STUDY ON PARTIAL REPLACEMENT OF PLASTIC WASTE AS FINE AGGREGATE IN CONCRETE

Elango A[1], Ashok Kumar A[2]
[1,2]Assistant Professor, [1]TKR College of Engineering & Technology (K9),
[2]TKR Engineering College (R9),Hyderabad, Telangana State.

ABSTRACT

Disposal of used Plastics is a major problem in the present era, as the usage of plastics is growing day by day and it takes hundreds of years for plastic material to degrade. So effective ways to recycle & reuse of plastics are being formulated. According to their composition, plastics have been classified into seven types each having their own recycle rate. The used plastics were collected, ground into smaller components, pulverized in order to get granules of plastic lower than 4.75mm size. The density of the Pulverized plastic was found to be 460 kg/m^3 & its specific gravity was 1.1. Sieve analyses were carried out & about 75% of the plastics were found to be in the range of 1 -1.7mm. 24 nos. of 10cm x10cm x10 cm cement concrete Cubes of 1:1.7:3.1 (M 20) mix were cast for 0%, 10%, 20%, 30%, sand being replaced with Pulverized plastic material. Volumetric proportioning was adopted instead of design mix since the density of plastic material was too low. Workability test, weight and compressive strength of the cubes were determined. The test results revealed that the compressive strength of concrete at seventh day decreased by about 3 to 3.2 N/mm^2 for 20% replacement & 4 to 6.5 N/mm^2 for higher replacements of Plastic when compared to conventional concrete. The water Cement ratio was also found to increase with the proportion of Plastics for a slump of 10 mm & weight of the cube decreased with an increase in replacement of Sand by Plastic Material. Thus it is inferred that Replacement of sand by plastic up to 20% can be adopted so that disposal of used plastic can be done as well the deficiency of Natural aggregates can be managed effectively.

KEYWORDS: Compressive strength, Flexural strength, Tensile strength, Plastic waste, Workability, Weight, Plastic partially replaced concrete.

1 INTRODUCTION

Due to rapid industrialization & urbanization in the Country, lots of infrastructure developments are taking place. This process has in turn led questions to mankind to solve the problems generated by this growth. The problems defined are acute shortage of constructional materials, increased dumping of waste products due to the very low biodegradability and the presence in large quantities of plastic waste, the disposal of these wastes constituted a major benefit to the environment protection. Today, research tends to the study of the possibility of recycling of these wastes in concrete where strength of concrete may not be major criteria under consideration, such as heavy mass of concreting in PCC (Portland Cement Concrete) in pavements. Recently, research works showed that, the plastic is becoming a major research in concrete of in self-compacting concrete and light weight concrete .Hence in order to overcome the above said problems waste products should be employed as construction material. Fine aggregates used in cement concrete is replaced by fine crushed plastics in known percentages and the optimum percentage at which higher strength is obtained is being calculated. In this investigation, we made the comparison of yield strength as well as ultimate strength for conventional concrete and concrete containing plastics at 7, 14, 28 days respectively. M20 grade concrete is chosen for the investigation. An attempt is made to find the optimum sand replacement by pulverized plastic in concrete.

Plastics The seven types are PET-Polyethylene Teraphthalate, HDPE- High Density Polyethylene, PVC-Polyvinyl chloride, LDPE- Low density Polyethylene, PP – Polypropylene, PS- Polystyrene, and Other PC- Polycarbonate. Combination of those plastics was adopted to be the replacementmaterial. This is mainly because of the easy availability of the plastic material, its density &workability. The various stages of processing of plastics into fine grain form The Properties of plastics are then analyzed by performing density, specific gravity & sieve analysis tests. Density of the material is determined by finding the weight and volume of a specified material. Then sieve analysis and specific gravity were done for a given amount of sample. It is also studied that there is lesser reaction between aggregate and reinforcements as the cleaned plastic material is almost inert.

