# Strength and Durability Properties of Concrete with Recycled Plastic Aggregate: A Review

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***Abstract*- Disposal of plastic waste is considered to be one of the biggest problems in the world over as plastic waste pollutes rivers, land, and oceans. Currently, India generates about 26000 tonnes of plastic a day, according to the statistics given by Central Pollution Control Board, Delhi. The non-biodegradable properties of plastic are causing severe impact on the soil and water quality and hence it must be either recycled or reused. Furthermore, due to the depletion of natural sources, construction industries are facing shortfall of river sand. The careless mining of natural sand and continuous depletion of its sources has led to the implementation of new environmental or land use legislations. This has caused the procurement of natural sand more difficult and expensive. To overcome this problem, utilization of plastic waste by converting it into fine aggregates for the production of concretes can be alternative solutions for its consumption. Over the past few decades, many researchers have used plastic waste as a replacement for aggregates in concrete due to its versatile properties like light in weight, flexible, strong, moisture-resistant, cheap etc. The objective of this paper is to conduct review of the researches carried out to know the future scope for using the plastic waste as replacement to fine aggregate in the production of concretes, particularly with regard to strength and durability aspects. Further, this review also focuses on the scope for utilizing the plastic waste in granular form for improving the quality of the concrete.**

***Index terms*- Concrete, plastic waste, and replacement of aggregate, shortfall of sand**

## I.INTRODUCTION

Plastic is cheap and widely available, but people frequently dispose of plastic items. With increasing dependence on plastic, the tendency to dispose of plastic casually has also become a part of the mainstream. Globally, 9 billion tons of plastic waste is produced, out of which, only 9% of the plastic is recycled (1). According to a British science journal report, plastics can cause a wide variety of adverse effects to people and the environment. Chemicals in plastics are absorbed by human bodies, and some of these can change the structure of hormones (3). Almost 200 different species of animals are known to ingest plastic debris (4). It is observed that if an animal consumes plastic, it can clog its stomach. The pollution in the oceans is also impacting marine species. Milk cartons with plastic linings, disposable water bottles, soaps with small plastic beads, and other products end up in the environment or in dumps. One of the ways to dispose the plastic waste is reduction of its volume by burning. But burning plastics is not a viable alternative as it generates harmful toxic gases (5). As a result, plastics continue to fill up landfills. Plastics buried in landfills can leach harmful chemicals into groundwater and therefore into the water supply. Plastic toxins in dumps and from litter can seep into the ground water, which people drink every day.

Several investigations are being carried out for utilization of plastic waste for developing various products and thereby contribute in the reduction of plastic pollution. Some researchers have tried to utilize the plastic wastes to act as an alternative to fine aggregates in the production of concretes. Sand and coarse aggregates are used extensively in the concrete production, and for each ton of cement, about 7 times more tons of sand and coarse aggregates are required.(6) Sand and gravel are quarried across the world and constitute for the large volume of solid material extracted globally. These are the highest volume of raw materials used on earth

after water. Today, they are being extracted at a rate far greater than what is renewed. The careless sand mining and continuously depleting the natural sand sources have led to the implementation of new environmental or land use legislations, making the procurement of natural sand very difficult and also expensive.(7) Further, this has resulted into heavy taxes or banning of the sand dredging in many parts of the world. Due to such restrictions put by government on mining of river sands, in recent years use of 'artificially crushed stone sand' or 'manufactured sand' is being done. However, as manufactured sand generally contains large proportion of micro fine particles due to its production process, it affects the strength and workability of the concrete.(8)

Thus, in view of the issues related to the threat of plastic waste to the environment and depleting sources of fine aggregates, it has become necessary to study the scope for utilizing plastic waste as a replacement for fine aggregates in the production of concretes, especially with regard to the strength and durability properties of concrete.

## II. LITERATURE REVIEW

Raghtate A. (9) The paper is based on impact on strength properties of concrete with the use of plastic. The investigator has performed experiments on concrete to study the compressive strength and split tensile strength properties using pieces of polyethylene bags in varying percentage namely 0.2, 0.4, 0.6, 0.8 and 1%. The results of the study indicate that compressive strength of concrete reduces as the percentage content of plastic pieces increases but the rate of reduction in compressive strength is found to be very low. A reduction in compressive strength upto 20% has been observed with the addition of 1% plastic pieces. However, the split tensile strength is observed to be increased, though the rate of increase is low. From the study, authors conclude that tensile strength of concrete can be increased by further adding plastic pieces in it.

