

Experimental Laboratory On Low-Density Polyethylene (LDPE) Waste Modified Concrete For Pavement Applications

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ABSTRACT

Plastic waste disposal and depletion of natural construction resources create parallel challenges for sustainable pavement engineering. This experimental study evaluates M30 concrete in which shredded low-density polyethylene (LDPE)/polyethylene carry-bag waste is used as a partial replacement for fine aggregate. The detailed experimental series reported in the project used replacement levels of 0%, 0.2%, 0.4%, 0.6%, 0.8%, and 1.0% by weight of fine aggregate. The reference mix contained 380 kg/m³ cement, 171 L/m³ water, 672 kg/m³ fine aggregate, 1206 kg/m³ coarse aggregate, and a water-cement ratio of 0.45. Workability was assessed by slump testing, while hardened performance was evaluated using compressive and splitting tensile strength tests at 7, 14, and 28 days; the report also discusses flexural behaviour and water absorption qualitatively. Compressive strength decreased as plastic content increased: the 28-day value fell from 25.96 N/mm² for the control mix to 20.30 N/mm² at 1.0% replacement. In contrast, 28-day splitting tensile strength increased from 4.12 N/mm² for the control to a maximum of 5.57 N/mm² at 0.8%, before decreasing to 5.12 N/mm² at 1.0%. The report further indicates decreasing slump with plastic content and reduced water absorption. The findings show that low replacement levels can provide a useful balance between waste utilization, crack resistance, and pavement-oriented performance, although excessive replacement reduces compressive capacity.

Keywords: LDPE waste; Plastic-modified concrete; Fine aggregate replacement; M30 concrete; Pavement applications; Compressive strength; Split tensile strength

I. INTRODUCTION

Concrete pavements are widely used because of their load-carrying capacity and service life, but their production consumes large quantities of cement, fine aggregate, coarse aggregate, and water. At the same time, discarded plastic bags create a persistent environmental burden because polyethylene does not readily degrade. Reusing plastic waste within concrete therefore offers a route to reduce disposal pressure while partially conserving natural aggregate resources.

This investigation evaluates shredded polyethylene carry-bag waste as a partial replacement for fine aggregate in pavement concrete. The experimental premise involves two competing effects. Plastic particles are lightweight, water-resistant, and capable of interfering with crack propagation, but their comparatively weak bond with cement paste and lower stiffness than mineral aggregate can reduce compressive strength when the replacement level becomes excessive.

For pavement applications, workability, compressive resistance, tensile crack resistance, flexural response, and moisture resistance are all relevant. The study compares conventional control concrete with plastic-modified mixes through laboratory testing at replacement levels from 0% to 1.0% of fine aggregate.

II. OBJECTIVES

- To evaluate the workability of concrete containing waste polyethylene carry-bag material.
- To determine the compressive and tensile strength behaviour of the modified concrete and compare it with conventional concrete.
- To assess the flexural behaviour and water-resistance trends relevant to pavement applications.
- To identify a practical low-percentage replacement range that supports waste utilization without unacceptable loss of concrete performance.
- To promote sustainable pavement construction through reuse of non-biodegradable plastic waste.

III. LITERATURE SURVEY

The reviewed literature generally indicates that waste-plastic inclusion can reduce concrete density and, at higher replacement levels, reduce compressive and flexural strength because plastic particles bond less effectively with the cement matrix than natural aggregate. The reviewed studies also indicate that low plastic dosages may improve crack resistance, impact response, vibration absorption, or moisture resistance, depending on plastic type, particle geometry, and replacement method.

The reviewed studies include investigations of recycled plastic in paver blocks, rigid pavement concrete, shredded polyethylene and polyethylene terephthalate particles, interlocking pavement blocks, and hybrid concrete containing plastic with supplementary materials. Across the reviewed work, the recurring design requirement is to control replacement percentage so that environmental benefit is achieved without compromising the structural performance needed for pavement service.

A continuing need exists for laboratory assessment of plastic-modified concrete for pavement construction, particularly with respect to workability, strength, durability, and water-resistance behaviour. The present experimental programme addresses these performance requirements.

IV. MATERIALS AND METHODOLOGY

Materials

The experimental concrete used ordinary Portland cement, locally available Zone II river sand as fine aggregate, crushed angular coarse aggregate, potable water, and shredded polyethylene carry-bag waste. The aggregate test results reported in the experimental chapter are summarized in Table 1.

