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Study of Waste PET Replacement on Concrete Strength and Plastic Waste Disposal Potential

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Abstract- Concrete is most widely used construction material and is produced in large amounts every year. Its economic production is major area of interest of industry. With current consumption plastic is another byproduct of food industry and Polyethylene Terephthalate (PET) being used in high amounts for storage purposes. PET is desirable due to light weight and good strength. Waste PET has been explored for use in concrete in recent times. Present study provides detailed comparison of strength and waste disposal potential by percentage replacement of concrete constituents with waste PET.

Keywords – **Polyethylene terephthalate, compressive strength, split tensile strength, percentage replacement.**

I. INTRODUCTION

The material inputs needed to make concrete in construction works i.e. cement, fine aggregates / sand and coarse aggregates are proving difficult to procure due to extensive demand especially in developing countries like India. Increasing demand of the coarse and fine aggregates is difficult to meet in wake of environmental protection. Replacing these inputs with available materials can help in decreased dependence on conventional materials. The use of plastic in concrete can be a viable option as there is possibility of converting waste plastic into fibres. The use of various plastics in concrete is possible. Keeping is view the availability of waste plastic bottles is possible area to explore any desirable result. Waste PET bottles can be used in form of replacement for fine aggregates by crushing them. It can also be converted into fibres by shredding, cutting, etc. Use of fibres in concrete has proven helpful to enhance properties of concrete. If use fibres for this purpose are made from waste plastic, it will act like incentivising recycling of waste plastic.

This project involves study of use of recycled PET bottles as replacement in concrete mix. Objectives of this study are as mentioned below.

1. To study the effect of use of waste plastic bottles in form of replacement in concrete on its compressive strength.
2. To analyse waste disposal potential of PET waste achieved by replacement of concrete mix components.

II. LITERATURE REVIEW

Use of various plastic fibres in concrete has been area of emerging interest. Fibres made of plastics like nylon, polyethene, polypropylene, polyethylene terephthalate have been used in different studies in past. Plastics being available in form of waste, has been a growing concern of disposal. A lot of researches in recent times has been done to use waste plastic in form of fibre in concrete. Below is a literature review based on studies to use plastic in concrete as replacement of concrete inputs.

Balte and Daule (2017) studied effect of 0.5% to 2% with increment of 0.5% replacement of fine aggregates with PET fibre on properties of concrete. They reported optimal strength at 1.5% replacement. There was increase of 4%, 8% and 59% in compressive strength, split tensile strength and flexural strength respectively. **Ramadevi and Manju (2012)** examined the impact of 0.5%, 1%, 2%, 4% and 6% replacement of fine aggregates with ground PET fibres. Results revealed increase in compression and tensile strength. **Patil et al. (2016)** observed increase of 13% in compressive strength while split tensile and flexural strength increased by 38% and 65% respectively. **Asha and Resmi (2015)** experimented to optimize benefits of straight and crimped fibres made from waste PET bottles. **Irwan et al. (2013)** used recycled PET bottles by grinding them into irregular fibre. They prepared concrete specimens by adding 0.5%, 1% and 1.5% PET fibres from waste PET bottles. **Baldenebro-Lopez et al. (2014)** used fibres made by cutting walls of PET bottles spiral shape with two different lengths. **Kim et al. (2010)** studied concrete properties by processing recycled PET sheeting into stranded and embossed fibres. The ultimate load carrying capacity increase for all fibre contents.

III. MATERIALS AND METHOD

A. Cement

Cement is one major component of concrete. It acts as binding material which sets, hardens and adheres coarse and fine aggregates together. Cement used now days is mostly lime and calcium silicate based. Ordinary Portland cement is most commonly used type of cement used for manufacturing concrete around the world. Portland cement is hydraulic cement which upon hydration with water becomes adhesive. Ordinary Portland cement requires about 23% and 15% water by weight of cement inform of bound water and gel water.