M.Mahesh et al (10) The investigators carried out research work by using polyethylene plastic waste in the form of fibres in the concrete. Waste plastic fibre with 2%, 4%, and 6% has been used in the concrete. Compressive strength and split tensile strengths are determined for concrete specimens after curing them for 7, 14 and 28days. The results show that the compressive strength and Split tensile strength decreases as the percentage of plastic fibers increases, but the rate of strength reduction of concrete is observed to be very low. A considerable reduction in the self-weight of concrete is also observed. The researchers conclude that the mechanical properties of concrete can be affected by 5% - 10% using waste plastic fibres.

Tamang L.(11) The paper presents the study of various mechanical properties of concrete using plastic as a replacement for coarse aggregate. The plastic aggregate was prepared melting the plastic at 150-1800C, allowing setting and then crushing to required size. Concrete with 20% of plastic aggregate has highest compressive strength but 2% less than that of nominal concrete. Split tensile strength test shows tensile strength at15%replacement has highest tensile strength but 30% less than nominal concrete. This paper emphasizes that compressive strength of concrete does not get affected by plastic aggregate but tensile strength gets affected severely. The results conclude that the effective utilization of plastic waste can be done by using optimum of 15% plastic aggregate as a replacement for coarse aggregate without affecting the mechanical properties of the concrete.

Manikandan.P(12) The study is carried out to determine the compressive strength of concrete with replacement of fine aggregates with scrapped plastics and that of coarse aggregates with crushed plastic in the concrete. The plastic waste having density 0.93 to0.97 g/cm3 was used as 5%, 7% and 9% replacement for fine and coarse aggregate. Compressive strength test carried out after 7 days and 28 days found that there is an increase in the compressive strength with increasing the percentage of plastic aggregate in concrete. From the study, the researchers conclude that the compressive strength of the concrete with scrapped plastic as a replacement for fine aggregate is more than that of the concrete with crushed plastic as a replacement for coarse aggregate.

Chien C. et al(13) The research paper presents the study of effectiveness of using high density polyethylene plastic waste as a replacement for fine aggregate in the concrete. The workability test results found that as the percentage replacement of fine aggregate with the HDPE plastic aggregate increases,

the slump decreases. This test is performed on concrete with HDPE plastic as a replacement for fine aggregates which does not have stable shape, which resulted in inaccurate slump values. The tests for determining split tensile strength, compression strength and heat absorption were performed on cylindrical specimens of 100mm (diameter) x 200mm (height) and slab of 305mmX305mmX25mm.The results from the study conclude that beyond 10% replacement of fine aggregate with plastic aggregate, there is significant loss in workability, increase in compressive strength and heat absorption of the concrete with HDPE plastic waste as a replacement for fine aggregate in the concrete.

Harini B. et al(14) The investigators carried out the research work to determine various mechanical properties of concrete incorporating plastic waste. The concrete is produced with the replacement of fine aggregate by plastic aggregate in a range of percentage of 5%, 6%, 8%, 10%, 15% and 20%.The good performing mix i.e. concrete with15% replacement of fine aggregate with plastic aggregate is prepared using silica fume as a binding material with various percentages. The workability test found that as the plastic content increases in the concrete, workability goes on increasing due to smooth surface and low water absorption of plastic aggregate. Various tests were performed for determining the compressive strength, flexural strength and direct tensile strength of the concrete. From the results, the authors conclude that the strength properties of the concrete with plastic waste as a replacement of fine aggregate improve when cement is incorporated with silica fume. Also the formation of micro cracks is prevented with the use of silica fume with the cement in the concrete incorporating plastic.

Jaivignesh B.et al(15) The paper presents the research carried out to improve the mechanical properties of the concrete incorporated with plastic waste by using steel fibers in the concrete. The fine aggregate were replaced by plastic fines and coarse aggregate with plastic coarse aggregate in the concrete. Steel fibers with 0.3% of the cement are used in the concrete. The compressive strength, split tensile strength and flexural strength of the concrete with plastic aggregate and steel fibers was determined and found to be lower than that of controlled mix concrete. The results found that the compressive strength, split tensile strength and flexural strength get affected by the use of plastic in the concrete. It concludes that the weak bond between plastic aggregate and cement due to hydrophobic nature of plastic affects the mechanical properties of the concrete. The steel fibres used in the concrete remain ineffective.

