Development of Composite Material for Construction Purpose/Precast Composite using Plastic as Aggregate along with Steel Fibres

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Abstract - *Plastic accounts for a major waste in today's Era all over the world. India alone generates about 6.8 million tonnes of plastic waste (CPCB annual report 2014). This plastic can be recycled and reused to avoid any ill effects caused from it. Natural sand resources are being depleted from the various sources and government has imposed restrictions on the use of natural sand from the rivers. An alternative to natural sand is artificial sand but again it is derived from crush rocks, these rocks are also a part of natural resources. Therefore, waste plastic could be used as an alternative. One of the important reuse of plastic can be in the form of aggregates in concrete. Waste plastic generated could be crushed and grinded and could be used partially or complete replacement for the fine aggregates. The current study targets, To explore the use of polypropylene waste as partially replacement to fine aggregate in concrete beyond 20%. Also to take care of strength parameters 1% steel fibres are added by weight of cement in concrete. The current analysis looks at replacement of fine aggregate with plastic waste by 20%, 25% and 30%. To explore the properties of concrete with recycled plastic - cubes, cylinders and beams are cast. The properties of concrete using recycled plastic are thus established by experimental analysis.*

Key Words: (**Reused Plastic Waste, Concrete, Fine Aggregate, Steel fibre, Polypropylene Waste**.)

1. INTRODUCTION

A lot of non useable items are created from manufacturing processes, essential factories. The rising consciousness about the environment has immensely added to the related with dumping of the generated wastes. One of from it that is waste plastic, which used in discrete applications. Despite, many attempts have been done to explore its use in concrete. The expansion of new materials using as a recycled plastics is necessary to both the construction and the plastic reusable at manufactory.

Plastics becomes independently and integral part of our lives. The quantity of plastics used every year has been growing gradually. Plastic's property (i.e. low density, strength, easy to use designs, fabrication capabilities, light weight, and low cost.) are the factors behind such extraordinary growth. Plastics have been used in every other industry in world, for obvious reason.

Plastic is not easy to dispose and takes years to disintegrate. India alone generates about 6.8 million tonnes of plastic waste. This plastic can be recycled and reused to avoid any ill effects caused from it. Natural sand reserves are being depleted from the various sources and government has imposed several restrictions on the use of natural sand from the rivers. An alternative to natural sand is artificial sand but again it is derived from crush rocks, these rocks are also a part of natural resources. Therefore, waste plastic could be used as an alternative. One of the important reuse of plastic can be in the form of aggregates in concrete. Waste plastic generated can be crushed and grinded and could be used partially or complete replacement for the aggregates.

1.2 Problem Statement

Development of composite material for construction purpose/ precast component using plastic waste as fine aggregate along with hooked end steel fibres. Many studies have been completed on the properties of plastic wastes like Polyethylene Terephthalate (PET) bottles, Polycarbonates, Polyurethane foam, etc. In this project, we have used Polypropylene (PP) waste as a replacement for fine aggregates. Also, we added hooked end steel fibres as reinforcement members

1.3. Materials and Methodology

1.3.1. Materials and Properties,

The plastic used in the composite was Polypropylene obtained from grinding the runner of waste drip irrigation pipes. This plastic was use in concrete to replace fine aggregates in the percentages of 20%, 25% and 30%. The research work carried in this regard maximum up to 20% of fine aggregates could be replaced with plastic waste. Thus, this research intends further study the scope of using plastic waste beyond 20%. The grinded plastic waste is as shown in *Image 1*

Fig -1: Grinded plastic waste aggregates

Along with the grinded waste plastic, 1% steel fibres have been used to compensate the strength parameters. The steel fibres used are of aspect ratio 80 and performance class 80. Tensile strength of the steel fibres is 1050 N/mm^2. The steel fibres used are as shown in *Image 2*.

Fig -2: Steel Fibers

Consplast super QC-163, a free flowing Brownish liquefied, was used as a super plasticiser with relative density as 1.22 at 25°C.

Coarse aggregate of size 20mm was used having specific gravity 2.95. Crushed sand having specific gravity is 2.75. OPC Cement Grade 53 was used. Specific gravity of OPC grade 53 cement was 3.15. Normal water was used for both(i.e. mixing and curing). All the materials were obtained on RMC site, except plastic aggregates and steel fibres.

1.3.2. Methodology

All the materials were obtained on site. The proportion of materials to be used was calculated as per the concrete mix design for M30 grade. Plastic replacement was done as per the percentage by weight of fine aggregates in respective proportions. 1% steel fibres by weight of cement were added in the aggregate cement matrix. The mixing was done in a mixer as shown in the *Image 3.* Water was added during the process of mixing. Admixture was added after the addition of water in small quantities. As per the guidelines, steel fibres were added in the end after addition of all materials. Mechanical mixing was done which was followed by filling the moulds with composite. Hand tamping was adopted as per specifications in the IS code for proper compaction. Four specimen of cubes and beams and three specimens of cylinders of different batches were made for testing. Slump cone test was carried before placing the concrete in the mould.

