Assessment of Mechanical Properties of Concrete Using Waste Plastic Gel as Replacement of Water-Cement

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Abstract- Concrete is a fundamental engineering material used in modern construction. The use of plastic waste in concrete as a binding material can reduce the use of cement and help to reduce plastic waste in the environment. This study aims to replace water cement with waste plastic gel. Plastic gels were prepared by heating mixed waste plastic in a container at high temperatures with sand and aggregate. 150 mm x 150 mm concrete Testing cubes are prepared. This study investigates the optimum quantity of waste plastic gel with different mix ratios (1:3:6, 1:2.5:5, 1:2:4, 1:1.75:3.5, and 1:1.5:3) and found that mix ratio (1:1.75:3.5) gives maximum compressive strength. Samples were tested in 3 days, 7 days, 14 days and 28 days and compressive strength was almost constat. Water absorption is also minimum in waste plastic concrete.

Index Terms Waste Plastic Concrete, Plastic Gel, Compressive Strength

I. INTRODUCTION

With the increasing demand of concrete, raw materials like coarse aggregate, river sand are abstracted from natural resources, and this makes overuse of natural resources. On the other hand, increasing use of plastic waste makes negative impacts on the environment [1]. Up to five trillion plastic bags are used annually worldwide, and one million plastic bottles are bought every minute. As plastic production and use have increased, developing countries have had difficulty controlling the garbage produced by plastic [2]. Innovative sustainable solutions are required to address the expanding global issues of management of plastic waste and reduction of natural aggregates in construction[3]. Utilizing plastic waste for construction material uses can consistently supply environmentally friendly construction materials.[4]. Around the world, concrete is a leading construction material for a variety of applications. Concrete's characteristics vary greatly due to its heterogeneity Concrete's performance is determined by the way its constituents are combined, particularly its compressive strength[5]. If 5%–20% of the sand is substituted with plastic waste, the plastic concrete's compressive strength is found to decrease by roughly 35% to 50%. The resulting concrete is feasible for non-structural elements which have not required high compressive strength, depending on the mechanical qualities found in experimental investigations with varying percentages of low-density polyethylene LDPE replacement[6]. Using a 100% plastic aggregate mix, density and compressive strength of concrete significantly decreases but is sufficient for non-structural uses [7]. Cement production is a large source of carbon emissions; the building industry has a considerable impact on environmental sustainability. Ordinary Portland cement (OPC) production requires a lot of energy because it involves calcining limestone and using fossil fuels[8]. Like Replacing aggregate by plastic waste, cement also can be replaced by plastic waste. Preparing paver block by replacing varying percentages of cement with different types of plastic waste as a binding material increases the strength of paver block with increase in plastic waste binding material, but strength is reduced by 31.17% when it is exposed to temperature[9]. The amount of plastic in the molded materials affected heat conductivity. In brick and concrete block when plastic content increased, decreases in heat conductivity were noted [10]. To create the binding phase of the plastic Waste concrete (PWC), two different kinds of plastic waste—high density polyethylene (HDPE) and low-density polyethylene (LDPE)—are mixed (HDPE/LDPE blend ratio: 50/50) and then heated at 250°C. To prepare the PWC samples, the melted plastic is then combined with sand and gravel in two plastic contents (50 percent and 60 percent). Next, the microstructure, density, water absorption capacity, stress-strain behavior, compressive and split tensile strength, and PWC samples that have been cured for 1, 3, 7, and 28 days are assessed. The study's findings demonstrate that creating construction material with melted plastics as the sole binder is feasible.[11]

Most of the research has been conducted using waste plastic as a replacement of fine and coarse aggregate by different percentages or waste plastic as a binding material prepared under controlled conditions. Controlled conditions may not be always feasible to prepare waste plastic gel. In this study Concrete was prepared using hot mixed (aggregate, sand and plastic are placed together in a container and heated container without controlling temperature to melt plastic and manually mixed all ingredients) has made, which is economical and simple method to prepare workable waste plastic concrete. The objective of this study is to determine the optimum proportion of concrete ingredients (plastic gel: sand: aggregate) which gives maximum compressive strength. Complete replacement of cement with waste plastic gel was made. Variation of compressive strength of waste plastic concrete cube with age and water absorption test was made

II. MATERIALS AND METHOD

2.1 Plastic waste

Plastic waste, including plastic bags, water bottles, junk food packing plastics etc. was collected from public places, market areas etc. randomly. Separation, shredding of plastic was not done. All types of plastic available as waste were included as raw material.

