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Investigating the Effects of Using Plastic Waste as Fine Aggregate in Self Compacting Concrete

Ankur Singh[1], Ankita Singh[2] and Disha Agrawal[3]

[1]Delhi Technological University, Delhi-110042, India

*Email:

ABSTRACT: Self-Compacting Concrete (SCC) has properties of low yield stress, high deformability and good segregation resistance. It is defined as fresh concrete that flows under its own weight and does not require external vibration to undergo compaction. The aim of this was to study and find the viability of replacing sand (fine aggregate) partially with recycled plastic waste (PET). Different SCC mixes were prepared with consistent water/cementitious ratio of 0.368 with 550 kg/m3 of paste volume. The plastic waste content was varied with 0, 2.5, 5, 7.5, 10, 12.5% by weight of sand and was designated as Fine plastic waste (FPW) and were considered as the experimental parameters. The mixes were tested against their workability properties as SCC mixes, regarding tests namely L-Box test height ratio, V-funnel flow time and slump flow diameter. Cubic compressive strength was also measured against 28-days curing period. The experimental results indicated that plastic in small percentages could be incorporated and can successfully partially replace fine aggregate in self-compacting concrete.

Keywords: SCC, Fine plastic waste, Slump flow test, V-funnel test, L-box test.

I INTRODUCTION

Self-Compacting concrete is a low yield stress and highly flowable concrete. Its main characteristics are cohesion, passing and filling abilities. It can spread into densely packed formworks by virtue of its own weight, without utilizing any vibration techniques. SCC can be pumped to long distances due to its high flowability and also enables faster construction due to its easy placement. It requires less manpower and provides a smooth and well finished surface. As a result of this construction sites are getting safer due to reduced human factor. For wall elements, and also in deep structural members, this type of concrete is majorly employed as in these cases, normal concrete can block the flow, bleed and segregate leading to local defects thus reducing mechanical properties and the surface finish. This also provides more freedom to designers and constructors. SCC can also be used in areas where mechanical compaction is not possible, including underwater construction, cast in-situ, walls with congested reinforcement, or pile foundations.

In general, the term plastic waste can be used to describe a wide range of synthetic and semi synthetic organic amorphous solid materials that find their derivation in oils and natural gases. Plastic is termed as a modern marvel of polymer chemistry and have become a dispensable part of human life. There are several types of plastics that are used widely in the world today such as, Polyethylene Terephthalate (PET) as in plastic bottles, Polyvinyl Chloride (PVC) as in window and door profiles and pipes and fittings, High Density Polyethylene (HDPE) as in grocery bags, juice containers, Low Density Polyethylene (LDPE) as in food storage containers, Polypropylene (PP) as in liners for diapers and sanitary pads and hot food containers, Polystyrene (PS) as in egg cartons and disposable cups, Miscellaneous plastics as in polycarbonate and acrylic. The wide variety in plastic products has led to overflow of plastic products in the world and with this the amount of plastic waste generated is rapidly increasing. This plastic waste does not breakdown under the action of natural processes and remains as it is in the environment for thousands of years. The environment is getting polluted day by day with the increasing use of plastic. The best solution is to recycle and reuse. The construction industry proves to be a great solution for an efficient reuse and disposal of this plastic waste. Using plastic waste in the concrete mix not only helps in reducing waste, but is also found to enhance some of the properties of concrete. There have been many researches that have investigated the effect of plastic on concrete. Bala Rama Krishna (IJCIET-2018) concluded that replacement of sand with 30% HIPS (High Impact

Polystyrene Plastic) granules reduced approximately 10% of the compressive strength compared to normal SCC [1]. Ashok kumar (IJCESR-2018) studied the that replacing sand with plastic in normal concrete of upto 20% did not have a huge negative effect on consistency of fresh concrete properties, average reduction recorded in hardened concrete properties were 25.2%, 22.76% and 13.6% relative to compressive strength, modulus of elasticity and flexural strength values respectively [2]. Adewumi John Babafemi (MDPI-2018) investigated and found that plastic as aggregate leads to an increase in air content and a reduction in compressive strength. The ductility of the concrete also increases upto 50%, however the fracture energy reduces with the increase in plastic content [3]. Nayan N (JETIR-2017) investigated in using E-plastic waste material in partial replacement of coarse aggregate varying from 5% to 30% found out that fresh properties relative to slump flow, L box height ratio and V funnel test all satisfied the guidelines of SCC found in EFNARC. All properties saw decrease in values as the replacement % were increased [4]. Through this study we seek to discover the effect of replacing fine aggregate in self-compacting concrete with recycled plastic (PET & PVC) waste. Sand was replaced in 5 different contents of waste of 2.5, 5, 7.5, 10, 12.5% by weight. The plastic waste taken is passed through a 1mm sieve and can be categorized as Fine Plastic Waste (FPW). The mixes were investigated in relation of workability in terms of slump flow diameter, L box height ratio and V-funnel time. 28-days cubic compressive strength was also tested for all the mixes.