Table 1. Aggregate properties used in the experimental programme

Property	Coarse aggregate	Fine aggregate	Reported limit
Specific gravity	2.75	2.69	2.6–3.0
Elongation index	27.4%	—	35%
Flakiness index	25.3%	—	35%
Abrasion value	27%	—	<30%
Impact value	16.7%	—	30%
Water absorption	0.47%	—	2%
Angularity number	10	—	0–11
Aggregate crushing value	20.3%	—	30%

M30 mix design and replacement series

The reference concrete was designed as M30 grade in accordance with IS 10262:2019. The baseline quantities reported for one cubic metre are given in Table 2. Plastic replacement was then varied while the basic concrete matrix was maintained.

Table 2. Baseline M30 concrete mix

Material	Quantity
Cement	380 kg/m ³
Water	171 L/m ³
Fine aggregate	672 kg/m ³
Coarse aggregate	1206 kg/m ³
Water-cement ratio	0.45

Table 3. Detailed plastic-replacement levels used in the result series

Mix	Plastic replacement of fine aggregate (%)
P0	0.00
P0.2	0.20
P0.4	0.40
P0.6	0.60
P0.8	0.80
P1.0	1.00

Specimen preparation and testing

Concrete was mixed, placed in standard steel moulds, compacted, demoulded after approximately 24 hours, and water-cured. Cubes measuring $150 \times 150 \times 150$ mm were used for compressive strength. Cylinders measuring 150 mm in diameter and 300 mm in height were used for splitting tensile strength, while $100 \times 100 \times 500$ mm beams were described for flexural testing. The hardened specimens were evaluated at 7, 14, and 28 days in the detailed results section.

Table 4. Laboratory test programme

Test	Specimen / method	Reported ages
Slump	Fresh concrete; slump cone	Immediately after mixing
Compressive strength	$150 \times 150 \times 150$ mm cubes	7, 14, 28 days
Split tensile strength	150×300 mm cylinders	7, 14, 28 days
Flexural strength	$100 \times 100 \times 500$ mm beams	Discussed in report
Water absorption	Oven-dry and saturated mass comparison	Discussed in report

V. RESULTS AND DISCUSSION

Fresh concrete workability

Slump decreased progressively as the percentage of waste polyethylene increased. This reduction was attributed to the lightweight, irregular plastic particles and their influence on mixture cohesion and internal movement. Although numerical slump values are not tabulated in the results, all mixes were described as sufficiently workable for placement and compaction.

Compressive strength

Table 5. Compressive strength results (N/mm²)

Plastic (%)	7 days	14 days	28 days
0.00	16.15	20.40	25.96
0.20	14.27	18.35	23.25
0.40	12.80	17.57	22.10
0.60	11.25	15.26	20.28
0.80	9.26	13.28	19.87
1.00	8.30	16.67	20.30

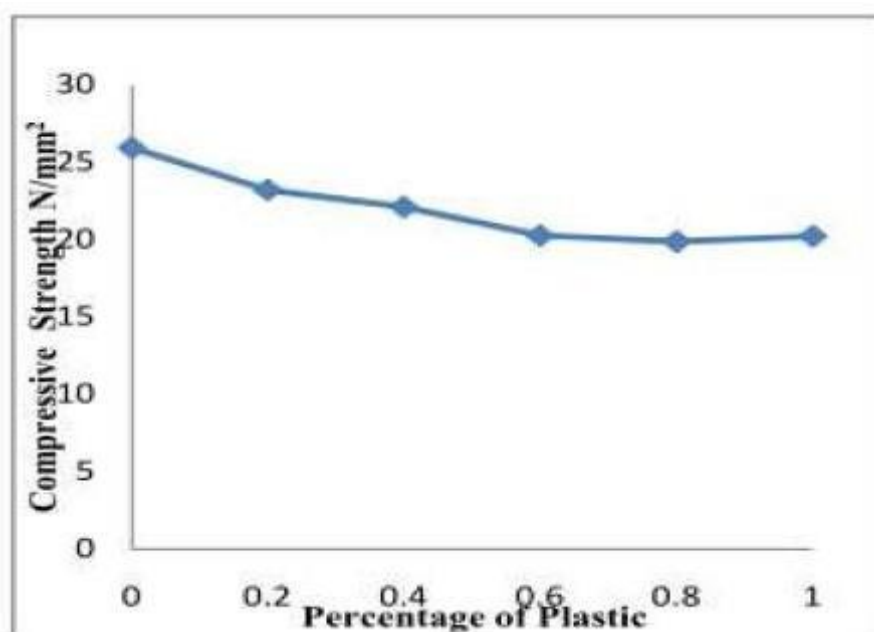


Fig. 1. Variation of 28-day compressive strength with plastic replacement.