2.2 Aggregates

Fine aggregate was taken from natural rivers. IS code was used to determine Properties of fine aggregate. Lab test was made for Specific gravity and grain size distribution.

Table II.1 Materials and test detail

Material	Source	Test	Specification
Fine aggregate	River	Sieve analysis	IS 383:1970
		Water absorption	
		Specific gravity	IS 2386 (Part III) :1963
Coarse aggregate		Sieve analysis	IS 383:1970
		Water absorption	
		Specific gravity	IS 2386 (Part III) :1963

2.3 Method of mixing and sample preparation

Concrete was prepared using hot mixed (aggregate, sand and plastic mix together in a container and heated container without controlling temperature to melt plastic) has made. After completing mixed, $150mm \times 150mm \times 150mm$ cubes were prepared in mold properly placing material in three equal layers and compacted using tempering rod. Compacted specimen in the mold was then left 24 hours for cooling.

a b

Figure II-1 (a) melting of waste plastic and mixing of concrete ingredient, and (b)Test specimen/samples

2.4 Study design

Different mix proportions were taken to determine the optimum ratio of ingredients (plastic gel: sand: aggregate). Where M denotes mix and ratio are in the form of waste plastic gel: sand: aggregate

Table II.2 Mix proportion

Mix no.	Waste Plastic (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)	
			10 mm	20 mm
M (1:3:6)	10	30	30	30
M (1:2.5:5)	10	25	25	25
M (1:2:4)	10	20	20	20
M (1:1.75: 3.5)	10	17.5	17.5	17.5
M (1:1.5:3)	10	15	15	15

For each test appropriate numbers of samples were prepared and tested on respective days specified in table 2.3. Total of 60 each mix has total 15 samples and out of these 3 samples of each mix ratio was tested on each specified day. Water absorption test was conducted only for 28 days.

Table II.3 test Sample specification

Test	Shape and dimensions of the specimens	Time duration (in days)	Specification
Compressive strength	150mm × 150mm × 150mm	3,7,14, 28	IS 516:_1959
Water absorption	150mm × 150mm × 150mm	28	BS 1881-122: 2011

III.RESULTS AND DISCUSSION

Different test results for fine aggregate, coarse aggregate and concrete cube have been presented in the following section.

3.1 Test result for fine and coarse aggregate

The particle size distribution of sand was tested according to IS 383:1970 [12]. Results obtained are presented in following table 3.1. Fine aggregate used in this study falls under the zone II and Fineness modulus was 2.50

Table III.1 Gradation of sand

Sieve Size (mm)	Wt. Retain (gm)	% Retained	Cumulative Retained	% Passing	% passing Zone II (IS 383)
4.75	0	0.00	0.00	100.00	90-100
2.36	35	3.50	3.50	96.50	75-100
1.18	165	16.50	20.00	80.00	55-90
0.6	234	23.40	43.40	56.60	35-59
0.3	416	41.60	85.00	15.00	08-30
0.015	135	13.50	98.50	1.50	0-10
Fineness modulus = 250.4/100 = 2.50					

Sieve analysis of coarse aggregate 10 mm and 20 mm was done according to standard IS 383:1970 [12]using following size and result are presented in following table 3.2.