Fig -3: Mechanical Mixer

After 24 hours, the moulds were opened and the composite was place in tank for 28 days. With proper curing of 28 days, the composite was taken off from the curing tank and taken for testing. The various test carried out on hardened concrete were compressive strength test (for cubes), flexural strength test (for beams) and splitting tensile strength tests (for cylinders).

Before testing, weights of all composites were noted. Cube moulds were of size 150mm conforming to IS-10086-1982. Cubes were tested on a Digital Compression Testing machine. Gradual load was applied and readings were noted at failure. Beams was tested on Universal Testing Machine (UTM) and placed in as a single point load was applied to the uppermost surface as cast in mould. Cylinders were tested on a Digital Compression Testing machine, bearing strips was placed between lower and upper surface before the application of load.

Table -1: Casting Details

Sr. no	Concrete	Days	Steel Fibre (Percent)	Percentage plastic waste	Cubes	Cylinder	Beams
1	Conventional concrete	28 day	No steel	No plastic	4	3	4
2	Concrete using Plastic Waste	28 Day	1% steel fibres	20%	4	3	4
				25%	4	3	4
				30%	4	3	4

1.3.3. Concrete Mix Design

Concrete Mix design (According to IS - 10262 - 2009)

A. Design Mix stipulation -

1. Grade of concrete - M30
2. Characteristic compressive strength required in 28 days - 38.25N/mm2
3. Exposure conditions - Moderate
4. Slump of concrete- 60 +/- 25

B. Design Data -

1. Cement - OPC 53 Grade
2. Max. nominal size of aggregates - 20mm
3. Source of aggregate -Crushed sand
4. Grading Zones; Fine aggregate (20mm) -
5. Zone I
6. Specific Gravity of cement - 3.15
7. Specific Gravity of Fine Aggregate - 2.75
8. Specific gravity of Coarse Aggregates (20mmm) - 2.95
9. Admixture - Consplast QC 163 Super
10. Water absorption of Fine aggregates - 3.5%
11. Water absorption of Coarse aggregates (20mm) - 1.11%

∴ For 1 m^3 of concrete, mix proportions are,

Cement = 340kg

Water = 153kg

Fine aggregate = 813kg

Coarse aggregate = 1308kg

Super plasticiser = 3.4kg

Accounting for water Absorption of fine aggregates and coarse aggregates, reducing the amount of coarse aggregates by 1.11% and fine aggregates by 3.5% and adding to water content, we get the following quantities;

∴ For 1m^3 of concrete, mix proportions are,

Cement = 340kg.

Water = 196kg.

Fine aggregate = 784kg.

Coarse aggregate = 1296 kg.

Super plasticiser = 3.4 kg.

2. Tables and figures

2.1 Tables

The compressive strength test, flexural strength test and the split tensile strength test results have been tabulated and shown as below.

Compressive strength test was carried out on Digital Compression testing machine (FHCT- 2000D) according to the procedure given in IS Code. Flexural strength test was carried out on Universal Testing Machine (UTM) and splitting tension test was carried out on digital compression testing machine (FHCT – 2000D)

Table 2 - ***Average Compressive strengths of composites***,

Sr. No	Percentage Replacement (%)	Average Weight (kg)	Average Compressive strength
1	0	9.20	40.30
2	20	8.15	31.63
3	25	8.02	30.43
4	30	7.91	28.36

Table 3 - ***Average Flexural strengths of composites,***

Sr. No	Percentage Replacement (%)	Average Weight (kg)	Average Modulus of Rupture
1	0	42.91	3.51
2	20	38.17	2.61
3	25	36.72	2.41
4	30	35.55	1.90

Table 4 - ***Average Splitting Tensile strengths of composites,***

Sr. No	Percentage Replacement (%)	Average Weight (kg)	Average Tensile strength
1	0	13.76	4.069
2	20	12.40	3.150
3	25	12.26	3.096
4	30	12.00	3.070

2.2. Figures

According to the results obtained, the respective compressive, flexural and split tensile strengths have been plotted as a comparative study for conventional concrete to the plastic aggregate composite.

The following figures represent a comparison of average strengths obtained by bar chart and comparison of strengths obtained of each specimen with strengths conventional concrete.

