Performance Evaluation of Concrete Containing Plastic-Waste, Fly-Ash and Foundry-Sand for Structural Applications

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***Abstract*— The processing and recycling of plastic waste have gained significant momentum due to its value as a resource for various industries, along with the hazardous nature and low recycling rates of plastic materials. Addressing the environmental and ecological issues associated with electronic plastic waste disposal presents a partial solution. Utilizing plastic waste in construction materials offers benefits such as cost reduction, enhanced structural strength, and improved road infrastructure. This paper studies the use of waste plastics and foundry sand as partial replacement of fine aggregate and the use of fly ash as partial replacement of cement in M30 concrete. Concrete mix with 0% waste material is the control mix and water cement ratio adopted is 0.45 in accordance with the Indian Standards specification IS-10262:2019. A design mix proportions of 1: 1.4: 2.6 was investigated for the research. The percentages of replacements of foundry sand is 15% and 20%, HDPE plastic is 4%, 6% and 8% by weight of fine aggregate and fly ash is 20% and 30% by weight of cement. Tests were performed for compressive strength and flexural strength of concrete for all replacement levels of fine aggregate and cement. The results indicate that there is an increase in compressive strength and flexural strength up to 15% replacement with foundry sand, 6% replacement with waste HDPE plastic and 20% replacement with fly ash.**

***Index Terms*— HDPE, Plastic waste, Flyash, Foundry sand**

I. INTRODUCTION

Block paving is a versatile, attractive, functional, and cost-effective option that requires minimal maintenance when properly manufactured and installed. In India, most concrete block paving has performed well, though issues such as occasional surface wear and variable block strength remain. As natural resources dwindle and industrial and residential waste increases, sustainable construction development emphasizes the use of innovative materials and recycling to address resource shortages and environmental conservation.

Annually, India generates approximately 5.6 million tons of plastic waste, which pollutes the environment and negatively affects both humans and animals. Proper disposal following government regulations is crucial.

Foundry sand has been used in molding and casting. Its physical and chemical properties vary depending on the casting process and industry. While molding sands are recycled multiple times, they eventually degrade and must be replaced, resulting in substantial waste. Foundry sand, a high-quality silica sand by-product from metal casting industries, generates 9 to 10 million tons of waste annually. Over the past 20 years, more than 30 million cubic meters of waste have been discarded in landfills. Reusing this waste is now being promoted to mitigate environmental issues.

II. OBJECTIVES OF THE STUDY

1. To determine the suitability of waste foundry sand as partial replacement of natural sand at replacement levels of 15% and 20%.
2. To assess the suitability of HDPE plastic waste as a partial replacement for natural sand at levels of 4%, 6%, and 8%.
3. To evaluate the suitability of fly ash as a partial replacement for cement at levels of 20% and 30%.
4. To evaluate compressive strength and flexural strength of concrete paver blocks.

III. EXPERIMENTAL PROGRAM

3.1 Materials used

A. Cement (OPC)

Ordinary Portland Cement 43-grade conforming to IS:8112 is used. The cement used is fresh and without any lumps. The specific gravity of Cement is 3.10.

B. Aggregates

Aggregates give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is a good gradation of aggregates. Minimum paste means less quantity of cement and less water, which further means increased economy, higher strength, lower shrinkage and greater durability. The properties are tested as per IS:383-1970.

B.1 Fine Aggregates

M-Sand is used as fine aggregates. The specific gravity and fineness modulus are found to be 2.62 and 2.74 respectively for zone-II.

B.2 Coarse aggregates

The specific gravity of C.A is 2.80 and water absorption is 0.8%.

C. Foundry Sand

It is used as partial replacement for fine aggregates. The specific gravity is 2.56 and water absorption is 1.5%.

D. Fly Ash

It is used as partial replacement for cement. The specific gravity of Fly Ash is 2.70

E. HDPE Plastic

It is used as partial replacement for fine aggregates. Water absorption is 0.5%.