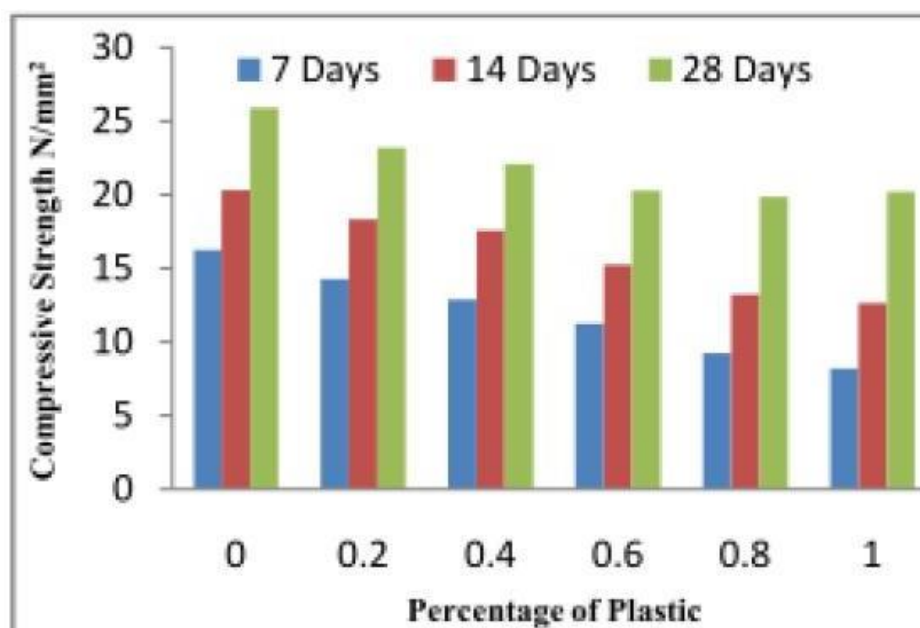


Fig. 2. Compressive strength development at 7, 14, and 28 days.

All mixes gained strength with curing age. The control mix recorded the highest 28-day compressive strength of 25.96 N/mm². As plastic replacement increased, the 28-day value decreased to 23.25, 22.10, 20.28, and 19.87 N/mm² at 0.2%, 0.4%, 0.6%, and 0.8%, respectively, with a small increase to 20.30 N/mm² at 1.0%. The overall decline was attributed to weaker bonding between polyethylene particles and cement paste and to the lower stiffness of plastic compared with natural mineral aggregate.

Splitting tensile strength

Table 6. Splitting tensile strength results (N/mm²)

Plastic (%)	7 days	14 days	28 days
0.00	1.54	1.82	4.12
0.20	1.85	1.96	4.38
0.40	2.35	2.63	4.92
0.60	2.83	2.98	5.16
0.80	3.12	1.80	5.57
1.00	3.85	3.12	5.12

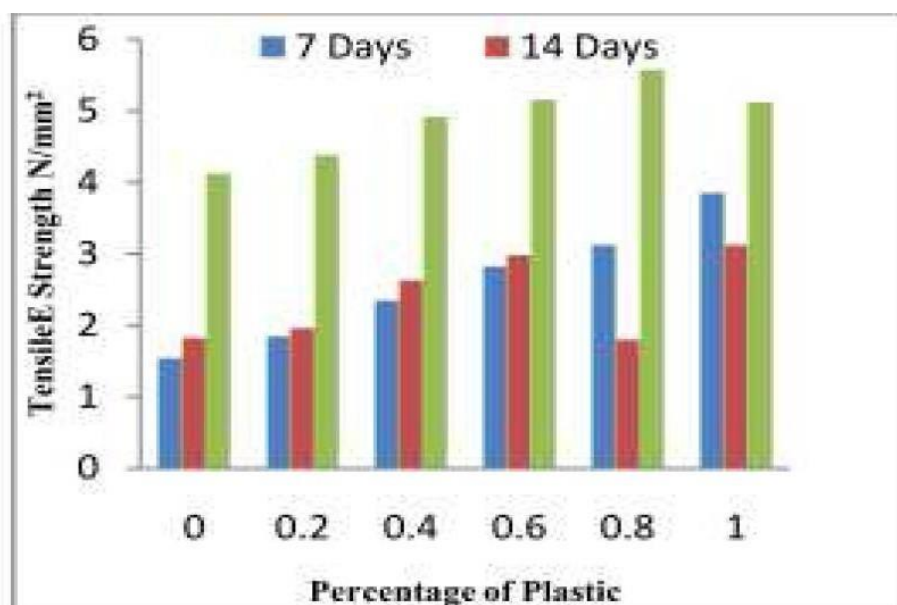


Fig. 3. Splitting tensile strength at 7, 14, and 28 days.