Table III.2 Sieve analysis of coarse aggregate of 10 mm size

Sieve size (mm)	Aggregate retained on each sieve (gm)	% retained	Cumulative % retained	% Passing
20	0	0	0	100
10	908	30.27	30.27	69.73
4.75	2075	69.17	99.44	0.56
Pan	17	0.57	-	-
Total	3000	-	129.71	-

Table III.3 Sieve analysis of coarse aggregate of 20 mm size

Sieve size (mm)	Aggregate retained on each sieve (gm)	% retained	Cumulative % retained	% Passing
40	0	0	0	100
20	199	6.63	6.63	93.37

10	2776	92.53	99.16	0.84
4.75	25	0.83	100	0
Total	5000	-	205.79	-

Specific gravity of fine and coarse aggregate fall under the standard of IS 2386 (Part III) :1963[13]. Value of water absorption specific gravity of fine and coarse aggregate are presented in following table 3.4.

Table III.4 water absorption and specific gravity of fine and coarse aggregate

Physical properties	Fine aggregate	10 mm	20 mm
Water absorption (%)	1.1	0.5	0.70
Specific gravity	2.66	2.70	2.78

3.2 Test Result of waste plastic cube

Test results of cubes made from waste plastic gel, sand and aggregate in different proportions show that with increase in waste plastic gel compressive strength also increases up to 1:1.75:3.5. Further increase in waste plastic gel compressive strength had decreased. It was found that Mix ratio M (1:3:6), M (1:2.5:5), M (1:2:4), M (1:1.75: 3.5) and M (1:1.5: 3) have compressive strength 4.58, 8.91, 9.85, 11.24 and 9.47 respectively. Mix ratio 1:1.75: 3.5 gave the maximum value of compressive strength. above and below this ratio compressive strength decreased.

From literature It is found that strength initially rises as resin dosage increases, but that strength either falls or stays the same as resin content grows after reaching its peak [14]. It is not same condition as resin used but in this study plastic gel is used instate of resin.

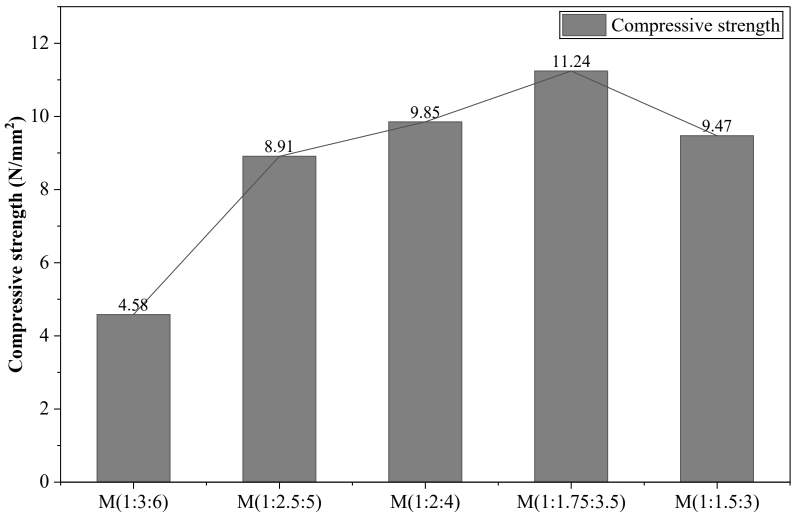

Figure III-1 28 days compressive strength of waste plastic cube

Compression test was performed on the 3rd day, 7th day, 14th day and 28th day of casting for different mix ratios. All ratios gain almost 28 days of strength at 3 days and there is no significant difference in strength with age of concrete. This result shows that waste plastic concrete can attain maximum strength in minimum days so it can be used where rapid construction is required. Waste plastic concrete reduces the curing time.