Plastic type	Name	Properties	Density Range	Common Uses
1 PETE	Polyethylene Terephthalate	Tough, rigid, shatter-resistant softens when heated	1.38-1.39 g/mL	Soda, water, juice, and cooking oil bottles
2 HDPE	High Density Polyethylene	Semi-rigid, tough, and flexible	0.95-0.97 g/mL	Milk and water jugs, bleach bottles
3 PVC	Polyvinyl Chloride	Strong, semi-rigid, glossy	1.16-1.35 g/mL	Detergent bottles, shampoo bottles, shrink wrap, pipes
4 LDPE	Low Density Polyethylene	Flexible, not crinkly, moisture proof	0.92-0.94g/mL	Garbage bags, sandwich bags, 6-pack rings
5 PP	Polypropylene	Non-glossy, semi-rigid	0.90-0.91 g/mL	Yogurt cups, margarine tubs, screw-on lids/ caps
6 PS	Polystyrene	Often brittle, sometimes glossy, often has strong chemical reactions	1.05-1.07 g/mL	Styrofoam, egg cartons, packing pellets, take-out containers

Fig. 1. Type and characteristics of plastic waste

2 EXPERIMENTAL METHODOLOGY

The test program consisting of casting and testing of concrete cubes (100mm x 100mm x 100mm) 6 No's are made to determine the compressive strength of M20 concrete with the ingredients of ordinary Portland cement 53 Grade, natural river sand and the crushed stone of maximum size 20 mm and also casting and testing of partially plastic waste replaced (10%, 20% & 30% of replacement with fine aggregate in concrete) concrete cubes (100mm x 100mm x 100mm), cylinders(100mm x 200mm),prisms (500mm x 100mm x100),cylinders (150mm x 300mm) are made to determine the compressive strength, flexural strength, modulus of elasticity and durability properties of concerned specimens with the grad of M20 concrete with ingredients of ordinary Portland cement 53 Grade, natural river sand and the crushed stone of maximum size 20 mm were used. Each three numbers of specimens of average value gives the mechanical and durability properties of concrete for curing period of 7 and 28 days.

Table 1 Preliminary test results on materials

Materials	Specific gravity	Fineness modulus
Cement	3.15	-
Coarse aggregate	2.70	-
Fine aggregate	2.69	2.5
Plastic waste	1.1	3.75

Mix proportion

The grade of concrete used in the present investigation was M20.The mix was designed using IS 10262-2009. The mix design and the proportions of the mixes of materials required for 1 cubic meter of concrete in ordinary grade concrete

Table 2 Mix Proportion for Reference Concrete

CEMENT		FINE AGGREGATE		COARSE AGGREGATE		WATER (l/m^3)	W/C
Weight (kg)	Volume (kg/m^3)	Weight (kg)	Volume (kg/m^3)	Weight (kg)	Volume (kg/m^3))		
1207	383.2	1786	664.32	3120	1185	191.2	0.5

Table 3 Mix Proportions for Partially Replaced Plastic Waste Concrete

% of plastic waste replacement (design mix) (C:F.A:C.A:P.W)	CEMENT		FINE AGGREGATE				COARSE AGGREGATE		WATER (l/m^3)	W/C
			SAND		PLASTIC					
	Weight (kg)	Volume (kg/m^3)	Weight (kg)	Volume (kg/m^3)	Weight (kg)	Volume (kg/m^3)	Weight (kg)	Volume (kg/m^3)		
10% plastic waste replacement **(1:1.6:3.09:0.1**)	1207	383	1664	618.75	50.116	45.56	320	1185	192	0.5
20% plastic waste replacement **(1:1.5:3.09:0.2)**	1207	383	1542	573.2	100.2	91.12	320	1185	192	0.5
30% plastic waste replacement (**1:1.4:3.09:0.3**)	1207	383	1418.2	527.24	150.34	136.68	320	1185	192	0.5

2.1 COMPRESSIVE STRENGTH TEST

In the case of cubes, the specimen is placed in the machines such a manner that the load is applied to opposite sides of the cubes as cast as shown in Figure, the axis of the specimen is carefully aligned with the center of thrust of the spherically seated plate. No packaging is used between the face of the test specimens and the steel plate of the testing machine. A spherically seated block is brought to bear on the specimens; the movable portion is rotating gently by hand so that uniform seating may be obtained. The load is applied without shock and increased continuously until the resistance of the specimen to the increasing load can be sustained. The maximum load to the specimens is then recorded.

$$\textbf{Compressive strength} = \frac{\text{ultimate load}}{\text{area of specimen}}$$

