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Durability Performance of SCC Produced with Plastic Waste and Fly Ash

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ABSTRACT

Concrete is most useful thing in construction industry but it has a negative impact also. Raw materials used in manufacturing of concrete affects the environment in one or the another negative way. A step taken in this direction is the use of waste products along with or in replacement of cement and aggregates. Many of these materials are already in use, like silica fume, fly ash, plastics etc. Some recent studies show that it can be used construction industry due to some of its properties like inert behavior, resistance to degradation etc. Also use of waste plastic can help in reducing plastic waste.
The present study deals with study of durability of SCC mixed with fly ash and plastic. One of the main characteristics influencing the durability of concrete is permeability to ingress of water, oxygen, carbon-dioxide, chlorides, sulphate and other compounds. Most of the durability problems in concrete can be attributed to volume change in concrete. volume change in the concrete in caused by many factors. The entire hydration process is nothing but internal volume change, effect of hydration, sulphate attack, carbonation, corrosion of steel. The internal and external restraints to volume change in concrete results in cracks, eventually concrete deteriorates degrades and ultimately fails. Experiment is conducted by replacing the cement with 30% fly ash, fine aggregate by 20% and 40% plastic granules. Plastic used is polyethylene terephthalate Durability test conducted on concrete are sulphate attack test and water absorption test. In sulphate attack test 28 days cured concrete cube are immersed in 5% concentration sulphuric acid solution for 28 days then split tensile strength test and compressive strength test carried out. Water absorption test is conducted and percentage of amount of water absorbed is noted Test results of the normal concrete cube and plastic concrete cube are compared.

Keywords: Durability test, SCC, fly ash, plastic waste, sulphate attack test, water absorption test..

1. INTRODUCTION

Aggregates used in construction are the most mined materials in the world. Modern blasting techniques increased the number of quarries at places wherever competent bedrock deposits are available. Also construction demand at places where neither stone, nor sand and gravel are available is usually satisfied by shipping inaggregate by rail, barge or truck. Indian construction industry today is amongst the five largest in the world. The demand for new construction is ever increasing with the rise in population. Hence the need of non-renewable aggregate has become a challenge. The future seems to be in dark for the construction sector.
Researches are being conducted using alternative for aggregate in the construction field. Focusing on the environment and safeguarding natural resources, new waste materials have been used in the construction industry. In India, due to growing population the quantity of solid waste is increasing rapidly. Among the solid waste materials, plastics represent 8% by weight of the total solid wastes. These nonbiodegradable plastic materials will finally end up as earth fill.

For solving the disposal of large amount of plastic materials and to meet the increasing need for aggregates, reuse of plastic in concrete can be considered as a feasible application. Plastic aggregates will not be crushed as easily as natural aggregate since plastic are polymers made up of long string molecules consisting of carbon atoms bonded with other atoms such as hydrogen, nitrogen, oxygen, fluorine. They develop a crystalline structure which is strong, hard and more resistant to chemical penetration and degradation. Hence it will be a boon to the construction industry, if plastic can be utilized to prepare aggregates.

2. EXPERIMENTAL STUDY

Cement: 43 Grade M40 Cement was used in concrete according to the BIS specifications 12269-1987.
Coarse aggregate: Aggregates passed from 20mm sieve were mixed in the ratio of Specific gravity and water absorption of the coarse aggregate are 2.70 and 0.30% respectively.
Fine aggregate: M-sand with maximum size of 4.75 mm was used. Specific gravity and water absorption of the sand are 2.60 and 1.00% respectively. Plastic: polyethylene terephthalate (PET) plastic waste of size 3.5mm with a specific gravity of 1.04 was replaced fine aggregate partially. The surface of PET aggregate is smooth in surface texture and spherical in shape as shown in Figure below.
Fly Ash: Class F Fly ash was replaced for cement.
Specific gravity of fly ash was 2.2.
Water:Potable tap water at room temperature was mixed for developing SCC according to BIS 456-2000 recommendations. Super Plasticizer: A sulphonated naphthalene polymer based Fosroc Conplast SP430 super plasticizer was used.

polyethylene terephthalate (PET) plastic granules

Mix Proportions

SCC having cementitious content of 309.4 kg/m^3 was produced replacing cement partially with 30% fly ash by weight.specic gravity of cement is 3.15 and M-sand with different % of PET granules by volume respectively. Coarse aggregate of 20mm were used of complete 100% proportion. Fine aggregate content was 975kg/m^3 and replaced with 10- 40% PET aggregate. The water to binder (cement + fly ash) ratio was 0.43 for all mixes. SCC with only replaced 30% fly ash was considered as the reference mix. M40 grade SCC was used to determine durable properties.