Mathew P. et al.(16) The aim of research was to investigate the optimum percentage replacement of natural coarse aggregate (NCA) with plastic coarse aggregate (PCA) in concrete which will lead to improve the mechanical strength properties of the concrete. Replacement at various percentage of natural coarse aggregate with plastic coarse aggregate was carried out and mechanical strength tests were performed. It showed that the workability of 20% PCA concrete significantly superior to NCA concrete which is due to the lower water absorption rate of plastic aggregates. The results found that, a percentage replacement of 22% NCA with PCA was found to improve the compressive strength of the concrete.

Das S. et al(17) The research is carried out to determine the impact of replacing fine aggregate with plastic waste on the mechanical properties of the concrete. An ACI mix of M28 is prepared and plastic waste is used in it as a replacement for fine aggregate. The plastic is grinded to required size and then used as fine aggregate with the percentage of 2 %, 4 %, 6 %, 8 % & 10% of fine aggregate in the concrete. Various tests are performed to find out compressive strength, tensile strength and post-heating compressive strength. From the results, the researchers conclude that the strength properties of concrete with plastic aggregate as a replacement of fine aggregate improve upto 6% and then reduce for further addition of plastic aggregate.

Dhaarani D.(18)The researchers carried out research work to determine the performance of concrete on the scale of mechanical properties by using crushed plastic waste as a partial replacement of natural coarse aggregate in it. M40 grade concrete is developed with 10, 20 and 40% replacement of crushed stone aggregate by plastic waste and various tests are performed to determine workability, compressive strength and flexural strength of the specimen. The factors considered while designing the mix are structural requirements of concrete, the exposure conditions and method of concreting. It is concluded that concrete with 10% replacement of

coarse aggregate by plastic aggregate shows compressive strength almost equal to that of the normal concrete but the flexural strength of the concrete shows decrease due to the weak bonding ability of waste plastic.

Muzafar A.(19) The aim of the research was investigate the effects on properties of concrete due to partial replacement of aggregate with recycled plastic solid waste. Replacement of 0%, 10% and 20% of coarse aggregate with recycled plastic is done, maximum packing density of aggregate is achieved by varying sizes of recycled plastic aggregate and various tests are carried out to determine workability, compressive strength, tensile strength and thermal analysis of the concrete. By varying water cement ratio it is found that with increasing water cement ratio, the workability increases; whereas, increase in percentage plastic aggregate reduces the workability of concrete. The results of the tests conclude that compressive strength of concrete get reduces with increase in plastic aggregate and thermal conductivity and temperature in concrete with plastic aggregate is lower than that of the nominal concrete.

Youcef G. et al(20) The investigators carried out research work to determine the feasibility of using recycled plastic bag waste as replacement for fine aggregate in concrete. The concrete specimen prepared with 10%, 20%, 30% and 40% replacement of fine aggregate with recycled plastic aggregate are tested to find out compressive strength, flexural strength and ultrasonic pulse velocity. The results showed that since plastic sand was added in concrete, it has good workability. Also, ultrasonic pulse velocity test found that the density of concrete decreases as plastic aggregate is used as a replacement of fine aggregate in the concrete. The authors conclude that there is significant reduction in the development of mechanical strength of the concrete with plastic aggregate waste as replacement for fine aggregate in concrete. Two possible reasons for reduction of strength properties of concrete focused in the study are:(i) low roughness of plastic aggregate which reduces bonding between the grains and cement paste and its circular shape which increases the void volume in the mortar, reducing the density of concrete, and (ii) plastic has less load carrying capacity than that of natural sand.

Malkapur S. et al(21) The investigators aimed at studying the effects of partial replacement of coarse aggregate by waste plastics on the mechanical properties of the various concrete mixes. Concrete mixes with 10%, 20% and 30% replacement of coarse aggregate by waste plastic are prepared and tested for workability, compressive strength, split tensile strength, flexural strength and elastic modulus properties of the concrete with plastic. The workability test results found that as the plastic percentage in the concrete increases, the water requirement of the mix increased by1.5% for each 10% increment in plastic content. The results so obtained conclude that the concrete mixes with replacement of coarse aggregate by plastic waste upto 30% are found satisfactory.