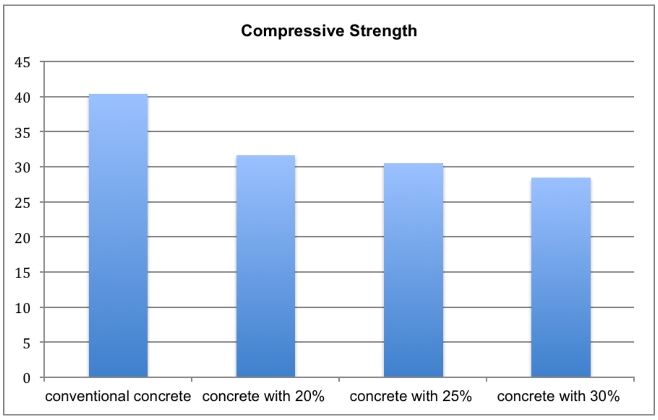

Figure 1- A comparison of average compressive strengths.

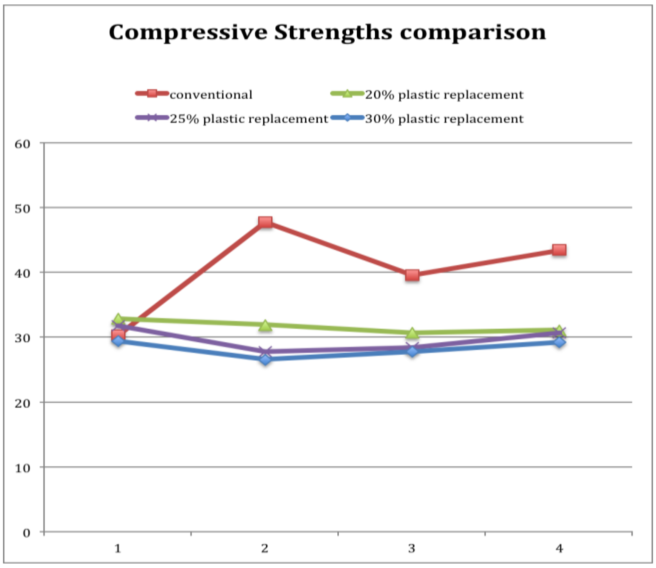

Figure 2 - Compressive strengths comparison of each specimen.

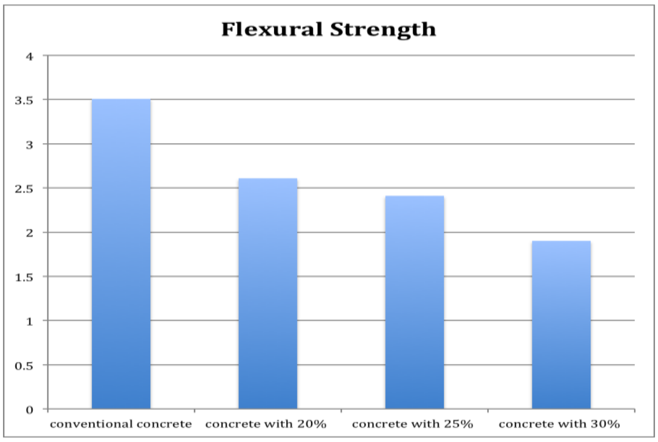

Figure 2- Average Flexural strengths comparison.

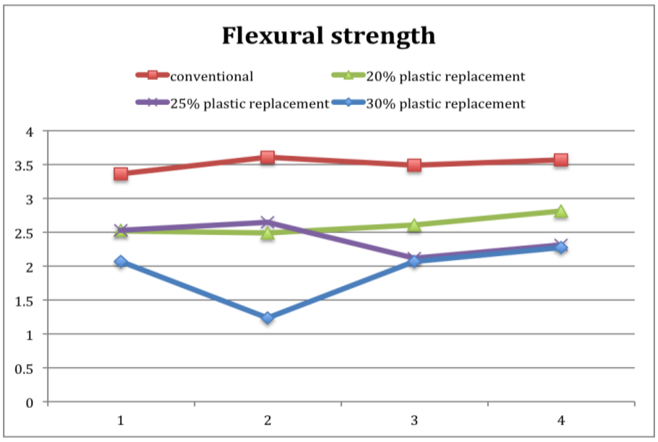

Figure 4- Flexural strengths comparison of each specimen.