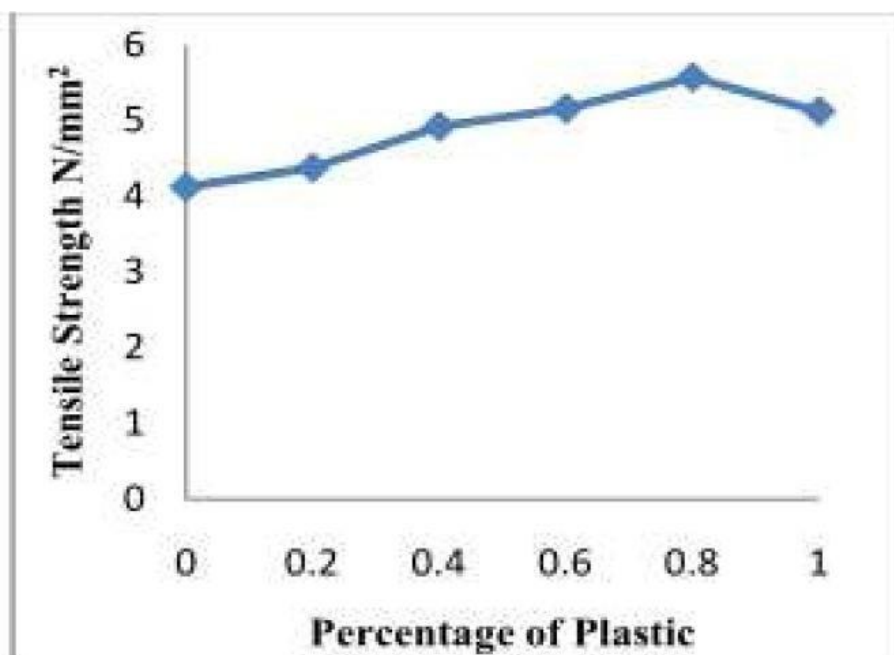


Fig. 4. Variation of 28-day splitting tensile strength with plastic replacement.

The 28-day splitting tensile results show a different trend from compressive strength. Tensile strength increased from 4.12 N/mm² for the control to 4.38, 4.92, 5.16, and 5.57 N/mm² as the replacement level increased from 0.2% to 0.8%. The maximum reported 28-day value occurred at 0.8%. At 1.0% replacement, the value decreased to 5.12 N/mm². The improvement at lower replacement levels was attributed to the ability of shredded plastic particles to restrict microcrack propagation and improve crack resistance.

Flexural behaviour and water absorption

Flexural performance was described as satisfactory at lower plastic replacement levels, while excessive replacement reduced performance because of weaker plastic-paste bonding. Water absorption was also described as lower for plastic-modified concrete, consistent with the non-porous character of polyethylene particles. Numerical flexural-strength and water-absorption datasets are not presented with the reported results; these outcomes are therefore discussed qualitatively.

Pavement performance interpretation

The combined results demonstrate a trade-off. Increasing plastic content reduces compressive strength and workability, while low replacement levels can improve split-tensile crack resistance and reduce water absorption. The highest 28-day split-tensile value occurred at 0.8%; however, no single numerical replacement level was identified as optimal across every performance criterion. Lower replacement percentages provided the more balanced combination of workability, strength, durability, sustainability, and pavement suitability.

VI. CONCLUSION

- Waste polyethylene carry-bag replacement of fine aggregate significantly influenced both fresh and hardened concrete behaviour.
- Workability decreased as plastic content increased, although all experimental mixes remained capable of placement and compaction.
- Compressive strength increased with curing age for every mix but generally decreased as plastic replacement increased; the control recorded 25.96 N/mm² at 28 days.
- The 28-day splitting tensile strength increased from 4.12 N/mm² in the control to a maximum of 5.57 N/mm² at 0.8% replacement, then decreased to 5.12 N/mm² at 1.0%.
- The tensile improvement was associated with restriction of microcrack propagation by shredded plastic particles.
- Flexural behaviour was satisfactory at lower replacement levels, while water absorption decreased with plastic inclusion.
- Lower replacement levels were identified as more suitable for balancing pavement performance with the environmental benefit of diverting non-biodegradable plastic waste from disposal.

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