

Utilization of Waste Plastic as Partial Replacement of Fine and Coarse Aggregates in Concrete Blocks

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Abstract - Plastic is generated in large quantities all over the world. It is believed that the breakdown of plastic takes time of more than thousand years. Improper plastic waste management leads to several environmental and health hazards. To overcome this problem recycled plastic aggregate (RPA) made using shredded plastic waste Polypropylene (PP) has been added by replacing it with various percentages (0-20%) of both fine and coarse aggregates. Several tests including fresh state properties like workability and hardened state properties like compressive strength test, split tensile strength test and dry density test were performed on the partially replaced specimens of cubes (150mm X 150mm X 150mm) and cylinders (150mm X 300mm) after 3, 7, 14 and 28 days of curing period. Later based on the results of properties of mixed concrete with plastic aggregates were examined and compared with the original control mix concrete with normal aggregates. Replacement of natural aggregates by recycled plastic aggregate (RPA) can be used as an alternative and sustainable approach towards environmental friendly construction practice. The use of plastic waste material as a substitution of variable percentage of fine and coarse aggregates (0-20%) designed for M-40 grade concrete although reduces the concrete properties namely the fresh and hardened state properties of the concrete but can be used for various lower grade strength applications such as precast bricks, partition wall, panel wall, canal lining and so on.

Key Words: Concrete, Recycled Plastic Aggregate, Polypropylene, Shredded Plastic Waste, Fresh state Properties, Hardened state properties, Strength.

1. INTRODUCTION

The world has created over 9 billion plenty of plastic since 1950. As of 2015 only 9% of the plastic waste was recycled, about 12% incinerated and about 79% ended up in landfills or some place in the environment (PlasticsEurope Market Research Group, 2018). Moreover about 180 billion plastic bottles were purchased in 2006 which raised to 480 billion after a decade (The Guardian, 2017). Only 7% of the waste plastic bottles turned into new bottles and the rest ended up in landfills or oceans. According to Ecowatch the usage of plastic bags worldwide annually lies between 500 billion to 1 trillion. A research by (National Geographic, 2018) states that there will be about 12 billion metric tonnes of plastic in landfills by 2050 if the plastic consumption increases at the current rate. Despite of limitations being imposed on the

production and usage of plastic, post consumer plastic waste the problem is not yet solved. India in the present scenario discards 70% of its total plastic production as waste. It is estimated that 5.6million tonnes per annum (TPA) of plastic waste is generated in this country (Central Pollution Control Board, Delhi, 2013). The various types of plastic are Polyethylene Terephthalate (PET), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) etc. The waste plastics availability based on various types of plastic are 23% LDPE, 17.3% HDPE, 18.5% PP, 12.3% PS, 10.7% PVC, 8.5% PET and 9.7% of other types (Zoorob and Suparma, 2000).

So many foraging cows in India have died from ingesting plastic bag litter that many of the states in the country have banned the distribution of plastic bag and the effect of plastic waste has a direct and a deadly effect on marine and wildlife after ingesting plastic or getting entangled in it. The availability of conventional fine aggregates i.e. river sand has become scarce and sand mining affects the riverbed characteristics increasing the cost of concrete. Polypropylene (PP) is one of the most widely used consumer plastic and has a wide range of applications like manufacturing of pipes, kettles, plastic containers, plastic bags, bottles, food containers, stationary folders, packaging, protective covers and storage boxes. PP being recyclable has a resin identification code of number "5".