Table 4 Result of Compressive strenght

Specimen (cube 100mm x 100mm x100 mm)	Avg compressive strength results (7days)	Avg compressive strength results (28days)
Reference concrete	19.5	26.6
10% partially plastic waste replaced concrete	18.5	25.6
20% partially plastic waste replaced concrete	18.2	21.33
30% partially plastic waste replaced concrete	10.7	14.4

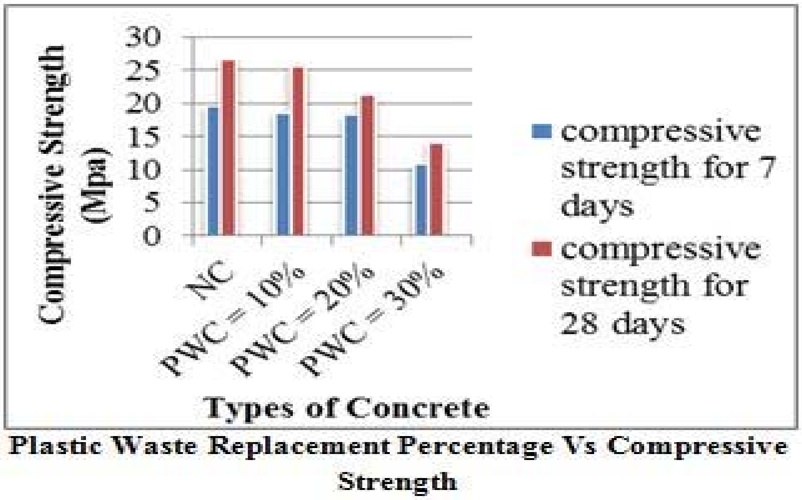

Fig.2 plastic Waste Replacement Percentage Vs Compressive Strength

2.2 MODULUS OF ELASTICITY

For cylinder of size 150mm diameter and 300mm long were cast to determine the Modulus of Elasticity of concrete. The cylinder were placed inside the young's modulus testing apparatus called compressometer, providing equal clearance to top and bottom of specimen. Each cylinder was tested in 300T capacity compression testing machine (CTM). Loads were applied by means of 1T and the reading is noted in the deflectometer.

Table 5 Result of Elasticity

S.No	Concrete type	Experimental Value × 10^4 (N/mm^2)	Theoretical Value × 10^4 (N/mm^2)
1	Reference concrete	2.25	2.23
2	10% of plastic waste replaced concrete	2.01	2.23
3	20% of plastic waste replaced concrete	1.8	2.23
4	30% of plastic waste replaced concrete	1.40	2.23

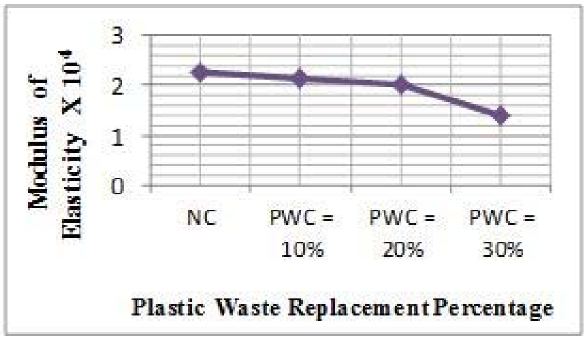

Fig 3. **Plastic Waste Replacement Percentage Vs Modulus of Elasticity x 10^4**

The results of modulus of elasticity of concrete containing different percentages of plastic aggregates. They concluded that the value of modulus of elasticity decreased with increase of plastic waste partially replaced as fine aggregate in concrete.

2.3 FLEXURAL STRENGTH TEST

For each mix two prisms of size 500mm long, 100mm breadth, and 100mm depth were cast to determine the flexural strength of concrete. The prisms were placed on the two supports. The applied load is distributed by two points (two point load). The load is applied gradually, the breaking points of the results as shown in table 3.11 and graph 3.10. Tests were conducted as per IS 516-1959.

