EVALUATION OF STRENGTH AND DURABILITY OF WASTE PLASTIC MIX CONCRETE

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ABSTRACT *The safe disposal of plastic is the most challenging issue for the solid waste management across the globe. Concrete is one of the best choices of construction material in many countries today. This has increased the fast vanishing of natural resources. It could be worth experimenting the use of plastic waste in concrete to overcome the duel issues of shortage of raw material and safe disposal of plastic waste. This work aims to study the possibility of disposing waste plastic as fine aggregate in concrete. In this study waste plastic mix concrete is also reinforced with polypropylene fiber to get the advantages of fiber reinforced concrete. For this, an experimental study was carried out with three different grade of concrete (M20, M25 & M30) to evaluate mechanical and durability properties of waste plastic mix concrete with and without the addition of fiber. Sand is substituted with plastic waste at a dosage of 15% by volume which is the optimum percentage without considerable reduction in strength. Results show that adding polypropylene fiber we can improve the quality of waste plastic mix concrete. Thus it is inferred that replacement of sand by plastic waste up to 15% can be adopted so that disposal of used plastic can be done as well as deficiency of natural aggregate can be managed effectively.*

Keywords: *Normal concrete; Waste plastic; Fiber; Mechanical and Durability properties.*

1. INTRODUCTION

Due to rapid industrialization and urbanization in the country, lots of infrastructure developments are taking place. This process has in turn pose questions to mankind to solve the problems generated by this growth. The problem defined is acute shortage of construction material and increased dumping of waste materials [2]. Hence in order to overcome the above said problems waste products should be employed as construction material. The consumption of plastic has grown substantially all over the world; it leads to create large quantities of plastic based waste. Disposal of used plastic is the major problem in the present era, as the usage of plastic is growing day by day and it takes hundreds of years for plastic materials to degrade. It neither decays nor degenerates either in water or soil. It produces many toxic gases when burns. So an effective way to recycle and reuse of plastic is to be formulated. Otherwise it will be very harmful to our sustainable environment.

Concrete is the versatile material for civil engineering construction. The major problem in construction industry is the unavailability of construction materials. Sustainable concrete has received great attention in today's scenario of scarcity of resources [4]. Various attempts have been made to reduce the use of fine aggregate, course aggregate and other ingredients of concrete which are nonrenewable. So search for new construction materials and a method to dispose plastic waste introduce a new concept called waste plastic mix concrete (WPC).Past investigation suggest that partial replacement of aggregate of concrete with waste plastic can improve properties such as abrasion resistance, impact resistance, ductility, shock absorption and thermal conductivity. It also shows that addition of plastic to concrete causes some reduction in mechanical properties such as compressive strength, split tensile strength, flexural strength etc. Literature reviews suggest that addition of polypropylene fiber in normal concrete (NC) improves these mechanical properties. Taking the advantages of this, polypropylene fibre is added to WPC to make polypropylene fibre reinforced waste plastic mix concrete (PFR-WPC). However, no attempt has been made so far to evaluate the effect of addition of polypropylene fiber to WPC.

This paper reports the strength and durability characteristics of waste plastic mix concrete with and without addition of polypropylene fiber specimens of strength 20 to 30 MPa. Tests were performed for cube and cylinder compressive strength, split tensile strength, flexural strength, water absorption, sorptivity and resistance to marine and acid attacks.

2. MATERIAL SPECIFICATION

2.1. *Cement*

Portland pozzolana cement conforming to IS: 1489
part I 1991 was used in this study.

Table 1. Properties of cement

Properties		
Standard Consistency		30%
Specific Gravity		3.1
Fineness		0.85%
Setting Time	Initial	120 minutes
	Final	310 minutes
Compressive Strength	3 Days	29.4 M Pa
	7 Days	38 M Pa
	28 Days	43 M Pa

2.2. *Fine aggregate*

M sand passing through 4.75 mm IS sieve conforming to grading zone II of IS 383:1970 and having specific gravity of 2.5 was used in this study.

Table 2. Properties of fine aggregate

Properties		Results
Fineness modulus		3.83
Specific gravity		2.5
Water absorption		1.8%
Void ratio		0.455
Bulk density	Loose	1636 Kg/m3
	Compact	1725 Kg/m3

2.3. *Coarse aggregate*

Crushed aggregate available from local sources with maximum size of 20 mm and conforming to IS 2386:1963 (part I, II and III) was used as coarse aggregate in this study.

Table 3. Properties of coarse aggregate

Properties		Results
Fineness modulus		5.6
Specific gravity		2.8
Water absorption		5%
Void ratio		0.699
Bulk density	Loose	1503 kg/m3
	Compact	1690 kg/m3

2.4. *Plastic waste*

Plastic aggregate is obtained by crushing the plastic waste. Maximum size of particle is 4.75mm and conforming to grading zone II.