Many researchers investigated the properties of waste plastic incorporated in structural concrete. It is possible to produce self compacting concrete having compressive strength in excess of 35MPa when the fine aggregates are partially replaced by PET plastic waste (Sheelan and Nahla, 2017). As the size of recycled PET particle is increased, the Young's Modulus of specimen was decreased, and simultaneously the compression strain increases (Liliana et al., 2013). (Jalali et al., 2011) examined the durability characteristics of polymeric wastes in concrete (Tyre rubber and PET bottles). Furthermore, tests were also performed for w/c ratios (0.5 and 0.6), and it was indicated that the mixes with 10% replacement resulted to have the best mechanical properties, and the mixes with 20% replacement resulted to have lower compressive strength (Albano et al., 2009). (Ozbakkaloglu et al., 2017) performed tests on short term mechanical properties of concrete containing waste Polypropylene as a replacement of coarse aggregates under elevated and ambient conditions of

temperature. Moreover, the tests showed that higher the replacement of (RPA's) in the specimen, lower is the corresponding workability of the mix. (Nursyamsi and Winner., 2016) conducted research by knowing the effect of using pet plastic waste gradations and concluded that lower fineness modulus of waste plastic aggregate caused lighter production of concrete. (Semiha et al., 2009) conducted laboratory tests on the usage of shredded waste PET bottles with GBFS and deduced that the mortar produced could be used as an earthquake resistant material as the dead weight of the specimen dwindled. Moreover its use termed productive for the environmental concern. (Batayneh et al., 2007) studied the impact of waste ground plastic on the slump of specimen. Partial replacement of fine aggregate by waste plastic aggregate upto 20% replacement was studied. It was observed that the slump was reduced to 25% compared to the control specimen for a 20% replacement of fine aggregate with plastic particle content. (Choi et al., 2005) noticed the effect of using PET waste aggregate on workability of concrete. The water-cement ratio were planned to be 0.45,0.49 and 0.53 and the waste plastic replacement ratios were 0%,25%,50% and 75% of fine aggregate by volume. As the water-cement ratio increases the increase in the workability was observed to be 52%, 104% and 123% respectively. (Ismail et al., 2007) reported that as the waste plastic ratio increases the slump is prone to decrease drastically. This decrease can be ascribed to the fact that the plastic waste particle was not only spherical and smooth in shape but were also non uniform in shape which caused less fluidity. (Babu et al., 2004) noticed better flow and less segregation while using expanded plastic mixes without the use of bonding additives. (Al-Manaseer and Dalal., 1997) reported the impact of waste plastic aggregate on the bulk density on concrete. The bulk density reduced and was noticed to be directly proportional to the waste plastic aggregate content further it was reduced by 2.5%, 6% and 13% for the concrete specimen containing 10%, 30% and 50% plastic aggregates respectively.

2. EXPERIMENTAL PROGRAM

2.1 General

Specimens were cast for different volume percentages of plastic partially replacing natural aggregates in concrete with recycled plastic aggregates (fine-coarse) i.e of 0-0%, 5-5%, 10-10%, 15-15% and 20-20% conforming to IS:10262-2009.

2.2 Material Properties

2.2.1 Cement

Grade 43 Birla Shakti ordinary portland cement (OPC) was used for casting cubes and cylinders for all concrete mixes. Laboratory tests conforming to IS: 4031-1988 conducted on cement are given below in Table 1.

Table -1: Physical properties of cement

Physical properties	Test results
Consistency	33%
Initial setting time	48 min
Final setting time	240 min
Specific gravity	3.15
Fineness	4.8%

2.2.2 Aggregate

As per the laboratory tests the various physical properties of fine and coarse aggregates are given in Table 2.

Table -2: Physical properties of fine and coarse aggregate

Physical properties	Fine aggregate	Coarse aggregate
Type	M-sand	Crushed
Specific gravity	2.57	2.6
Water absorption	14.46%	3.645%
Max size	Nil	10mm
Fineness modulus	2.875	7.68
Grading zone	IS:383-1970, conforms zone II	IS:383-1970, conforms 10mm downsize

2.2.3 Water

Water used conforms to IS: 3025 (part 22, 23)

2.2.4 Waste plastic (PP) fine aggregate

Waste PP collected was grinded in a blade mill to the size of 0.1-3mm. The grinded PP was washed and sun dried to obtain the final product. Then the obtained particles were separated through sieves and subsequently reassembled according to the granulometric curve of the fine aggregate.