Table 6 Result of Flexural Strength

S.No	Concrete Type	Experimental Value (N/mm^2)	Theoretical Value (N/mm^2)
1	Reference concrete	3.4	3.13
2	10% of plastic waste replaced concrete	3.2	3.13
3	20% of plastic waste replaced concrete	3	3.13
4	30% of plastic waste replaced concrete	2.6	3.13

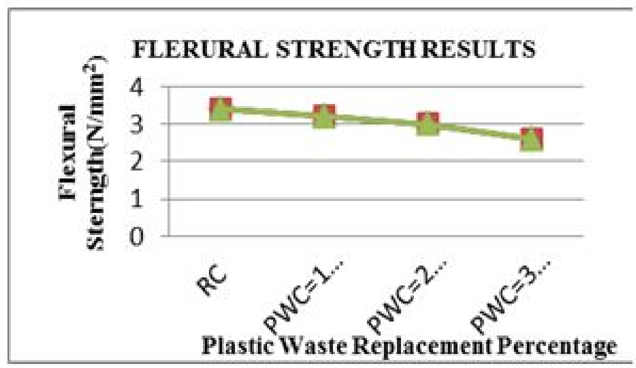

Fig 4 .Test Results for Flexural Strength

Concrete mixes of up to 30 percentages of plastic particles are proportioned to partially replace the fine aggregates. They concluded that the addition of plastics as fine aggregate in concrete led to a reduction in the flexural strength of the tested samples.

DURABILITY PROPERTIES

2.4 DENSITY, ABSORPTION AND VOIDS IN CONCRETE:

Density, Absorption and Voids were tested as per ASTM C 642-06. This test method is useful in developing the data squired for conversions between mass and volume for concrete. It can be used to determine conformance with specifications for concrete and to show difference from place to place within a mass of concrete

Table 7 Water Absorption, Density & Voids for Reference Concrete

S. NO	Specimen size(mm)	Weight 'A' (g)	Weight 'B' (g)	Weight 'C' (g)	Weight 'D' (g)	Water absorption (%)	Density (g/cm^3)	Voids (%)
1	100 × 100 × 100	2400	2502	2560	1445	4.3	2.15	14.3
2	100 × 100 × 100	2388	2508	2560	1421	4.9	2.09	15.1
3	100 × 100 × 100	2402	2522	2589	1450	4.8	2.10	16

Table 8 Water Absorption, Density & Voids For 10% of Plastic Waste Partially Replaced Concrete

S. NO	Specimen size(mm)	Weight 'A' (g)	Weight 'B' (g)	Weight 'C' (g)	Weight 'D' (g)	Water absorption (%)	Density (g/cm^3)	Voids (%)
1	100 × 100 × 100	2328	2395	2460	1420	4.4	2.2	15.9
2	100 × 100 × 100	2300	2385	2495	1390	3.6	2.08	17.6
3	100 × 100 × 100	2318	2405	2518	1364	3.7	2.00	17.3

Table 9 Water Absorption, Density & Voids For 20% of Plastic Waste Partially Replaced Concrete

S. NO	Specimen size(mm)	Weight 'A' (g)	Weigh t 'B' (g)	Weight 'C' (g)	Weight 'D' (g)	Water absorption (%)	Density (g/cm^3)	Voids (%)
1	100 × 100 × 100	2240	2320	2380	1384	3.5	2.2	21.8
2	100 × 100 × 100	2248	2323	2438	1392	3.3	2.1	18
3	100 × 100 × 100	2258	2334	2486	1374	3.3	2.03	20.5

Table 10 Water Absorption, Density & Voids For 30% of Plastic Waste Partially Replaced Concrete

S. NO	Specimen size(mm)	Weight 'A' (g)	Weight 'B' (g)	Weight 'C' (g)	Weight 'D' (g)	Water absorption (%)	Density (g/cm^3)	Voids (%)
1	100 × 100 × 100	2187	2253	2330	1371	3.0	2.2	25
2	100 × 100 × 100	2192	2254	2432	1375	2.8	2.07	23
3	100 × 100 × 100	2172	2236	2384	1378	3.0	2.1	22

2.5 ACID RESISTANCE TEST

Acid Resistance on concrete has been reported from many other parts of the world. 100mm size cube specimens are taken out from the curing tank after 28 days of curing the specimens are allow drying for 5 days and noting the initial weight. The surfaces of the specimen are thoroughly noted. Then 5% HCL (M= 35.43 g/mol) is mixed per liter of ordinary water. Cube specimens are then immersed completely in the acid solution for 7 days. After 7 days the cube specimen are taken out from the acid solution and kept dried.