II EXPERIMENTAL STUDY

2.1 Material Properties

CEMENT: Ordinary Portland Cement OPC 53 (Wonder Cement) was used. Following were the tested properties of cement:

Table: 1 Cement properties

Normal Consistency (%)	34%
Initial Setting Time	29.5mins
Final Setting Time	600mins
Specific Gravity	3.15

Fineness of Cement	4.14

AGGREGATES: Coarse aggregate of size 10mm was used and was obtained from Kotputli while the fine aggregate was obtained from Charkhi Dadri.

Table: 2 Aggregate Properties

Ingredient	Sp. Gr	WA(%)
FA	2.72	1.17
CA (10mm)	2.80	0.40

ADMIXTURE: A poly-carboxylic ether type of superplasticizer was used in order to improve the mixes' workability. It acts by steric hindrance effect.

Table: 3 Admixture properties

Name	MasterGlenium SKY 8233
Relative Density	1.08 at 25°C
pH	>= 6

Plastic Waste: Plastic (PET) was gathered which included bottles of soft drink, one-time use bottles. PVC waste was gathered from construction sites and abandoned houses. The gathered waste was put into a pulverizing machine and was sieved using 1mm sieve, the plastic passing through the sieve was then collected to prepare the mixes.

Table: 4 Waste Properties

Specific Gravity	1.32
Shape	Angular
WA (%)	0.2

2.2 Mixture Design

Mixes incorporating plastic wasted were designed having a constant water/cementitious ratio of 0.368 and paste volume of 550 kg/m^3, Class F Fly ash was used (27% of cement content by weight). Fine aggregate was replaced with plastic waste at 5 designated contents of 2.5, 5, 7.5, 10, 12.5% by weight of fine aggregate. Total of 5 different SCPWC mixes were prepared along with the reference SCC mix. Shown in Table 4.

Table: 5 Mix proportions for self-compacting plastic waste concrete (kg/m^3)

Mix ID	**SCC**	**2.5FPW**	**5FPW**	**7.5FPW**	**10FPW**	**12.5FPW**
W/C	0.368	0.368	0.368	0.368	0.368	0.368
Cement	400	400	400	400	400	400
PFA	150	150	150	150	150	150
C.A. (10mm)	816	816	816	816	816	816
F.A.	787	767.325	747.65	727.975	708.3	688.625
Admixture	4.4	4.4	4.4	4.4	4.4	4.4
Water	215	215	215	215	215	215
FPW	0	19.675	39.35	59.025	78.70	98.375

2.3 Testing Procedure

All the tests that were conducted following the guidelines and proper safety procedures. Testing of the fresh properties of SCC mixes were carried out by following the guidelines in EFNARC (2005) [5]. The lower and upper limits for EFNARC classes for the V-funnel (measures the flow time i.e. viscosity), Slump flow (measures the total spread i.e. filling ability), and L-box test (measures the passing ratio i.e. passing ability) are given below in Table: 6, 7 and 8 respectively. The average of the three samples was considered for compression test results, as per IS.516.1959 [6].