B. *Coarse aggregates*

Coarse aggregates provide volumetric stability to concrete. Cement paste binds these aggregates to form hard mass. Normally the size of coarse aggregates is measures as maximum nominal size of particles. Commonly used nominal size of aggregates is 10 mm, 20 mm and 40 mm. Based on shape these aggregates are classified as round and angular. Angular aggregates provide good bonding due to pointy edges. Rough surface texture of aggregates is desired as it provides better binding. Natural aggregates are procured from river deposits and quarried rocks by crushing them. Good hardness, soundness and abrasion resistance are desirable properties of coarse aggregates.

C. Fine aggregates

Fine aggregates help cement paste to hold coarse aggregates in suspended form. Thus, segregation of cement pastes and coarse aggregates is prevented by fine aggregates and plastic behaviour of wet mixture is promoted. These advantages make fine aggregates its use necessary especially if concrete is needed to be transported. Fine aggregates are graded in form of four grading zones viz. grading zone I, II, III and IV in IS 383: 1970. Grade zone I corresponds to coarse size and fineness increases towards zone IV. Fine aggregates conforming to zone II were used in test.

D. Polyethylene terephthalate (PET)

Polyethylene terephthalate is a polymer which is formed by the use of terephthalic acid and ethylene glycol. It colourless, durable and lightweight substance which makes it an excellent material for use as packaging material. It has a density of about 1.3-1.4 g/cm^3 and water absorption of about 0.16%. Major use of PET is in bottle containers used for packaging of water and soft drinks. It is a thermoplastic polymer formed by chain reaction process. This thermoplastic nature makes PET a 100% recyclable material and is most recycled plastic worldwide.

Mix design

Mix design as per IS 10262:2009 and IS 456:2000 was done for water cement ratio of 0.4, 0.5 and 0.6. Below are calculated mix quantities.

TABLE-1 Quantity of ingredients per m^3 concrete

Cement	492.5 Kg/m^3
Water	197 Kg/m^3
Fine aggregates	638.20 Kg/m^3
Coarse aggregates	1134.58 Kg/m^3
Water-cement ratio	0.40

TABLE-2 Quantity of ingredients per m^3 concrete

Cement	394 Kg/m^3
Water	197 Kg/m^3
Fine aggregates	705.93 Kg/m^3
Coarse aggregates	1151.78 Kg/m^3
Water-cement ratio	0.50

TABLE-3 Quantity of ingredients per m^3 concrete

Cement	328.3 Kg/m^3
Water	197 Kg/m^3
Fine aggregates	766.10 Kg/m^3
Coarse aggregates	1149.15 Kg/m^3
Water-cement ratio	0.60

IV. RESULTS AND DISCUSSION

A. Compressive Strength

Compressive strength being major requirement and it should not be negatively affected by any addition of PET fibres. In case of **Balte and Daule (2017), Ramadevi and Manju (2012) and Liliana et. Al (2013)** replacement of fine aggregates with PET fibres to observe compressive strength behaviour. **Irwan et. Al (2013), Ochi et. Al (2007), Kim et. Al (2009), Nibudey et. Al (2013) and Baldenebro-Lopez et. Al (2014)** have replaced total mix. **Patil et. Al (2016) and Asha and Resmi (2015)** tested replacement of cement with PET fibres.