Table 11 Test Results for Acid Attack Test (Reference Concrete)

Mix	Before Immersion of sulphate (kg) (28 days)	After immersion of sulphate (kg) (28 days)	Weight Loss (kg)	Comp. Strength Before Immersion of sulphate (N/mm^2)	Comp. Strength After Immersion of sulphate (N/mm^2)
Reference concrete	2.419	2.401	0.018	24.5	23.2
	2.411	2.402	0.009		
	2.416	2.409	0.007		
	2.401	2.389	0.012		

PWC 10%	2.392	2.374	0.018	21.5	20.2
	2.388	2.373	0.015		
PWC 20%	2.218	2.187	0.0031	20.6	18.7
	2.193	2.126	0.067		
	2.203	2.170	0.033		
PWC 30%	2.200	2.090	0.11	14.5	12.2
	2.110	2.080	0.03		
	2.010	1.970	0.04		

2.6 SULPHATE RESISTANCE TEST

Sulfate resistance test was conducted on 100 mm x 100 mm x 100mm cube specimen at 28 days. The sulfate solution was prepared by mixing 5% sodium sulfate and 5% magnesium sulfate in distilled water. The specimen was immersed in the sulfate solution for 24 hours, and it was allowed to dry for 24 hours at room temperature. This alternative wetting and drying is once cycle. Like this, the specimen was subjected to 30 cycles. Then the specimen was tested for compressive strength.

.Table 12 Result of Sulphate Resistance Test

Mix	Before Immersion of Sulphate (kg) (28 days)	After immersion of Sulphate (kg)(28 days)	Weight Loss (kg)	Comp. Strength Before Immersion of Sulphate (N/mm²)	Comp. Strength After Immersion of Sulphate (N/mm²)
Reference concrete	2.462	2.454	0.008	26.5	24.6
	2.418	2.413	0.005		
	2.410	2.401	0.009		
PWC 10%	2.385	2.365	0.02	2	23.8
	2.353	2.333	0.02		
	2.364	2.334	0.03		
PWC 20%	2.264	2.239	0.025	19	17
	2.256	2.228	0.028		
	2.252	2.220	0.032		
PWC 30%	2.110	2.01	0.10	15.4	14.2
	2.168	2.038	0.13		
	2.185	2.015	0.17		

RAPID CHLORIDE PENETRATION TEST

The test method consist of monitoring the amount of electrical current passed through 50 mm thick slices of 100 mm nominal diameter cores or cylinders during 6 hours at 30 minutes interval. The rapid chloride penetration test line diagram is shown in Fig.5 & 6.

Table 13 Rapid Chloride Penetration Test

Charge passed (coulombs)	Chloride penetration
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
0p<100	Negligible