Table: 6 Viscosity classes

Class	**T50(s)**	**V-funnel time (s)**

VS1/VF1	<=2	<=8
VS2/VF2	<=2	9-25

Table: 7 Slump flow classes

Class	**Slump flow (mm)**
SF1	550-650
SF2	660-750
SF3	760-850

Table: 8 Passing ability classes (L-box)

Class	**Passing ability**
PA1	>=0.8 with 2 rebars
PA2	>= 0.8 with 3 rebars

3 Results and discussions

3.1 Slump Flow diameter

The slump flow diameter test is used to measure the filling ability, or the horizontal free flow of self-compacting concrete. The slump flow diameter of the reference SCC mix came out to be 685mm which was determined as the average of the measured diameters of the concrete flowed. The slump values of SCPWC mixes were in the range of 680-630mm. As per the results of the test, it is seen that the self-compacting concrete with plastic waste as fine aggregate replacing up-to 7.5% aggregate comes under the classification of SF2, and thus, as per the guidelines it can be successfully used for walls and columns. Mixes with 10 and 12.5% of plastic waste are classified under. The slump flow diameter followed the trend of decreasing with increasing content of plastic waste. This is illustrated in the Fig1.

The results obtained indicates that the produced mixes fulfill the criteria of self-compacting concrete provided by EFNARC. It was observed that slump value decreased by 9.4% at 12.5% replacement ratio of plastic waste.

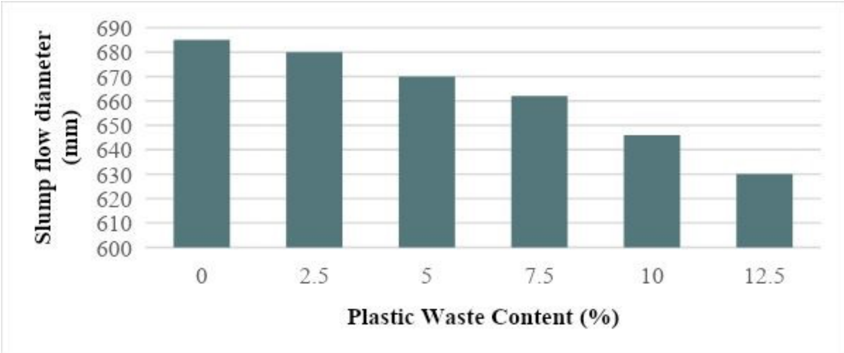

Fig: 1 Variation of slump flow diameter with respect to plastic waste content

3.2 V-funnel flow times

The V-funnel test is used to determine the flowability, or the filling ability of the concrete with maximum size of

20mm of aggregate. The V-funnel flow time of the reference SCC mix came out to be 8.3s. As illustrated in Fig2, the V-funnel flow times of the SCPWC mixes increases when plastic waste content is increased. Moreover, the concrete mix comprising of only 2.5FPW and the reference SCC mix is classified as VF1 class, and replacing aggregate with plastic waste in concrete drops the viscosity class to VF2. The results indicate that all the resulting mixes provide the

self-compacting criteria, with regards to EFNARC (2005).

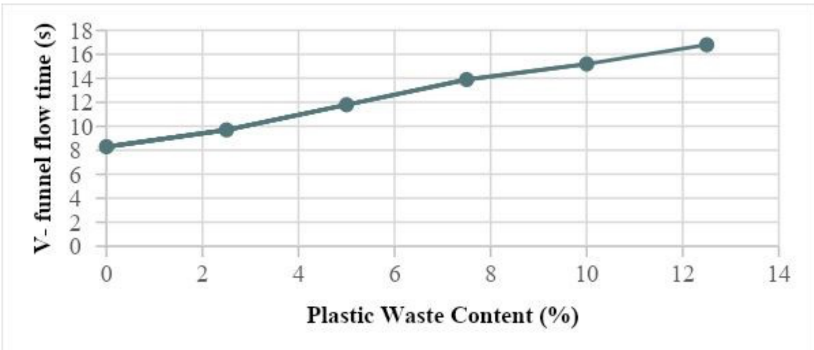

Fig: 2 Variation of V-funnel flow times with respect to Plastic Waste Content

3.3 L-Box height ratio test

The L-Box height ratio test is used to determine the passing and filling ability of self-compacting concrete. This test is carried out using a 3 bar L-box test. For reference mix, the L-box height ratio was 0.854 and upon replacement of fine aggregate with plastic we find that only the mix with designated content of 12.5% of plastic waste did not fulfill the criteria of self-compacting concrete regarding to EFNARC (2005) and rest were in the specified range as displayed in

Fig3. A L-box ratio of 1.0 indicates that the fluid behavior of self-compacting concrete is ideal. L-box ratio for 12.5FPW mix decreased by 10.5% when compared to the reference SCC mix.

