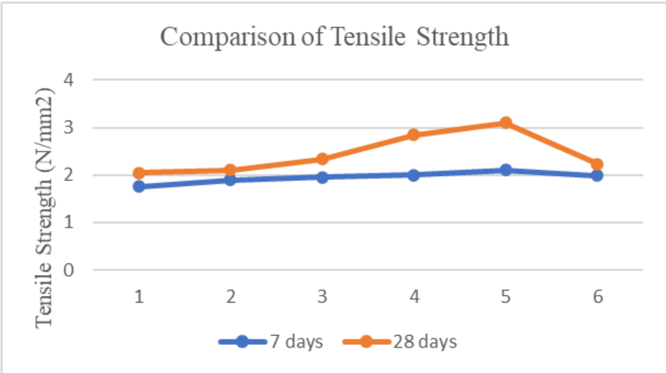

Chart- 5: Comparison of split tensile strength of concrete at 7 and 28 days

6. CONCLUSION

Waste plastic is added to concrete in replacement of coarse aggregates by proportion of 0%, 2%, 4%, 6%, 8% and 10%. Based on the results obtained from the present study, following conclusions are drawn-

(i) The material used in the experiment is found workable. As the percentage of plastic increases workability also increases due to smoothness and water absorption capacity of waste plastic is low in comparison to aggregate.

(ii) The modified concrete mix with addition of waste plastic replacing coarse aggregate up to 8% achieved strength within permissible limit hence, the material used are safe for construction purpose.

(iii) The flexural strength at each curing age is prone to decrease with increase of the waste plastic and aggregate ratio. This trend can be attributed to decrease in adhesive strength between surface of the waste plastic particles and the cement paste.

(iv) It is noted that tensile strength results are better and declined at trial no. 6.

(v) It is noted that the density of concrete is decreased while enhancing waste plastic content.

(vi) Using waste plastic in concrete can be a good option to improve strength of concrete and thereby environment friendly.

(vii) Using waste plastic as replacement of aggregate is useful where aggregates are in crisis, and this will help to conserve natural resources.

REFERENCES

1. Elango A and Ashok Kumar A "Study on Partial Replacement of plastic waste as fine aggregate in concrete" International Journal of Current Engineering And Scientific Research, Volume 5, Issue 5, 2018, ISSN (Print):2393-8374, ISSN (Online): 2394-0697

2. LhakpaWangmoThinghTamang, TsheringWangmo, Karma TsheringDarjay, Karma SangayPhuntsho, PhuntshoNamgyal, UgyenWangchuk "Use of Plastics in Concrete as Coarse Aggregate" International Journal of Education and Applied Research, Volume 7, Issue 5, 2017, ISSN (Print) 2249-4944, ISSN(Online) 2348-0033.

3. Amula.R.G, Azeef Ashraf, Muhammad Hussain, Rejith.K.U, Vijitha.V. " use of waste plastic as aggregates in Concrete" Panda, B.; Paul, S.C.; Lim, J.H.; Tay, Y.W.D.; Tan, M.J. Additive manufacturing of geopolymer for sustainable built environment. J. Clean. Prod. 2017, 167, 281–288. [CrossRef]

4. Paul, S.C.; van Zijl, G.P.A.G.; Tan, M.J.; Gibson, I. A review of 3D concrete printing systems and materials properties: Current status and future research prospects. Rapid Prototype. J. 2018, 24, 784–798. [CrossRef]

5. Baboo Rai, S. Tabin Rushad, Bhavesh Kr, and S.k. Duggal, "Study of Waste Plastic Mix Concrete with Plasticizer", International Scholarly Research Network, ISRN Civil Engineering, Volume 2012, Article ID 469272

6. T. Bragadeeshwaran, A.S. Kiruthika Devi, D. Manju Shree, R. Pakya Sree, "Partial Replacement of Coarse Aggregate with Waste Plastic in Concrete", ISSN: 2348-4098. Arivalagan. S, "Experimental Investigation on Partial Replacement of Waste Plastic in Concrete", International Journal of Engineering Sciences & Research Technology, ISSN: 2277-9655, November 2016.

7. Anumol S, Dr. Elson John, "Study on the performance of plastics as replacement for aggregates", International Journal of Engineering & Technology (IJERT), ISSN: 2278-0181, November 2015.

8. IS 10262-2009, "Concrete Mix Proportioning – Guidelines"

9. IS 383-2016, "Specification for Coarse and Fine Aggregates from Natural Sources for Concrete"

10. IS 456-2000, "Plain and Reinforced Concrete - Code of Practice"

11. IS 516-1959, "Method of Tests for Strength of Concrete"

Author's Profile

Amit Kumar Pandey
M. Tech (Structural Engineering) Final Year Student
Radha Govind Engineering College, Meerut