2.2.5 Waste plastic (PP) coarse aggregate

Waste PP collected was grinded in a blade mill to the size of 0.1-3mm to form flakes. These flakes obtained are heated to a temperature ranging between 170^o C and 180^oC to form melted blocks. The melted blocks are cooled to form solidified PP blocks. The agglomerate of PP are crushed using a crushing machine to obtain desired size (8-10mm).

3. MIX DESIGN

Specimens were cast for different volume percentages of plastic partially replacing natural aggregates in concrete

with Recycled plastic aggregates(fine-coarse)i.e.of 0-0%, 5-5%, 10-10%, 15-15% and 20-20% conforming to. IS:10262-2009 as shown in Figure 1. Cube specimens of size 150 mm X 150 mm X 150 mm were casted for different proportions with RPA's and compared with the properties of concrete prepared without RPA (control mix). Cylinder specimens of size 150 mm x 300mm were casted for different proportions with RPA's and compared with the properties of concrete prepared without RPA (control mix). The mix proportion is shown in Table 3.



Fig -1: Cube specimens (0-20%) replacement

4. RESULTS AND DISCUSSIONS

4.1 Slump

The slump is decreasing sharply with increase in waste plastic ratio as shown in Chart 1. Owing to the reduced slump values of waste plastic concrete mixes is due to slighter fluidity and non uniformity in shape of plastic particles.

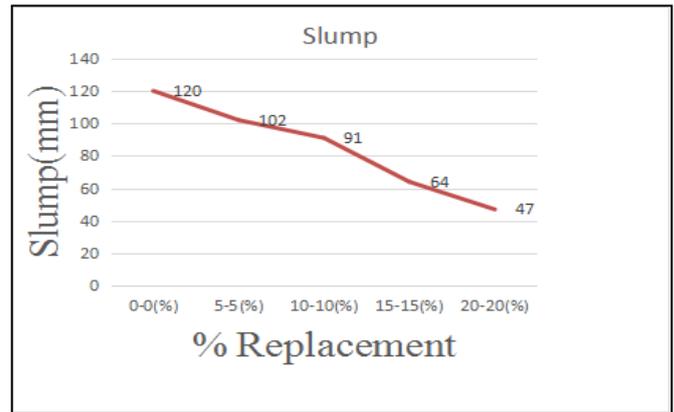


Chart -1: Graph for Slump vs % replacement of aggregates

4.2 Compressive strength test

Cubical specimens of size 150mm were used to cast desired cubes for various curing ages as per IS: 516-1992 and the average strength of three cubes was taken as the compressive strength of that specimen overall for better accuracy. The trend is shown in Chart 2. It is observed that there was a decrease in compressive strength by 27.7%, 47.7%, 71.9%, 81.0% with an increase in plastic content for various % replacement respectively. This reduction is attributed to the decrease in adhesive strength between cement paste and plastic aggregate.

4.3 Split Tensile strength test

Cylindrical specimens of size 150mm dia x 300mm height were cast for various curing ages and for various % replacement of fine and coarse aggregates. The tensile strength of resultant mix is obtained by taking average of three specimens. The trend is shown in Chart 3.

4.4 Dry density

Before performing compressive strength test the dry density is analyzed first for various curing periods of each specimen replaced by certain amount of waste plastic. It is found that the concrete specimens replaced by waste plastic contained reduced unit weight. This is due to the

Table -3: Mix proportions for 1 meter cube of concrete with various plastic percentage

Concrete Mix	Cement (kg/m ³)	Water (kg/m ³)	w/c	Fine Aggregate		Coarse Aggregate		
				NA (kg/m ³)	RPA (kg/m ³)	NA (kg/m ³)	RPA (kg/m ³)	RPA (%)
CM(Cont-rol Mix)	463	208	0.45	955	0	814	0	0-0%
Mix 1	463	208	0.45	907	48	773	41	5-5%
Mix 2	463	208	0.45	860	96	733	82	10-10%
Mix 3	463	208	0.45	812	144	692	123	15-15%
Mix 4	463	208	0.45	764	192	651	164	20-20%

fact that plastic possess lower unit weight compared to the density of coarse aggregate. The average of three samples was taken for every type of replaced specimen to achieve accuracy. Similar observations were also made by various other researchers. Table 4 shows the unit weight of respective specimens.