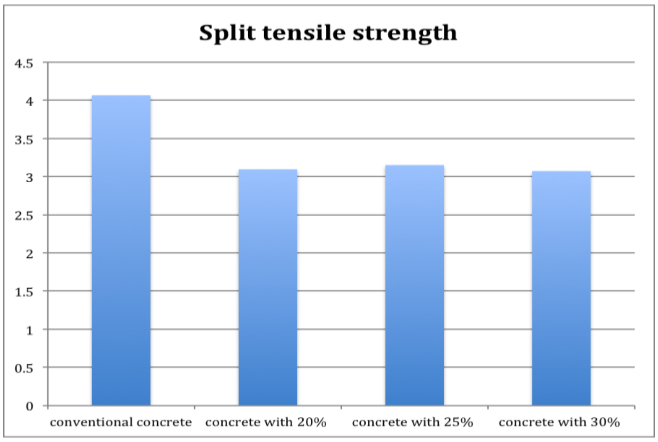

Figure 3- Average Flexural strengths comparison.

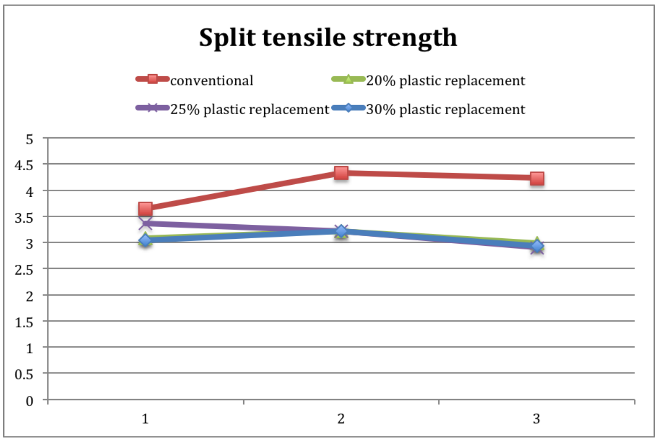

Figure 6- Split tensile strengths comparison of each specimen.

1. Equations

The equations used for the computation of the results are-

Compressive strength = $\frac{Load}{C/S\text{-}area}$ ...(1)

Flexural strength,

$f_b = \frac{P \times l}{b \times d^2}$ ...(2)

Where,

b = width of the casted specimen (in cm).

d = depth of the casted specimen at the point of failure (in cm).

l = length of the span (in cm).

p = maximum load (in kg).

Split tensile strength test,

$T = \frac{2P}{\pi L d}$ ...(3)

Where,

T = Splitting tensile strength (in kPa).

P = *M*aximum load (in kN).

L = Length (in m)

d = *D*iameter

3. Observations and Conclusions

3.1 Observation

1. The average weight of the cubes of 20%, 25% and 30% plastic waste aggregate replacement composite was observed to decrease as 8.15kg, 8.02kg and 7.91kg respectively.

2. The average weight of the beams of 20%, 25% and 30% plastic waste aggregate replacement composite was observed to decrease as 38.17kg, 36.72kg and 35.55kg respectively.

3. The average weight of the cylinders of 20%, 25% and 30% plastic waste aggregate replacement composite was observed to decrease as 12.40kg, 12.26kg and 12.00kg respectively.

4. The average compressive strength for 20%, 25% and 30% plastic aggregate replacement was 31.63MPa, 30.43MPa and 28.36MPa respectively.

5. The average flexural strength for 20%, 25% and 30% plastic aggregate replacement was 2.61MPa, 2.41MPa and 1.90MPa respectively.

6. The splitting tensile strength for 20%, 25% and 30% plastic aggregate replacement was 3.096MPa, 3.150MPa and 3.070MPa respectively.

7. It was observed that due to the addition of super plasticiser and due to negligible absorption of plastic aggregates, water was saved.

3.2 Conclusion

1. It was observed that there was decrease in the weights of the composite with increase in percentage of plastic replacement when checked with conventional concrete. There was a decrease of 12%, 13% and 14% in cubes of 20%, 25% and 30% replacement of plastic waste aggregate respectively.

2. The decrease in the weights of the beams when checked with conventional concrete was 11%, 14% and 17% of 20%, 25% and 30% replacement of plastic aggregates respectively.

3. Similarly for cylinders, when compared to conventional concrete there was a decrease of 10%, 11% and 13% in 20%, 25% and 30% of plastic waste replacement respectively.

4. There was a decrease in the strength of composite cubes when checked with to conventional concrete cubes. The percentage decrease in the strength of cubes of 20%, 25% and 30% composites was 21.5%, 24.5% and 29.6% respectively.

5. Similarly, there was a decrease in the flexural strength of composite when checked with conventional concrete beams as 25.6%, 31.3% and 45.8% of composites of 20%, 25% and 30% respectively.

6. However, the splitting tensile strength of the cylinders was constant with negligible variation, but it was still less than that of conventional concrete cylinders.

7. Addition of steel fibres helped to maintain the splitting tensile strength of the composites.

8. As the amount of plastic aggregates increased, the amount of water saved also increased.

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