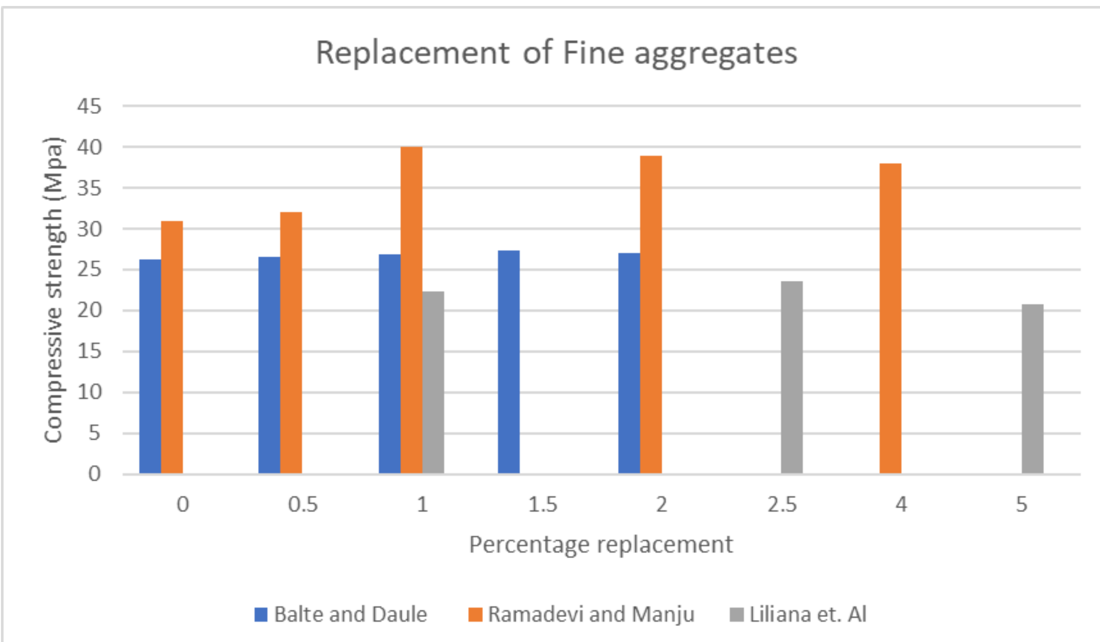

Figure 1. Comparison of compressive strength for different replacement percentages of fine aggregates

As evident from figure 1 for all replacements there is slight increase in compressive strength as compared to 0% replacement. **Ramadevi and Manju (2012)** have achieved optimum result for 1% replacement. They have used shredded and ground waste PET bottles. **Balte and Daule(2017)** have achieved strength at parity with normal concrete upon using 35mm long and 1 mm long fibres. In case of percentage replacement of total concrete mix with waste PET there can be observed decline in compressive strength after 0.5% to 1% replacement as shown in figure 2. this can be attributed to higher quantity of PET which alters concrete structures more predominantly. Thus, replacement of complete mix is less effective method as far as compressive strength is concerned. On examining the effect of percentage replacement of cement on compressive strength it can be observed that strength shows slight increase in both case as seen in figure 3. Based on these results replacement of fine aggregates and cement replacement can prove more effective as compared to percentage replacement of total concrete mix.

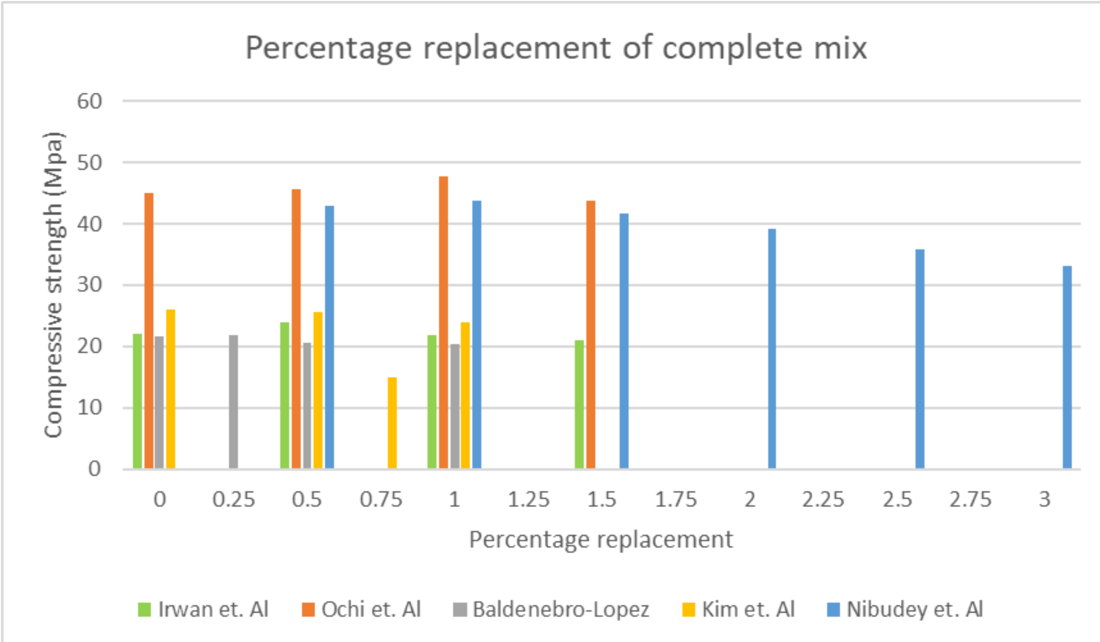

Figure-2. Comparison of compressive strength for different replacement percentages of complete mix