Table -4: Dry densities of control mix concrete and plastic added concrete

% Replacement	Unit Weight (Kg/m ³)
0-0% (CM)	2440
5-5%	2263
10-10%	2024
15-15%	1940
20-20%	1770

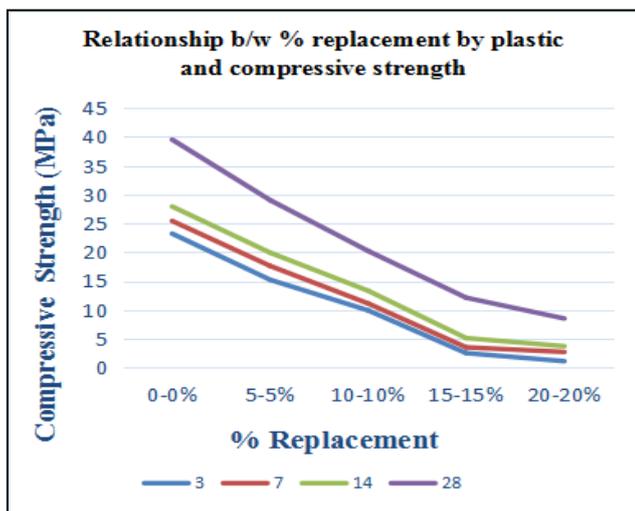


Chart -2: Compressive strength for different % replacements

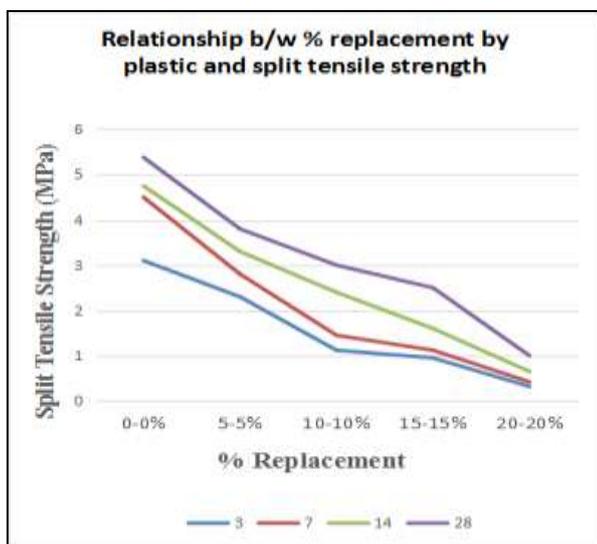


Chart -3: Split tensile strength for different % replacements

5. CONCLUSION

The present study observes that both the fresh and hardened state properties tend to decrease as the percentage replacement of plastic in the concrete mix increases. The slump decreases sharply with increase in waste plastic ratio. Nonetheless these type of mixes can be utilized in situations which require low degree workability. Moreover the compressive and Split tensile strength of the concrete mix also decreases with increase in waste plastic ratio for all curing ages. There was a decrease in compressive strength by 27.7%, 47.7%, 71.9%, 81.9% with respective increase in plastic content. The control mix was designed for M-40 grade and with a replacement of 5-5% the achieved strength was almost M-30 which can be used to make pathways, roadways and external walls and slabs. With a replacement of 10-10%, the achieved strength was almost M-20 which can be used as bedding of footings, domestic floors with reduced cost. Furthermore with a replacement of 15-15% the achieved strength was likely as M-10 which can be used as patio slabs, pathways and other nonstructural works. With lesser density the 10, 15, 20% replaced specimens fall under light weight concrete category hence decreasing the dead weight of the structure. The various civil engineering applications where it can be used are namely precast bricks, partition walls, panel walls, canal lining and so forth.

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