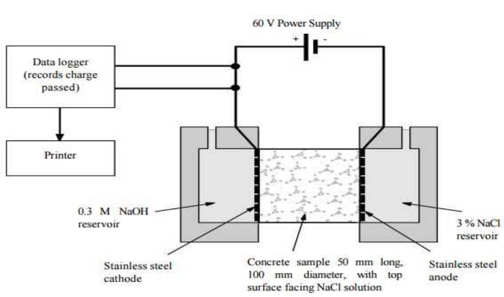

Fig 5 Rapid Chloride Penetration Test

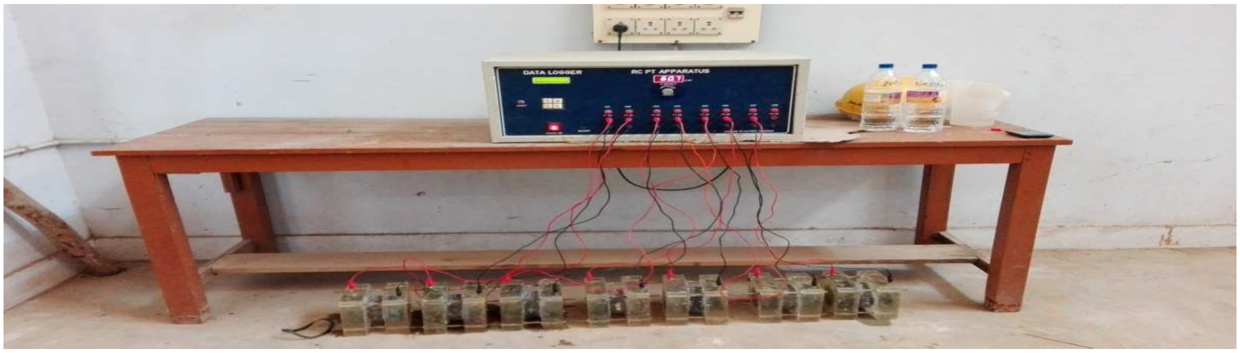

Fig 6 RCPT Test Setup

Table 14 Rapid Chloride Penetration Test-28 days

S.No	Time (Minutes)	RC mA	PWC 10% mA	PWC 20% mA	PWC 30% mA
1	0	41	46	52	72
2	30	44	51	56	78
3	60	47	56	60	81
4	90	49	58	62	86
5	120	52	61	66	92
6	150	56	66	68	97
7	180	64	67	71	99
8	210	66	69	79	105
9	240	70	76	84	112
10	270	72	86	89	125
11	300	76	88	93	137
12	330	79	90	98	143
13	360	81	92	101	145

Table 15 RCPT Results for 28 days

Mix Designation	Q = Charge passed (Coulombs)	RCPT Charge (Coulombs)	Remarks
RC	1410	1272	Low
PWC 10%	1589	1434	Low
PWC 20%	1668	1505	Low
PWC 30%	2340	2111	Moderate

RESULTS AND DISCUSSION

✓ The Same water cement ratio the slump of concrete is found to decrease with increase in replacement of Sand by Plastic material upto20% due to the angular and non-uniform plastic waste aggregates with sharper edges, beyond 20% replacement the concrete become stiffened and it is difficult to workable.

✓ The Weight of the cube decreases with an increase in replacement of Sand by Plastic material. It is seen that the decrease in weight is linear with increase in replacement.

✓ The variation of strength with age of Conventional and concrete with 10% replacement Sand by Plastic material follows a similar pattern.

✓ There is Gradual decrease in compressive strength for replacement up to 20% and then the strength decreases rapidly for 30% of Sand by Plastic material, after 30% the strength variation is somewhat gradual because unlike natural aggregate plastic waste aggregate cannot interact with cement paste and therefore the interfacial transition zone (ITZ) in aggregate containing plastic waste aggregate is weaker than that in the reference concrete.

✓ The reductions in flexural strength and E for concrete were relatively less prominent than the reduction in compressive strength of concrete due to incorporation of plastic aggregate.

✓ Considering durability properties up to 20% of plastic replacement the acid attack resistance and sulphate attack resistance of concrete are getting decreased due to increasing the incorporation of plastic waste as fine aggregate in concrete. Beyond 20% the concrete can afford only small amount of resistance against acid and sulphate attack

✓ Considering water absorption and voids, the water absorption getting reduced due to increase of plastic waste as fine aggregate because plastic waste has less water absorbing ability compared to the natural fine aggregate. Voids are getting increased to the increase of plastic aggregate due to various shapes and different types of plastic waste materials are used as fine aggregate in concrete.

✓ Rapid chloride penetration test shown that the penetration of chloride is low up to 20% of plastic waste replaced as fine aggregate. Beyond 20% the chloride penetration increased due to increase in porosity of concrete and inefficient bond between the plastic and other participants in concrete.

Conclusion

✓ Recycling of plastic waste with river sand reduces its negative environmental impact of river sand quarries, reduces the depletion of natural resources.

✓ Reuses the waste plastic products of plastic industry and reduces the amount of waste correlated with these industries.

✓ Replacements of river sand with different percentages of plastic waste (10%, 20%&30%of partial replacement) did not have a huge negative effect on the consistency of fresh concrete properties of concrete up to 20% of replacement. As for the hardened concrete properties, average reductions of 25.2%, 22.76 and 13.6% were recorded relative to the control mix in the compressive strength, modulus of elasticity and flexural strength values respectively. The Reductions were not significantly affected by the percentage replacement of normal concrete with plastic partially replaced concrete.

✓ Results of this test program have a positive impact on the usage of waste plastic fine aggregate in concrete making.

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