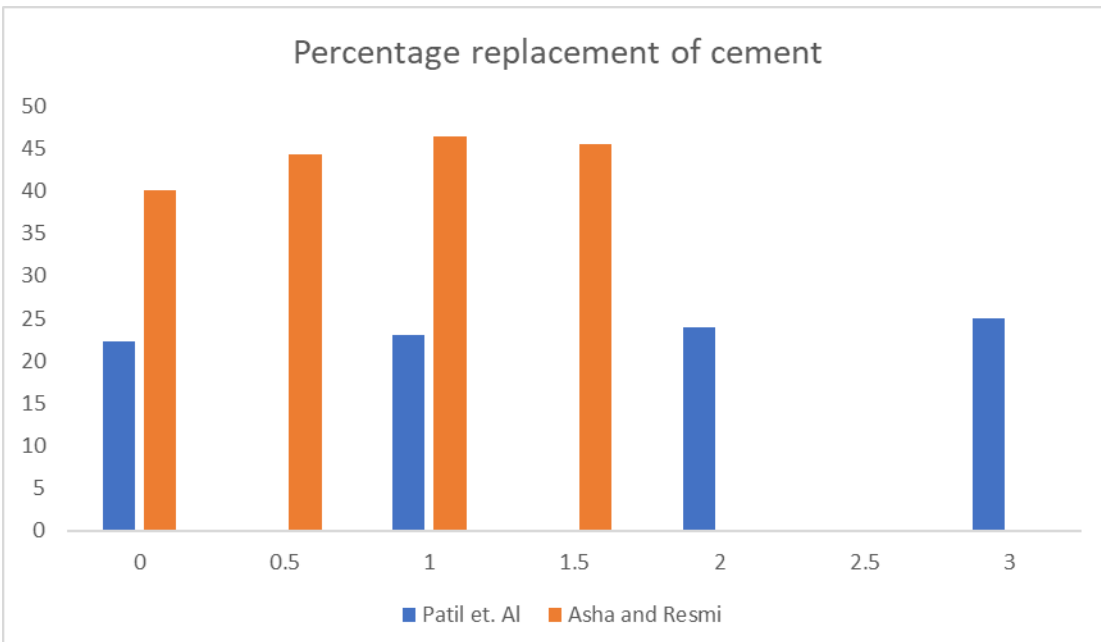

Figure-3. Comparison of compressive strength for different replacement percentages of cement

B. Waste disposal Potential

Waste disposal is one of major concern globally due to high use of plastics in daily use both domestically and industrially. PET is one of most abundantly used material for making containers like bottles and jars which are light and durable. But this plastic most probably ends in dumps instead of recycling. The replacement of concrete mix constituents even at minimal percentage close to 1% with waste plastic can be a resourceful solution.

Figure 4 shows comparison of plastic disposed while using 0.40 water cement ratio using fine aggregate and cement percentage replacement. The difference between two methods is 1.5 kg for 1% replacement.

