

Experimental Study of Modified M20 Concrete with Waste Plastic Polystyrene Cubes

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Abstract

The study of this research paper deals with the effectiveness of waste plastics used in concrete construction. The M20 concrete specimens were mixed with waste plastic material like polystyrene as cubes of different sizes such as 5, 6, 7, 8, 9, and 10 cm and were tested for their compressive strength. The standard size of waste plastic concrete specimens was 15 cm × 15 cm × 15 cm with the water-cement ratio taken as 0.5, and the specimens were tested on 28 days of casting in a compression testing machine. An average compressive strength of three concrete specimens for each waste plastic cube in the M20 concrete mix was taken. The effectiveness of different sizes of waste plastic cubes in the M20 concrete mix was compared and their compressive strength was evaluated. In conclusion, the findings of this study demonstrate a significant impact on the compressive strength of M20 concrete when incorporating waste plastics. Through this research, we seek to strike a balance between the convenience of waste plastic material and the sustainable concrete mix.

Keywords: Concrete, polystyrene, compressive strength, coarse aggregate, fine aggregate

INTRODUCTION

Concrete, a fundamental building material, is composed of four essential ingredients: cement, fine aggregate, coarse aggregate, and water. The unique balance mix among these components results in a durable substance widely employed in construction projects. Coarse aggregate constitutes the largest proportion of the mix, with fine aggregates, like sand, acting as filler materials that occupy the voids. The binding materials, such as lime or Portland cement, play a crucial role in uniting these components, while water reacts with the binding material to initiate the hardening process [1]. The resulting product is an artificial stone that exhibits formidable strength in compression but is relatively weak in tension [2].

Rapid industrialization has exacerbated the strain on natural resources, leading to a scarcity of traditional construction materials [3]. In response to these challenges, there has been a growing focus on exploring alternative solutions, with particular attention paid to incorporating waste materials in concrete production. This not only addresses the issue of resource scarcity but also contributes to sustainable and environmentally friendly construction practices [4].

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Our research delves into the utilization of sustainable waste alternatives within concrete mixtures. The reduction in compressive strength implies that careful consideration is essential when determining the optimal percentage of waste plastic inclusion in concrete mixtures [5].

By examining the impact of varying percentages of waste material on the compressive strength of

concrete, we aim to contribute to the ongoing efforts to develop an optimum concrete mix using waste material and result in sustainable construction as well as reduce the ecological footprint of the concrete industry [6].

Plastics have seamlessly integrated into our daily routines, revolutionizing modern living in manifold ways [7]. The use of plastic products is undeniable, with countless items molded and utilized daily to meet the diverse needs of society. However, the rapid use of plastics has given rise to a significant and escalating environmental challenge the accumulation of plastic waste [8]. Therefore, despite their widespread utility, the concerning reality is that most plastics are not biodegradable, which has led to the accumulation of an enormous amount of plastic waste globally [9].

Due to the environmental consequences of this mounting plastic waste, it becomes necessary to explore sustainable solutions that address both the prevalence of plastics in our daily lives and the challenge of waste management. The influence of waste plastic in concrete pavements, concrete blocks and pavers has been widely studied particularly in terms of durability, and strength [10, 11].

This paper deals with finding a balance between the waste material in the concrete mix. By investigating the impact of varying percentages of waste plastic content by volume on the compressive strength of concrete, we aim to uncover a potential solution for mitigating plastic waste while contributing to the development of eco-friendly construction practices without compromising the utility of the concrete.

EXPERIMENTAL PROGRAM

Material Used

1. Cement from the ACC brand used in the study is ordinary Portland cement (OPC) 53 grade as per the specification of IS code 8112:2013 and its following properties determined using a test as per IS code 4031-1988 as shown in Table 1.

Table 1. Physical properties of cement.

S/N	Properties	Value
1	Fineness of cement	Retained material under 10%
2	Standard consistency of cement	30%
3	Initial setting time	45 minutes
4	Final setting time	9 hours 30 minutes
5	Soundness test	Expansion below 10 mm

2. Sand used in the study is fine aggregates passing through a 4.75 mm sieve conforming to grading zone-II of IS 383:1970, as shown in Table 2.

Table 2. Physical properties of fine aggregate (sand).

S/N	Physical Properties	Value
1	Water absorption (%)	1.45
2	Specific gravity	2.53
3	Bulk density (kg/m ³)	1602.3
4	Shape of aggregate	Angular

3. Coarse aggregates of a maximum size of 20 mm are used in this study as per IS 383:1970. Locally available crushed stone is used in the study. The following physical properties of aggregate are shown in Table 3.

Table 3. Physical properties of coarse aggregate.

S/N	Physical Properties	Value
1	Water absorption (%)	1.52
2	Specific gravity	2.68
3	Bulk density (kg/m ³)	1328.1
4	Shape of aggregate	Angular

- Polystyrene (C₈H₈) is the waste plastic that is used in the study. It is a hard, transparent, stiff resin produced by the polymerization of styrene and is one of the most widely used plastics. It is widely used in the food service industry as rigid trays, containers, disposable eating plates, bowls, etc. The physical properties of waste polystyrene plastic is presented in Table 4.