3.2 Concrete Mix Proportioning

For M-30 (1:1.4:2.6) grade concrete and w/c = 0.45

a) Volume of concrete = $0.00363m^3$

b) Mass of cement = (0.00363×2416)/ (1+1.4+2.6)
= 1.75 kg

c) Volume of water = 0.45×1.75
= 735 ml

d) Mass of fine aggregate = 1.75×1.4
= 2.45 kg

e) Mass of coarse aggregate = 1.75×2.6
= 4.55 kg

Fig. 1 Materials used for the study

3.3 Mix proportion by varying percentage of foundry sand, fly-ash and HDPE plastic

Table No. 1 Material combinations used for the study

Combination	Binder		Coarse Aggregates	Fine Aggregates		
	Cement (in %)	Fly Ash (in %)	Coarse Aggregate (in %)	Natural Sand (in %)	Foundry Sand (in %)	HDPE Plastic (in %)
1	80	20	100	81	15	4
2	80	20	100	79	15	6
3	80	20	100	77	15	8
4	80	20	100	76	20	4
5	80	20	100	74	20	6
6	80	20	100	72	20	8
7	70	30	100	81	15	4
8	70	30	100	79	15	6
9	70	30	100	77	15	8
10	70	30	100	76	20	4
11	70	30	100	74	20	6
12	70	30	100	72	20	8

3.4 Methodology

Strength is one of the critical properties of concrete, as structural design necessitates that structural members withstand imposed loads. The mix has been done for M30. The control mix contains 0% waste materials, and the water-cement ratio adopted is 0.45, following the Indian Standards specification IS-10262:2019. A design mix ratio of 1:1.4:2.6 was investigated for the research.

Various percentages of replacements were studied:

- Foundry sand: 15% and 20% by weight of fine aggregates.
- HDPE plastic: 4%, 6%, and 8% by weight of fine aggregates.
- Fly ash: 20% and 30% by weight of cement.

IV. EXPERIMENTAL RESULTS

4.1 Compressive Strength Test on Pavers

Compressive strength = P/A

Table No. 2 Compressive strength test results

Comb	SL No.	Ultimate load in KN	Compressive strength in N/mm^2	Average load in KN	Average compressive strength in N/mm^2
1	1) 2) 3)	800 810 795	40 40.5 39.75	802.00	40.08
2	1) 2) 3)	790 800 805	39.5 40 40.25	798.33	39.97
3	1) 2) 3)	780 769 775	39 38.45 38.75	774.67	38.73
4	1) 2) 3)	790 800 802	39.5 40 40.1	797.33	39.87
5	1) 2) 3)	795 790 780	39.75 39.5 39	788.33	39.47
6	1) 2) 3)	780 770 755	39 38.5 37.75	768.33	38.47
7	1) 2) 3)	770 765 750	38.5 38.25 37.5	761.67	38.10
8	1) 2) 3)	750 759 742	37.5 37.95 37.1	750.33	37.57
9	1) 2) 3)	740 735 752	37 36.75 37.6	742.33	37.17
10	1) 2) 3)	760 755 765	38 37.75 38.25	760.00	38.00
11	1) 2) 3)	750 740 748	37.5 37 37.4	746.00	37.30
12	1) 2) 3)	720 730 735	36 36.5 36.75	728.33	36.47