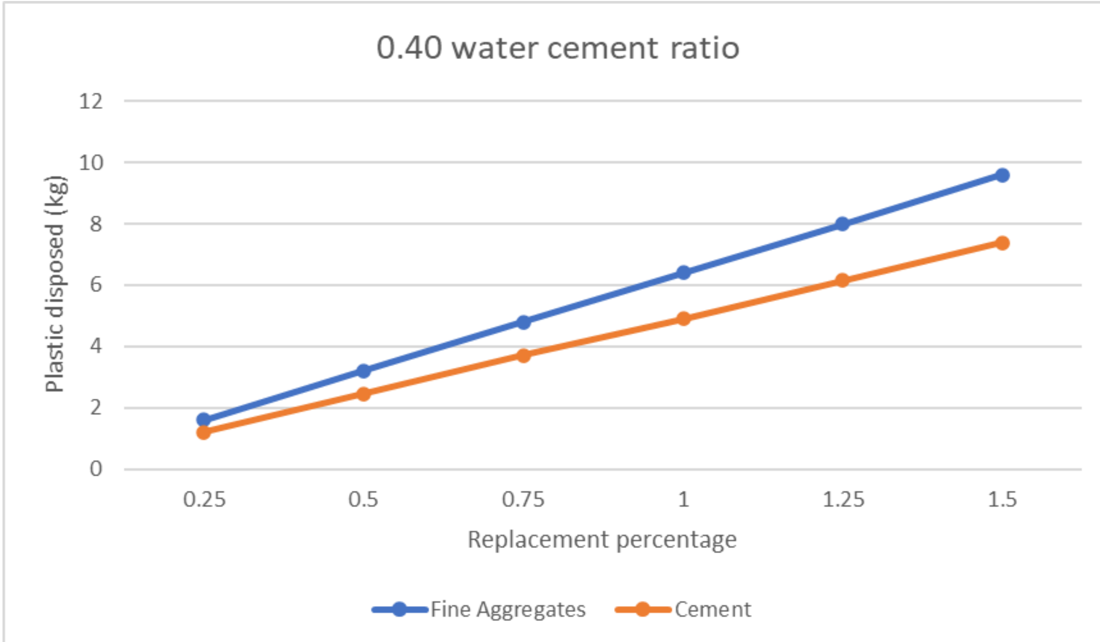

Figure 4. Weight of plastic disposed for fine aggregates and cement for 0.40 water cement ratio

Figure 5 depicts comparison for 0.50 water cement ratio where difference in plastic amount increases to 3.06 kg for 1% replacement.

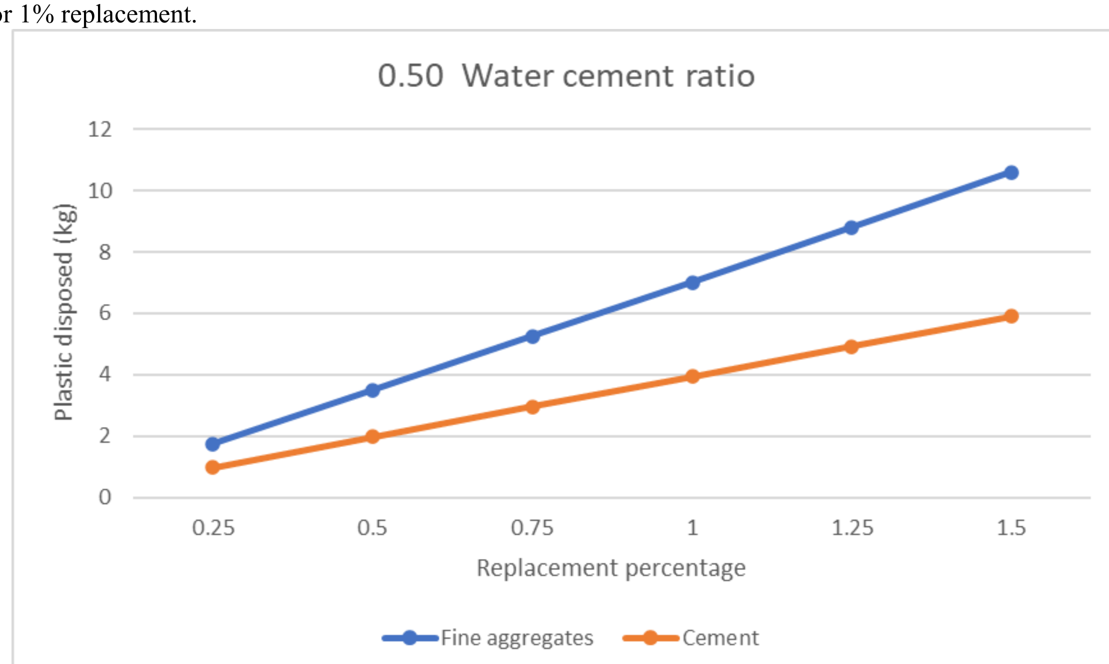

Figure 13. Weight of plastic disposed for fine aggregates and cement for 0.50 water cement ratio

