Utilization of Plastic Waste as a Partial Substitute for Aggregate in Concrete Mixes

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***Abstract*—The increasing accumulation of plastic waste particularly polyethylene terephthalate (PET), poses a significant environmental threat due to its non-biodegradable nature and the growing demand for landfill space. This study explores the feasibility of utilizing plastic waste as a partial substitute for natural aggregates in concrete mixes, offering a sustainable alternative for both waste management and construction practices. Recycled plastic aggregates were incorporated in varying proportions to partially replace coarse aggregates in concrete. The effects on workability, density, compressive strength and durability of the modified concrete were evaluated through a series of laboratory tests. Results indicate that while plastic aggregates reduce the overall weight of concrete and offer resistance to crushing, higher replacement levels may adversely affect strength properties. However, at optimized substitution rates, plastic-modified concrete can meet standard performance requirements for certain structural and non-structural applications. This approach not only contributes to environmental conservation by reducing plastic waste but also offers a viable material alternative in the construction industry.**

***Index Terms*—Waste Plastic, polyethylene terephthalate, Plastiphalt, recycle plastics, polypropylene, polyethylene, concrete mixture.**

I. INTRODUCTION

The exponential increase in plastic consumption over recent decades has resulted in a global environmental crisis. Plastics particularly those used in packaging and disposable applications are lightweight, durable and resistant to degradation traits that make them valuable in everyday life but problematic when it comes to disposal. A significant portion of plastic waste especially polyethylene terephthalate (PET) and low-density polyethylene (LDPE) ends up in landfills or as environmental litter due to inadequate recycling processes and poor waste management systems. These non-biodegradable materials persist in the environment for hundreds of years causing soil and water pollution, harming wildlife and contributing to urban flooding due to clogged drainage systems.

At the same time, the construction industry is facing its own sustainability challenges. The extensive use of natural aggregates in concrete production has led to the depletion of natural resources and increased environmental degradation through mining and quarrying. There is a pressing need to identify alternative materials that can reduce the environmental impact of both plastic waste and concrete production. This research explores the feasibility of using plastic waste as a partial substitute for coarse aggregates in concrete mixes. By incorporating shredded plastic into concrete the study aims to reduce the consumption of natural aggregates and divert plastic waste from landfills. The concept not only addresses two critical environmental concerns plastic pollution and natural resource depletion but also opens up new possibilities for sustainable construction practices. This study investigates the effects of varying proportions of plastic aggregates on the physical and mechanical properties of concrete including workability, density, compressive strength and durability. The goal is to determine optimal replacement levels where performance is maintained while achieving environmental and economic benefits.

II. LITERATURE REVIEW

Some selected literature review papers related to the utilization of plastic waste as a partial substitute for aggregate in concrete mixes are presented below.

Manjunath, B. A. (2016) this study reduction in the unit weight of the concrete, making it particularly suitable for applications where lightweight, non-load-bearing concrete is desired, such as in façade panels.

This is primarily due to the reduced bond strength between the cement paste and the plastic aggregates. Concrete typically occurs at the interface, where the bond between the cement matrix and the plastic aggregates breaks down. Ismail, Z. Z., & Al-Hashmi, E. A. (2008) This study demonstrates that the reuse of waste plastic as a partial substitute for sand in concrete mixes offers a promising and sustainable solution to two major issues the rising cost of construction materials and the environmental challenges posed by plastic waste. The approach not only contributes to more eco-friendly construction practices but also supports waste management efforts by giving discarded plastic a valuable and practical second life. Choi et al. (2005) this study identified the porous concrete using recycled aggregates and recycled PET with plastic into concrete as a fine aggregate replacement showed reduced strength but high permeability and thermal insulation properties ideal for pavement applications. Marzouk et al. (2007) present paper depicts the Recycled plastic waste as aggregate for lightweight concrete. This paper also demonstrated that concrete with recycled plastic aggregate met ASTM standards for lightweight concrete and showed good thermal performance. Ismail & Al Hashmi (2008) authors illustrates in this article use of waste plastic in concrete mixture as aggregate replacement. Using plastic bag waste as partial fine aggregate replacement improved workability and reduced density. Compressive strength decreased marginally up to 10% replacement. Hannawi et al. (2010) this study presents the use of waste plastic aggregates in cementitious materials. Plastic aggregates caused a significant drop in compressive strength beyond 10% replacement but improved lightweight characteristics. Rahmani et al. (2013) authors present on the mechanical properties of concrete containing waste plastic as aggregate using plastic aggregate (HDPE) at 5 to 15% replacement improved toughness and strain capacity but reduced compressive strength, limiting its use in structural elements.