Fig. 1. Plastic waste aggregate

Table 4. Properties of plastic aggregate

Properties	Results
Specific gravity	0.75
Fineness modulus	2.86
Zone	II
Water absorption	Nil

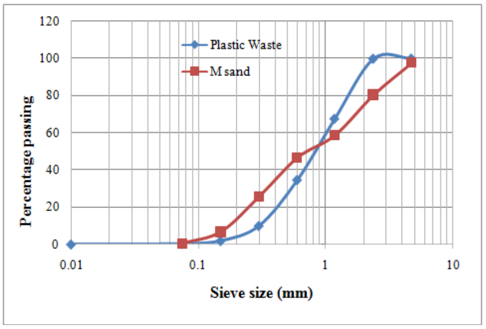

Fig. 2. Grain size distribution of fine aggregate and fine plastic

2.7. *Polypropylene fiber*

Fig 3.shows the polypropylene fiber used in present
study.

Fig. 3. Polypropylene fibre

3. EXPERIMENTAL METHODOLOGY

3.1. *Concrete mix design*

Based on trial mixes for different proportions of ingredients, the final design mix was prepared forM20, M25 and M30 grade of concrete as per IS10262:2009. The concrete mix proportion and w/cratio is given in the table5. The shredded plastic waste is added to concrete by 15% by volume which is the optimum percentage without considerable reduction in strength. The different specimens as per the requirement of test were cast. The specimens were tested after 28 days of curing. In each category there should be three specimens to be tested and average value is reported in the form of graphs.

4. MECHANICAL PROPERTY TESTS

The mechanical properties such as cube and cylinder compressive strength, split tensile strength and flexural strength were investigated.

Three specimens were cast for each test and average value was recorded.

4.1 *Compressive strength of concrete cubes*

The compressive strength was determined to find out the behaviour of NC, WPC and PFRWPC elements in compression. Preparation of specimens and testing were done as per IS: 516-1959. The specimens of size 150 × 150 ×150 mm were cast with the required mix proportions and were cured for 28 days for 28 day compressive strength. Compression testing machine of loading rate 11 kN/sec was used for the test. The loading was continued gradually and maximum load applied on the specimen was noted. Figure 4 shows the compressive strength of NC, WPC and PFRWPC.

Compressive strength was obtained by dividing the maximum load by the area of cross section of the specimen.

Compressive strength = F/A M Pa

Where, F = failure load in Newton

A = area of cross section of specimen in mm2

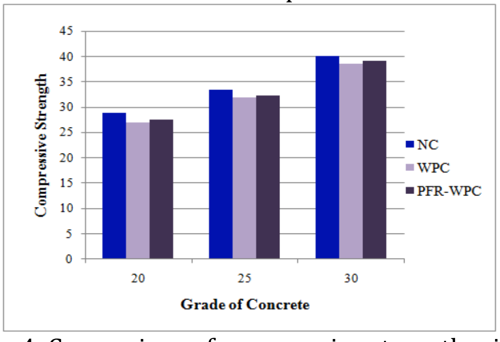

Fig. 4. Comparison of compressive strength with design strength

4.1.1. *Discussion on compressive strength test results*

The compressive strength of WPC was lowered by the addition of plastic, the reduction being in the range 4 to 7 %. This loss may be attributed to the poor bond strength between plastic particles and concrete. But this loss was compensated to a certain extent by the addition of polypropylene fibers to WPC whereby the loss percent reduced to around 3%.

4.2. *Split tensile strength*

The behavior of NC, WPC and PFRWPC elements in direct tension was determined by this test. The split tensile strength test was conducted on cylinders of size 150 Φ x 300mm at the age of 28 days confirming to IS: 5816-1970. The specimen was mounted on the testing platform of the compression testing machine. Two packing strips of 3 mm thick metal were placed at top and bottom. Load was applied uniformly till 37 breaking and the load was recorded. Figure 5 shows the compressive strength of NC, WPC and PFRWPC.

The split tensile strength was calculated as:

Split tensile strength = $2P/(\pi DL)$

Where, P = Load at failure

D = Diameter of the cylinder

L = Length of the cylinder

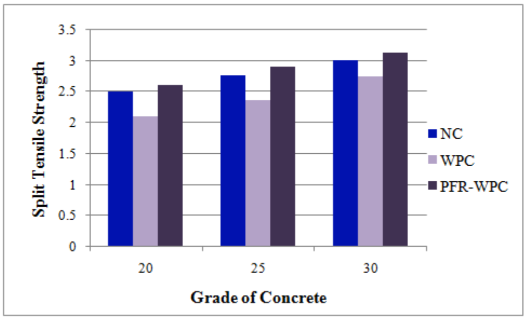

Fig. 5. Comparison of split tensile strength with design strength

4.2.1. *Discussion on split tensile strength test results*

The split tensile strength of WPC was lowered by the addition of plastic, the reduction being in the range 10 to 15 %. This loss may be attributed to the poor bond strength between plastic particles and concrete. But this loss was compensated to a certain extent by the addition of polypropylene fibers to WPC .There will be an increase in split tensile strength around 5 %..