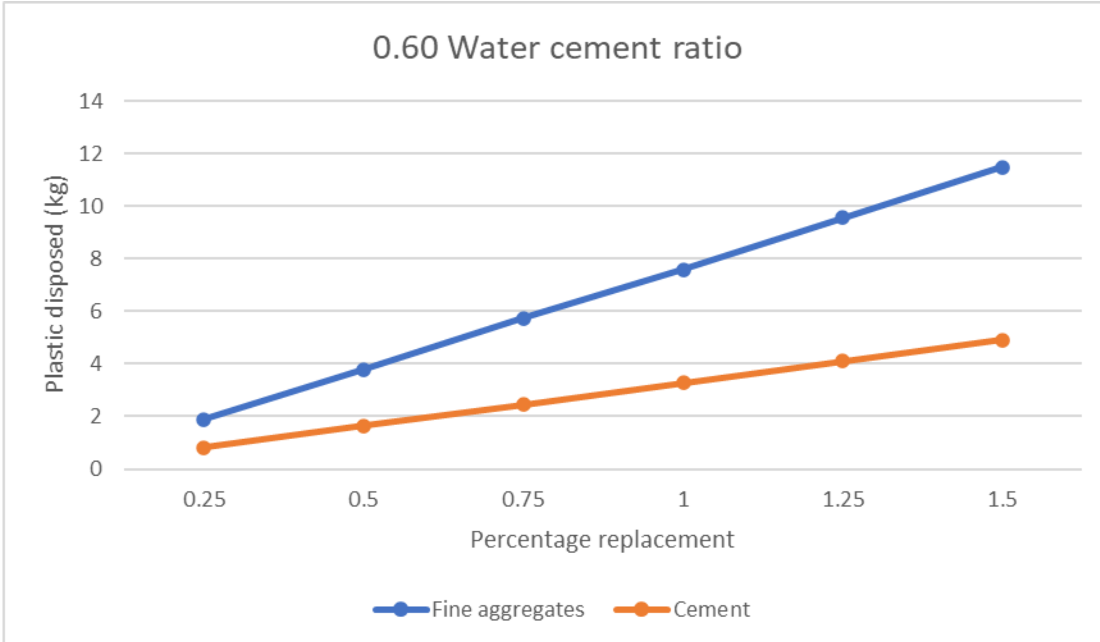

Figure 6. Weight of plastic disposed for fine aggregates and cement for 0.60 water cement ratio

Figure 6 gives comparison for 0.60 water cement ratio and difference for fine aggregate and cement replacement increases to 4.32 kg for 1% replacement.

It can be observed that at 1% replacement 6.4 kg to 7.6 kg plastic with fine aggregates replacement and 3.94 kg to 4.9 kg plastic with cement can be disposed of.

V. CONCLUSION

Present study has drawn comparison of compressive strength and split tensile strength based on different studies conducted in recent times on use of waste PET. There has been also provided in detail comparison of cost benefits realized upon percentage replacement of fine aggregate and cement for varying water cement ratio. Comparison has been done considering concrete mix design as per IS 10262:2009 and 0.25 to 1.5 percent replacement with 0.25 incremental values.

The analysis of strength properties can be summarized as follows-

- In all results it can be observed that compressive strength and split tensile have increased to variable amounts as compared to control specimen i.e. 0% replacement. There has not been any abrupt decline in strengths.
- Strength results have variations which are due to one or more factors among different grades tested, different methods of waste PET processing and difference in properties concrete ingredients. In spite of these 1% to 1.5% replacement has good results for most of cases.

Waste PET disposal potential comparison can be summarized as given below-

- Waste disposal potential for fine aggregates is higher as compared to cement replacement. The difference in waste disposed by fine aggregate replacement to that of cement replacement decreases when water cement ratio is
- Waste PET disposal potential for percentage replacement fine aggregate in more i.e. 6.4 to 7.6 kg as compared to percentage replacement of cement i.e. 3.9 to 4.9 kg for 1 m^3 concrete.

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