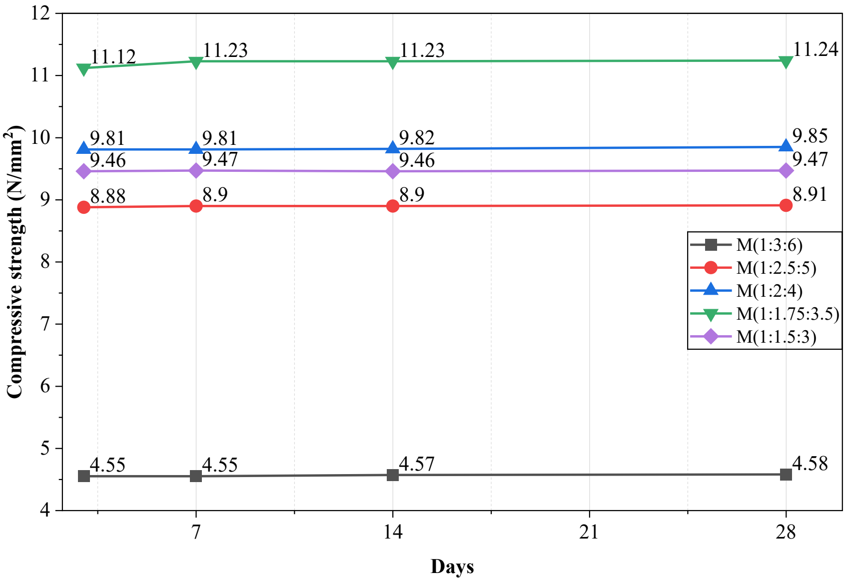

Figure III-2 Compressive strength variation with respect to age of concrete

Water absorption test at the curing age of 28 days by taking the specimens $150 \times 150 \times 150\, mm$ and result of water absorption are presented in following fig ….

$$\% \text{ Absorption} = \frac{\text{Difference in Weight}}{\text{Original Weight}} * 100\%$$

Water absorption value decreased with increase in waste plastic gel. In all ratio water absorption value is small. So, concrete made of waste plastic gel can be used in water retaining structures. Study shows that permeability and absorption depend on the interconnectivity of capillary pore.

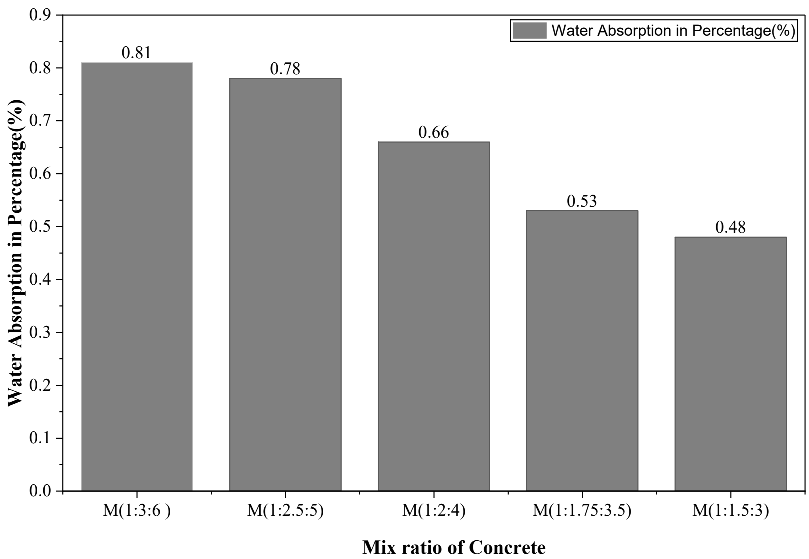

Figure III-3 Water absorption test

IV.CONCLUSIONS

In this study cement was completely replaced with waste plastic gel. Concrete cube was prepared by different mixed ratio of waste plastic gel, sand and aggregate. From obtained result following conclusion was made

i. Waste plastic Concrete has varied strength with respect to mix ratio. Maximum strength 11.24 N/mm^2 was obtained at M (1:1.75:3.5). Strength of concrete above and below this ratio was decreased. From compressive strength point of view concrete made using plastic waste gel can be used in any non-structural member.

ii. Waste plastic concrete gained full strength in short time, i.e. from test results 3 days' strength and 28 days' strength are nearly equal. So, curing time can be reduced using waste plastic gel instate of cement in concrete. Waste plastic concrete can be used where rapid construction is required.

iii. From Waster absorption test result can be conclude waste absorption value decreases with increase in waste plastic gel. Water absorption value is low in all types of mix so that waste plastic concrete can be used in water retaining structures and damp proofing.

V. RECOMMENDATIONS

Temperature effect is not considered in test. Tests can be done in different temperature conditions. Durability aspect of waste plastic concrete is also not considered in this study.

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