4.3. *Flexural strength*

The flexural strength was conducted on prisms of size 100 × 100 × 500 mm at the age of 28 days and confirming to IS 516-1959 to find out the behavior of beams and other flexural members when cast with NC, WPC and PFRWPC. The specimen was mounted on the universal testing machine and two point loading was applied hydraulically which was increased until failure. Figure 6 shows the flexural strength of NC, WPC and PFRWPC. The flexural strength of prisms was calculated as follows:

Flexural strength = $PL/bd2$

Where, P = Maximum load applied to the specimen

b = Measured width of the specimen

d = Measured depth of the specimen

L = Length of the span

4.3.1. *Discussion on flexural strength test results*

The flexural strength of WPC was lowered by the addition of plastic, the reduction being in the range 10 to 18 %. But this loss was compensated to a certain extent by the addition of polypropylene fibers to WPC .There will be an increase in flexural strength around 25 %.

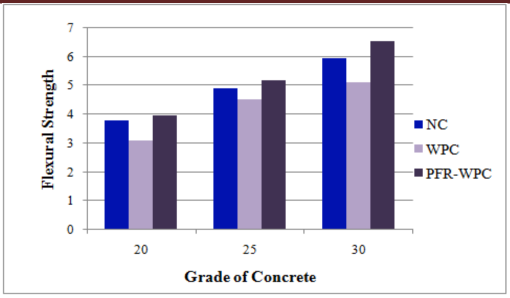

Fig. 6. Comparison of flexural strength with design Strength

5. DURABILITY PROPERTY TESTS

The durability properties such as water absorption, sorptivity, and resistance to seawater attack and acid attack were investigated. Three specimens were cast for each mix and the average value was used for the analysis. The durability test details are discussed below.

5.1. *Water absorption*

The water absorption test was carried out following IS 1237:1959 on 100 mm cube specimens to determine the porosity of specimens containing plastic aggregates. Figure 8 shows the results on NC, WPC and PERWPC. The water absorption of all the mixes was well below the permissible value of 10%. As the compressive strength increased, the mixes showed a decreasing capacity for water absorption. The water absorption of WPC was 50% of that of conventional NC. The presence of plastic particles which do not absorb water could be responsible for this result. The 15% higher absorption in PFRWPC over WPC may be attributed to the polypropylene fibers entrapping air during mixing.

5.2. *Sorptivity*

Sorptivity is a measure of the capillary force exerted by the pore structure causing fluids to be drawn into the body of the material. It is calculated as the rate of capillary rise in a concrete prism placed in 2 to 5 mm deep water.

For one-dimensional flow, the relation between absorption and sorptivity is given by, $i = St0.5$

where, i is the cumulative water absorption per unit area of inflow surface, S is the sorptivity and t is the elapsed time. The test was conducted in the laboratory on 100 mm diameter and 50 mm thick specimens preconditioned to a certain moisture level by drying in an oven at 50oC for 7 days. After cooling, the sides of the concrete samples were sealed and the initial weight was taken. The samples were then kept in a tray so that 2 to 5 mm depth was immersed in water as shown in Figure. At selected intervals of 1, 2, 3, 4, 5, 9, 12, 16, 20 and 25 minutes; the sample was removed and was weighed after blotting off excess water. The gain in mass per unit area over the density of water (gain in mass/unit area/density of water) versus the square root of time was plotted (not shown). The slope of the best fitting line was reported as the sorptivity.

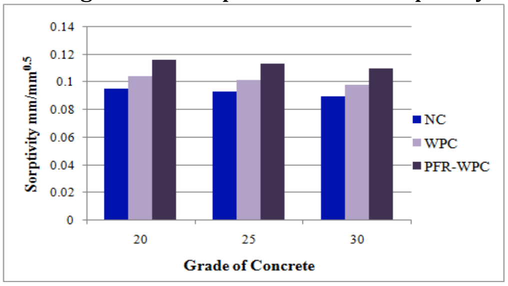

Fig 9. Comparison of sorptivity with design strength

Figure 9 shows that the sorptivity of WPC and PFRWPC were higher than that of NC. This may be due to the following reason. In the case of WPC, the plastic particles finer than fine aggregate act as micro fillers and fill most of the pores in the core portion of concrete. However, it may be noted that the interfacial shear between the plastic particles and the rest of the matrix is less. This leads to a relatively porous concrete in the outer shell of the specimen when compared to the core portion. Since sorptivity measures the capillary flow over a very small depth of 2 to 5mm which invariably lies in the outer shell, plastic waste mix concrete shows higher values of sorptivity in comparison to NC. The sorptivity values of all the specimens were in the permissible range of 0.09 mm/min0.5and 0.17 mm/min0.5 meant for normal concrete. The sorptivity decreased with increasing compressive strength.