Fig 5.1 Compression Testing under CTM

4.2 Flexural Strength Test on Pavers

Flexural strength = $3Pl/2bd^2$

Table No. 3 Flexural Strength test results

Combi nation	Sl. No.	Breaking load in KN	Flexural strength in N/mm^2	Average Breaking load in KN	Average Flexural strength in N/mm^2
1	1) 2) 3)	7.5 7.2 7.5	5.3 5.1 5.3	7.40	5.23
2	1) 2) 3)	7.3 7.2 7	5.17 5.1 4.95	7.17	5.07
3	1) 2) 3)	6.5 6.2 6.3	4.67 4.39 4.46	6.33	4.57
4	1) 2) 3)	7.3 7.2 7.1	5.17 5.1 5.03	7.20	5.10
5	1) 2) 3)	6.8 6.5 6.2	4.82 4.67 4.39	6.50	4.67
6	1) 2) 3)	6.2 6.3 6.1	4.39 4.46 4.32	6.20	4.39
7	1) 2) 3)	6.2 5.9 5.8	4.39 4.12 4.11	5.97	4.27
8	1) 2) 3)	6.1 5.8 5.6	4.32 4.11 3.97	4.83	4.13
9	1) 2) 3)	5.6 5.5 5.3	3.97 3.89 3.77	5.47	3.87
10	1) 2) 3)	6.1 5.8 5.5	4.32 4.11 3.89	5.80	4.10
11	1) 2) 3)	5.9 5.7 6	4.12 4.03 4.25	5.87	4.13
12	1) 2) 3)	5.5 5.3 5.2	3.89 3.77 3.68	5.33	3.78

Fig 5.5 Flexural testing under UTM

4.3 Graphical Representation of Results

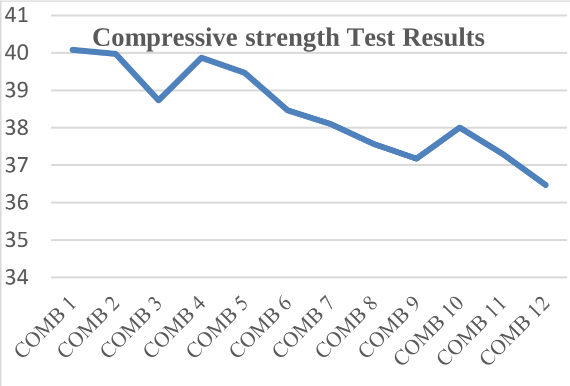

Fig .2 Graph of compressive strength test results

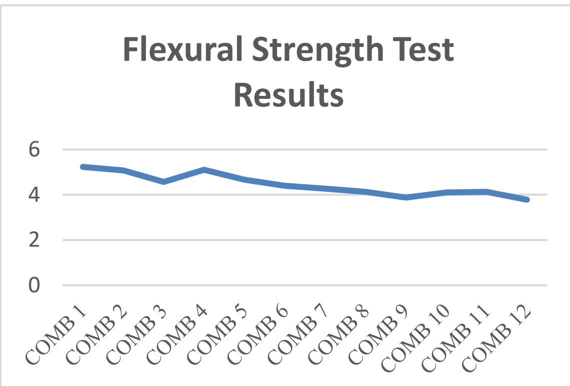

Fig. 3 Graph of flexural strength test results

V. CONCLUSIONS

1. The compressive strength and flexural strength of concrete specimens increased with higher replacement of fine aggregate by foundry sand, reaching maximum strength at 15% replacement. However, beyond this point, both strength parameters showed a decline. This trend suggests that the fineness of foundry sand, which is finer than traditional fine aggregate, reduces porosity in concrete, thereby increasing its density and strength. Nevertheless, beyond 15% replacement, the presence of binders in foundry sand, such as fine clay and carbon powder, weakens the bond between cement paste and aggregate, leading to reduced compressive strength.
2. The optimal replacement levels for waste HDPE plastic were found to be 4% and 6% for paver blocks. However, at 8% replacement, the compression test results did not meet the target strength.
3. Replacement of cement with fly ash yielded positive results at 20% replacement. However, increasing the replacement to 30% resulted in compressive strength values below the target strength.
4. Utilizing recycled materials such as waste foundry sand, plastic waste, and fly ash in concrete production conserves energy and preserves primary resources. The study concludes that increased material reuse leads to reduced resource consumption and promotes sustainability in the environment.

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PICTURE GALLERY

Pics of Material Procurement, Testing and Casting of Concrete Pavers