Table 4. Physical properties of polystyrene plastic.

S/N	Properties	Value
1	Molecular weight (g/mol)	104.1
2	Density (g/cm ³)	1.04
3	Solubility in water	Insoluble
4	Melting point (°C)	240

- Potable water was used for mixing as well as curing of concrete specimens.
Nominal Mix of M20 Concrete

The concrete mix has been designed for M20 grade as per IS 10262:2009. The volume of concrete required for a cube of 150 × 150 × 150 mm mold = 0.003m³. The quantity of cement, fine aggregate and coarse aggregate are 1.47, 1.47, and 2.94 kg, respectively. The quantity of cement, sand, aggregate and water for the preparation of the M20 concrete mix is shown in Table 5.

Table 5. Nominal mix of M20 grade of concrete.

Batch	Cement	Fine Aggregate	Coarse Aggregate	Water
Quantity	28.56 kg	47.62 kg	89.29 kg	14.28 L
Ratio	1	1.5	3	0.5

Testing of Concrete Specimen

The compressive strength of concrete cubes was evaluated using a compressive testing machine, as per IS 516-1959. The concrete specimens were cast and then placed in a water tank for a specific period. The specimens were sundried before the test. The curing period of specimen is 28 days. After curing period, the specimens were tested on the compression testing machine. The results are presented in Table 6. The rate of loading is 5 kN per second and the peak load at which the specimen fails was noted.

Compressive strength of concrete in kN/m³ or MPa = P/A

where, P = load on a specimen in kN and A = area of cross-section in m²

Table 6. Results of concrete cubes.

Cube Type	Description of Cube	Sample Cube	Percentage of Plastic in M20 Concrete Mix (%)	Compressive Load (kN)	Cross-sectional Area (mm ²)	Compressive Strength (MPa)
Control cube	M20 control mix without a plastic cube	1	0	475	22500	21.11
		2	0	475	22500	21.11
		3	0	470	22500	20.08
01		1	3.7	450	22500	20.00

	M20 concrete mix with a 5 cm plastic cube	2	3.7	445	22500	19.76
		3	3.7	440	22500	19.54
02	M20 concrete mix with a 6 cm plastic cube	1	6.4	440	22500	19.54
		2	6.4	450	22500	20.00
		3	6.4	445	22500	19.76
03	M20 concrete mix with a 7 cm plastic cube	1	10.1	440	22500	19.54
		2	10.1	445	22500	19.76
		3	10.1	430	22500	19.11
04	M20 concrete mix with an 8 cm plastic cube	1	15.1	430	22500	19.11
		2	15.1	425	22500	18.88
		3	15.1	420	22500	18.67
05	M20 concrete mix with a 9 cm plastic cube	1	21.2	350	22500	15.55
		2	21.2	360	22500	16.00
		3	21.2	355	22500	15.78
06	M20 concrete mix with a 10 cm plastic cube	1	29.6	310	22500	13.77
		2	29.6	315	22500	14.00
		3	29.6	310	22500	13.77



Figure 1. (a) Preparation of concrete, (b) casting of M20 concrete with different sizes of plastic cubes, (c) setup of concrete cube specimen in compression testing machine (CTM), and (d) failure load for each specimen is noted.

RESULT AND DISCUSSION

Testing of the cast specimens was done on the 28th day for compressive strength by using hydraulic compressive testing machine (Figure 1). After conducting compressive strength testing the test results are tabulated.

The results of the pressure test unequivocally demonstrate that as the proportion of plastic trash increases, the compressive strength value drops. After 28 days, the concrete cube with 0% plastic waste displayed the maximum compressive strength value of 20.08 N/mm².

In the present investigation, it is found that optimum up to 4% by replacing waste plastics there is a slight deviation of compressive strength (Table 7). From the test results, it was observed that the compressive strength value of the concrete mix decreased with the addition of waste plastics more than

4% of waste plastics (Figures 2–4). So, we can add waste plastics in concrete blocks as this will help to reuse plastics in concrete blocks.

Table 7. Nominal mix of M20 grade of concrete.

Type of Group	Average Compressive Strength (MPa)	Percentage of Plastic Replacing Concrete (%)	Percentage of Saving in Concrete (%)	Percentage of Reduction in Strength (%)	Efficiency
CC	20.08	0	0	0.00	0.00
01	19.91	3.7	3.7	0.75	4.90
02	19.82	6.4	6.4	1.10	5.81
03	19.77	10.10	10.10	1.50	6.70
04	18.81	15.10	15.10	6.00	2.51
05	15.55	21.20	21.20	22.50	0.95
06	14.23	29.60	29.60	28.90	1.02