## III. CONCLUSION

From the review of literature carried out related to the utilization of plastic waste as a replacement to aggregates in making concretes, following conclusions can be drawn:

1. Many of the researchers have focused on various strength properties of concrete by utilizing plastic waste as an aggregate for producing concretes. However, very few studies have been reported for studying durability properties of the concrete incorporating plastic waste. This highlights that there is necessity of studying durability properties of concrete incorporating plastic waste. The performance of the concrete against fire resistance is also one of the important durability factors to be considered for further study.
2. As grading of aggregates plays an important role in design of concrete, it is essential to consider its effect of shape and grading of plastic waste on strength and durability properties. The density of concrete gets improved by using densely graded plastic aggregate; hence utilizing the plastic waste in granular aggregate form with appropriate gradations finds a good scope for improving properties of concrete.

## REFERENCES

[1] Qualman D., (2017), “Global plastics production, 1917 to 2050”(online available)

https://www.darrinqualman.com/global-plastics-production/(Accessed on September 10, 2019)

[2] Mohan V., (2019), "India has a 26,000-tonne plastic waste problem" Times of India, (online available) https://timesofindia.indiatimes.com/india/india-generates-26k-tonne-plastic-waste-everyday-40-remains-uncollected/articleshow/67646745.cms (Accessed on September 10, 2019)

[3] Pangman k.,(2017), "Does Plastic Corrode?" (online available) https://sciencing.com/plastic-corrode-10042800.html (Accessed on September 21,2019)

[4] Madaan S.,(2019), " What is Plastic Pollution?" (online available) https://www.eartheclipse.com /environment/environmental-effects-plastic-pollution.html (Accessed on September 23, 2019)

[5] Lamb V., Marschke M. & Rigg J., (2019). "Trading Sand, Undermining Lives: Omitted Livelihoods in the Global Trade in Sand", Annals of the American Association of Geographers,[online available] https://scinapse.io/papers/2945988255 (Accessed on September 25, 2019)

[6] Ritchie H & Roser M , September 2018, "Plastic Pollution" (online available) https://ourworldindata.org/plastic-pollution (Accessed on November 18, 2019)

[7] "Importance of Sand in Construction Industry" (online available) https://www. infrabazaar. com/blog/Importance-of-Sand-in-Construction-Industry/302 (Accessed on November 20, 2019)

[8] Kapoor K., Gupta B. & Singh S., (2019), "Properties of Concrete Made with Plastic Aggregates" (online available) https://www. researchgate.net/publication/332235755_Properties_of_Concrete_Made_with_Plastic_Aggregates (Accessed on November 30, 2019)

[9] Raghtate A. (2012). "Use of plastic in concrete to improve its properties" IJAERS, vol. 1, pp 109-111.

[10] Mahesh M. et al. (2016). "Re-use of polyethylene plastic waste in concrete" IJEDR, vol. 4, pp 693-702.

[11] Tamang L. et al. (2017). "Use of plastics in concrete as coarse aggregate." IJEAR, vol. 7, pp 9-13.

[12] Manikandan.P and Senthamilkumar.S.(2015) "Compressive strength of concrete using plastic waste" IJIRSET,vol. 4, pp 12315-12320.

[13] Chien C. et al.(2015)."Concrete mixture with plastic as fine aggregates replacement", IJAMCE, vol. 2, pp 49-53.

[14] Dhaarani D. et al. (2018). "Crushed plastic waste in concrete", IRJET, vol. 5, pp 3638-3640.

[15] Muzafar A. And Siddi R. (2013) "Properties of concrete by the addition of plastic solid waste", IJSR, vol. 4, pp 1170-1173.

[16] Youcef G. et al. "Use of recycled plastic bag waste in the concrete", JISP: MMT, vol. 8, pp 480-487.

[17] Mathews P. et al. (2013). "Recycled Plastics as Coarse Aggregate for Structural Concrete", IJIRSET, vol. 2, pp 687-690.

[18] Das S. et al. (2016) "Utilization of plastic waste in concrete as a partial replacement of fine aggregate", 3rd International Conference on Advances in Civil Engineering, CUET, Chittagong, Bangladesh, pp 585-590.

[19] Harini B. And Ramana K.(2015) "Use of Recycled Plastic Waste as Partial Replacement for Fine Aggregate in Concrete" IJIRSET, vol. 4, pp 8596- 8603.

[20] Malkapur S. et al., "Effect of Mix Parameters on the Strength Performance of Waste Plastics Incorporated Concrete Mixes" HPC Journal of Structures, vol. 4, pp 1-8.

[21] B Jaivignesh* and A Sofi (2017)Study on Mechanical Properties of Concrete Using Plastic Waste as an Aggregate ICCIEE,IOP Conf. Series: Earth and Environmental Science, pp 1-6.