5.3. *Resistance to seawater and acidic solution*

The effect of seawater and acidic solutions on the durability of NC with plastic waste aggregates and polypropylene fibre was investigated by testing 100mm cube specimens for loss in mass and reduction in compressive strength. For determining the resistance to acid, the cubes were immersed in a 5% sulphuric acid (H2SO4) solution for 56-days.

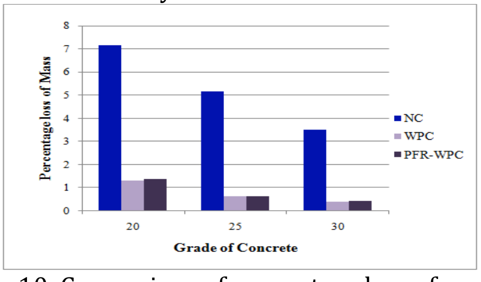

Fig 10. Comparison of percentage loss of mass with design strength

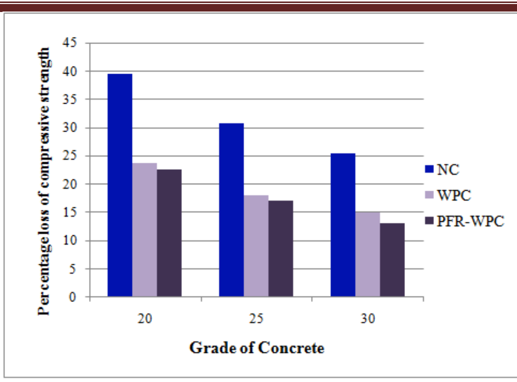

Fig 11. Comparison of percentage loss of compressive strength with design strength

Figure 10 and 11 indicates that the loss in mass was lesser than the loss in compressive strength. The reduction in mass was 3.5% for 30 M Pa NC while WPC and PFRWPC specimens having the same strength showed negligible reduction in mass (less than 1%). This may be due to the replacement of fine aggregates by plastic which is less reactive in chloride environment. When fibers were added to WPC, the mass loss increased by 5% compared to WPC without fibers. This may be due to air entrapping during mixing, which causes interior corrosion. The loss in mass and the reduction in compressive strength in acid solution were 7 % and 28 % respectively for WPC. The corresponding losses in PFRWPC were 8 % and 29 % for 30 M Pa.

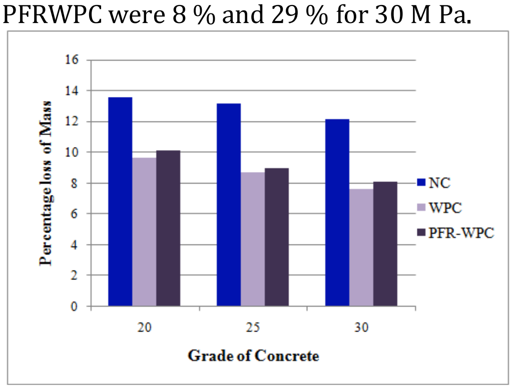

Fig. 12. Comparison of percentage loss of mass with design strength

6. CONCLUSIONS

The strength and durability characteristic of waste plastic mix concrete with and without the addition of fibers was investigated. The reduction in compressive strength due to the incorporation of waste plastic in NC could be compensated to some extent by the addition of polypropylene fibers. All the evaluated durability characteristics were found to be within the limits prescribed by the codes for normal concrete. These results suggest that plastic waste mix concrete may be a useful cementitious composite with better durability characteristics than normal concrete.

7. SCOPE FOR FURTHER WORK

Here the characterization of mechanical properties and durability properties were restricted to mixes with target strengths 20MPa, 25 MPa and 30 MPa. The study can be extended to higher grades of NC, WPC and PFRWPC. The durability studies were restricted to a limited number of tests. Other tests like effect of temperature, freezing and thawing effect, heat ofhydration test etc can be conducted.In this work strength reduction due to theaddition of waste plastic was compensated by theaddition of polypropylene fiber. Similar studies can be conducted by using other methods.

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