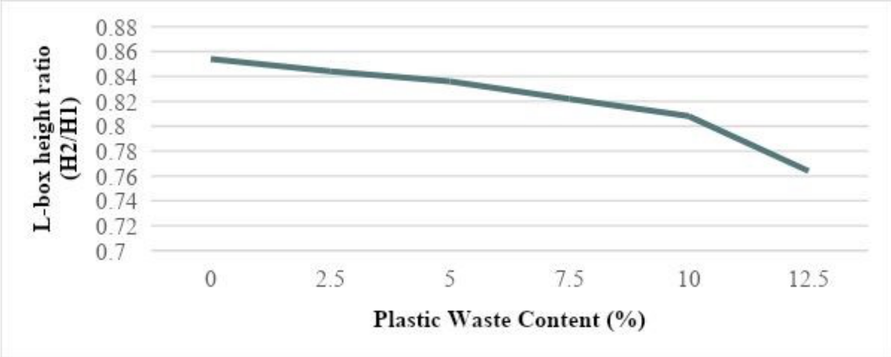

Fig: 3 Variation of L-box height ratios with respect to plastic waste content

3.4 Compressive Strength Test

Specimens of 150x150x150mm were filled and casted with respect to all the mixes. For 28 days, curing is done, proceeded by destructive testing done in an UTM. For each plastic waste mix 3 cubes were tested and the average of those values was taken cubic compressive strength for that mix. The results are illustrated in Fig4 and they show that increasing the plastic waste in the mixes decreases the strength of the mix. However, mixes up-to 7.5% FPW can still be classified as M40 grade of concrete and use for such purposes as these values are greater than the target strength for M40 grade calculated during mix design.

Compressive Strength = Load / Cross-sectional Area

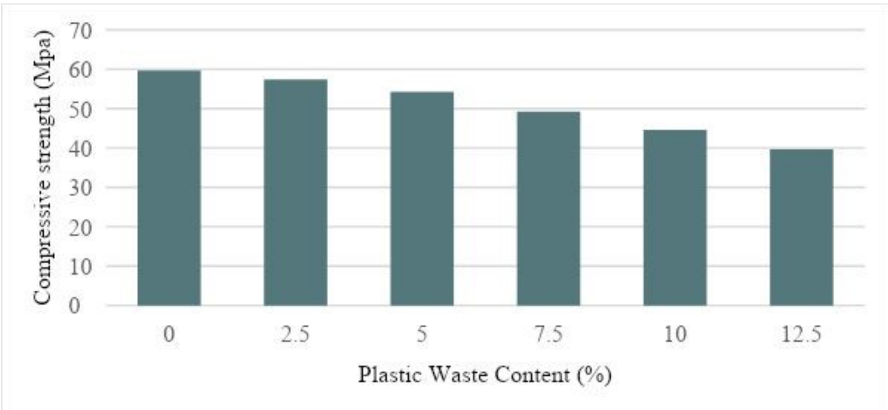

Fig: 4 Variation of 28day compressive strength with respect to plastic waste content.

IV CONCLUSIONS

The above investigation concludes the following:

- At a replacement ratio of even 7.5%, the SCC mix exhibited considerable compressive strength with respect to the reference mix and can be used as a viable option which could save almost 60kgs of plastic being dumped to landfills for every cubic meter of concrete laid.

- Self-Compacting concrete of strength of more than 40Mpa could still be produced even after replacement ratio of 10%.
- Only the mix with 12.5% of replacement ratio failed to classify under the EFNARC guidelines with respect to self-compacting concrete while testing L-box height ratio.
- All the SCC mixes could be categorized as VF2 class for V-funnel flow time test, where mix comprising of 2.5% replacement ratio could be classified as VF1 class, the same as the reference mix. This means that concrete with such mix proportions can be used in the concreting of columns and walls.
- By incorporating these mixes in today's construction world, we can reuse the waste plastic products of plastic industry and reduce the amount of waste correlated with these industries.
- Due to the shape and the properties of hydrophobicity and immiscibility with sand/cement, plastic aggregate increases the air content in the concrete.

V SCOPE FOR FURTHER RESEARCH

There is a vast variety of materials that can be tested and investigated against Self-compacting concrete for example GGBS or micro silica can be incorporated into the mix and the behavior of concrete can be tested against it.

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