III. METHODOLOGY

This study was conducted to evaluate the feasibility and performance of using plastic waste as a partial replacement for natural aggregates in concrete. The methodology involved several stages, including material selection, preparation of plastic aggregates, mix design formulation, sample casting, curing and testing. Ordinary Portland Cement (OPC) of grade 43 was used as the binding material. Natural river sand served as the fine aggregate, while crushed stone was used as the coarse aggregate. Clean, dry plastic waste mainly polyethylene terephthalate (PET) and low-density polyethylene (LDPE) was collected from post-consumer sources such as bottles and plastic bags. Collected plastic waste was washed, shredded into appropriate sizes and sieved to meet standard grading requirements. The plastic particles were used to partially replace fine or coarse aggregates by volume at varying percentages (e.g., 5%, 10%, 15% and 20%). Concrete mixes were prepared using a standard mix ratio with a fixed water-cement ratio. Control specimens with 0% plastic were also cast for comparison. Standard cube (150 mm × 150 mm × 150 mm) and cylinder specimens were prepared for compressive and tensile strength testing, respectively. All specimens were cured in water for 7 and 28 days. After curing, the samples were tested for workability (slump test), compressive strength, tensile strength and density. Results were compared against control samples to determine the effects of plastic aggregate inclusion. Figure 1 illustrated the image of Waste Plastic and Polyethylene terephthalate. This methodology provided a systematic framework to assess the mechanical and physical properties of plastic modified concrete, supporting conclusions on its potential for sustainable construction applications

IV. RESULTS AND DISCUSSION

According to the test result, Table 1 shows that plastic aggregates exhibit superior mechanical properties with the lowest impact (2.26%), crushing (0.24%) and abrasion values (0.42%), indicating higher strength and durability. They also possess the highest specific gravity (3.05) and lowest water absorption (1.52%), suggesting better resistance to moisture and higher density. Compared to conventional aggregates and sand, plastic aggregates demonstrate potential as a strong and durable alternative in construction materials.

Table 2 indicates that as the percentage of plastic aggregate (PA) replacement increases, the compaction factor gradually decreases. This suggests reduced workability with higher PA

content, with a notable drop from 97.92% at 0% replacement to 91.14% at 50%. Therefore, higher PA content may hinder effective compaction in concrete mixes.

Figure 1. Waste Plastic and Polyethylene terephthalate.

Table 1. Impact, Crushing, Abrasion value, Specific Gravity and Water Absorption

Test	Impact value (%)	Crushing Value (%)	Abrasion Value (%)	Specific Gravity	Water Absorption (%)
Conventional Aggregate	12.29	3.4	2.2	2.65	21.15
Plastic Aggregate	2.26	0.24	0.42	3.05	1.52
Sand	10.26	2.75	3.2	2.36	23.87

Table 2. The compaction factor test

Replacement of aggregate by PA in %	Partially Compacted Weight in kg	Fully Compacted Weight in Kg	Compaction Factor in %
0	18.8	19.2	97.92
10	18.36	18.82	97.56
20	17.94	18.42	97.39
30	16.78	17.86	93.95
40	15.78	17.12	92.17
50	15.12	16.59	91.14

Table 3. Compressive Strength of concrete with replacement by plastic

S. No.	Replacement of aggregate by PA in %	Compressive strength (N/mm^2) at 7 days	Compressive strength (N/mm^2) at 28 days
1	0	12.8	20
2	10	8.15	13.46
3	20	7.1	11.5
4	30	6.96	9.36
5	40	6.1	9.13
6	50	5.4	9.11

Table 3 shows that compressive strength decreases with increasing plastic aggregate (PA) content. At 0% replacement, the 28-day strength is 20 N/mm^2,

while at 50% replacement, it drops to 9.11 N/mm². This indicates that higher PA content reduces concrete strength, limiting its use in structural applications beyond certain levels.

Table 4. Results of Flexural Strength Test

S. No.	Replacement of aggregate by PA in %	Flexural Strength at 7 days	Flexural Strength at 28 days
1	0	40.47	53.4
2	10	41.28	59.03
3	20	37.95	51.07
4	30	38.32	51.59
5	40	36.42	49.28
6	50	35.86	48.32

Table 4 shows that flexural strength slightly increases at 10% plastic aggregate (PA) replacement but declines beyond that. The peak 28-day strength is 59.03 N/mm² at 10% replacement, compared to 53.4 N/mm² at 0%. However, further increases in PA content reduce strength, indicating optimal performance at lower replacement levels.

V. CONCLUSION

In conclusion, plastic aggregates offer excellent mechanical properties, including low impact, crushing and abrasion values, along with high specific gravity and low water absorption. However, increasing plastic aggregate content reduces workability and compressive strength. Flexural strength improves at 10% replacement but declines beyond that. Thus, plastic aggregates can be a viable, sustainable alternative in construction when used in moderate proportions, particularly up to 10% replacement, balancing strength, durability and workability for non-structural and semi-structural applications.

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