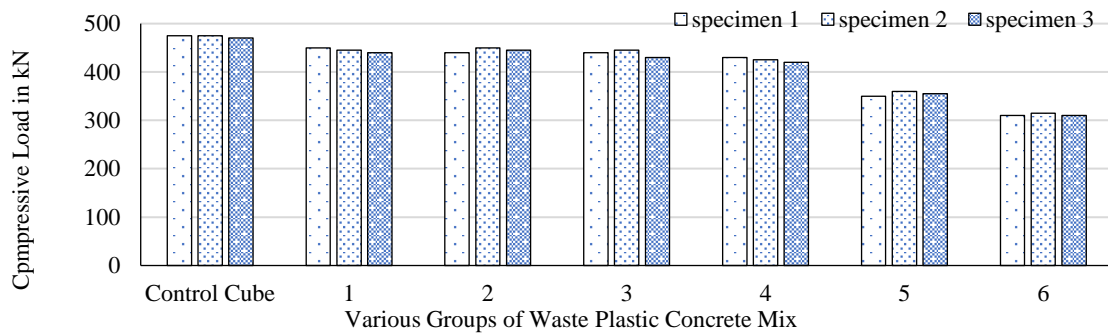


Figure 2. Graph representing failure load of three specimens of each group of waste plastic concrete mix.

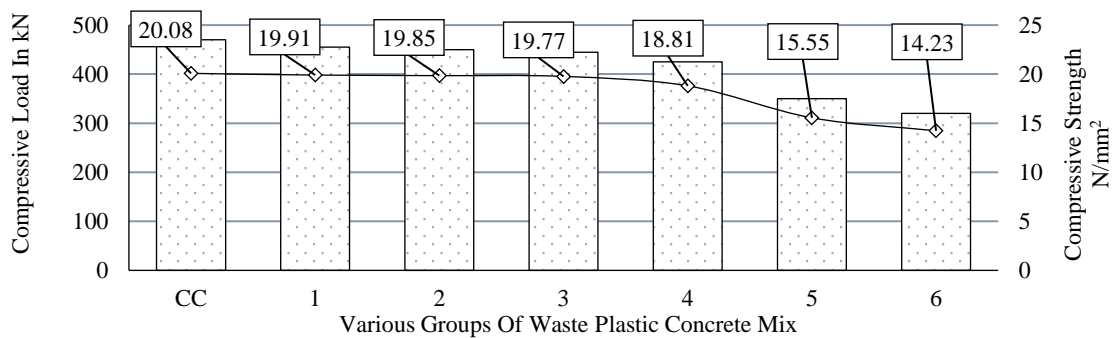


Figure 3. Graph representing average failure load and compressive strength of each group of waste plastic concrete mix.

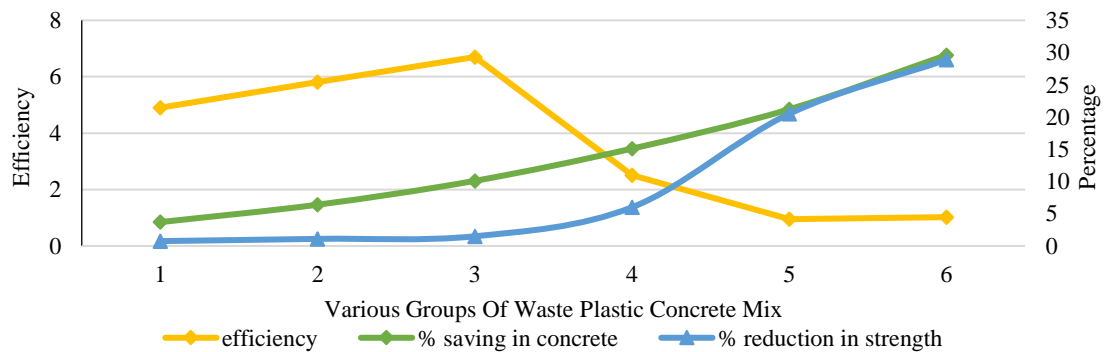


Figure 4. Graph representing percentage saving of concrete and percentage reduction in concrete and overall efficiency of each group of waste plastic concrete mix.

CONCLUSIONS

In conclusion, the research findings indicate a clear correlation between the percentage of waste plastics in a concrete mix and the resulting compressive strength. The baseline concrete cube with 0% plastic waste exhibited a maximum compressive strength of 20.08 N/mm². As the percentage of plastic waste increased, there was a noticeable decline in compressive strength.

The compressive strength values for various percentages of plastic content in the concrete mix were as follows: 19.91 N/mm² (3.7%), 19.82 N/mm² (6.4%), 19.77 N/mm² (10.1%), 18.81 N/mm² (15.1%), 15.55 N/mm² (21.2%), and 14.23 N/mm² (29.6%). As determined by the research, the optimum percentage of plastic content is 10.1%. At this level, the concrete mix demonstrates a maximum saving of concrete while experiencing a minimal reduction in strength for the M20 concrete mix.

These findings suggest that incorporating waste plastics, specifically polystyrene, in concrete construction can offer cost-effective and energy-conservative benefits. The research underscores the potential of utilizing waste materials in construction practices to address environmental concerns and promote sustainable building solutions. As we move towards more eco-friendly construction methods, the integration of waste plastics in concrete emerges as a viable and practical option, provided the optimal percentage is carefully considered for a balance between resource efficiency and structural performance.

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