Test procedure

a.Water absorption test

All SCC cube specimens of size 10 × 10 × 10cm were prepared to determine the water absorption. The water absorption test at the curing age of 28 days was performed according to ASTM C642-13. The specimens after demoulding were immersed in water until the age of 28 day. The specimens were air dried and placed in an oven at 100ºC until a constant weight W1 in kg is obtained. Specimens were again immersed in water for period of 4 hours and saturated surface dried specimens were weighed W2 in Kg .Thus, the water absorption (%) according to the equation was calculated as shown in equation 1.

Water absorption (%)=[(W2– W1) / W1] x 100 eqn (1)

b.Sorptivity test of concrete

This test was performed according to ASTM C1585 − 13 to determine the rate of absorption of water measuring the change in mass of a concrete specimen with respect to time when only one surface is submerged in water container to a depth of 3–5 mm. Test procedure is conducted until constant sorptivity value is obtained. Capillary suction of water in unsaturated concrete is high in initial contact of water. The cylindrical specimens of dimensions 100mm diameter and 50mm depth were sealed with plastic cover except bottom surface. Weights of samples were measured. Place the support at the specimen's bottom and fill the container with tap water until 3-5 mm of concrete bottom surface. Start the stop watch and record the mass change from initial contact with water to different time periods. 60sec, 5min, 10min, 20min, 30min and 60 min for initial rate of absorption and secondary absorption rate is considered at time intervals mentioned in ASTM.

The sorptivity was calculated as shown in equations 2 and 3 and Tested.

$I=S\sqrt{t}$ (eqn 2)

therefore $S=I/\sqrt{t}$ (eqn 3)

Wherein
S= sorptivity in mm, t= elapsed time in minute

$I=\Delta w/Ad$

Δw= change in weight = W2-W1
W1 = Oven dry weight of cylinder in grams W2 = Weight of cylinder after 30 minutes capillary suction of water in grams.
A= floor area of the specimen through which water penetrated.

d= density of water

c. Sulphate attack test

Concrete cubes after 28 days of curing are immersed in 3% Sulphuric acid concentration solution. They are immersed for period of 28 days and later cubes are dispatched for compressive strength test. compressive strength of conventional concrete cubes and blended scc concrete cubes are compared. Compressive strength=P/A wherein

P=ultimate load in KN

A= cross sectional area of concrete specimen in mm^2

%of loss of strength=(CS1-CS2/CS1)*100

CS1=compressive strength of concrete before acid curing

CS2=compressive strength of concrete after acid curing

3. RESULTS AND DISCUSSION

a.Influence of PET aggregate on water absorption of SCC specimens

The water absorption test values of SCC specimens after curing of 28 days are shown in Figure 1. The water absorption with PET aggregate reduced with an increase in percentage replacement. Acceptance criteria according to CEB-FIP, 1989 is shown in Table I. Since the values for all mixes were in between 3%-6%, it was observed that SCC with 0-30% PET was average in water absorption at the age of 28 days. Water absorption increased abruptly after 30% replacement of PET and reduced up to 20% PET replacement compared to SCC without PET. Because of Poor bonding existed between cementitious paste content and PET, water absorption values were average but satisfactory. The water absorption values of SCC specimens with PET at the age of 28 days were 3.90%, 3.12%, 3.28%, 3.22% and 5.11 for 0%, 10%, 20%, 30%, and 10% respectively. Interestingly, the water absorption with plastic waste up to 30% replacement showed better performance than reference concrete having absorption value was
3.9%. The reason for reduction in water absorption was due to water repellent nature of PET and water absorption nature of fly ash. This combination balanced the water content in SCC for hydration filling all pore structure. Good compaction of concrete also reduces the water absorption. SCC filled almost all pores during its flow in casting since it contained more binder content including fly ash and different aggregates including PET ranging from 20mm-3.5mm size particles. It possesses less porosity due to different gradations existed in SCC.
In this test, the pozzolonic activity highly resisted the water absorption in longer curing periods i.e., 90 days. All the values obtained were showing good performance up to 30% PET and the similar reduction trend followed the age of 28 days. Since fly ash was used, it formed more C-S-H gel all over the matrix with connecting chains. Though PET had no action in concrete chemistry, it just acted as inert and resisted hydration inhibiting water movement. Until 30% replacement, all these negative effects were negligible. But the high volume addition of PET aggregate increased the porosity of concrete due to spherical shape and smooth texture of PET compared to natural sand. The water absorption of SCC with 10% PET was higher, the value was above 5% which makes the concrete in nature.

PET resists water up to 30% and further replacement due to availability of more plastic per unit area disintegrate the cohesiveness and packing density of concrete that also leads to bleeding during mixing the concrete and effects durability severely.

Table (1) .Acceptance criteria according to CEB-FIP, 1989

Water absorption	Performance
<3%	good
3%-5%	average
>5%	poor

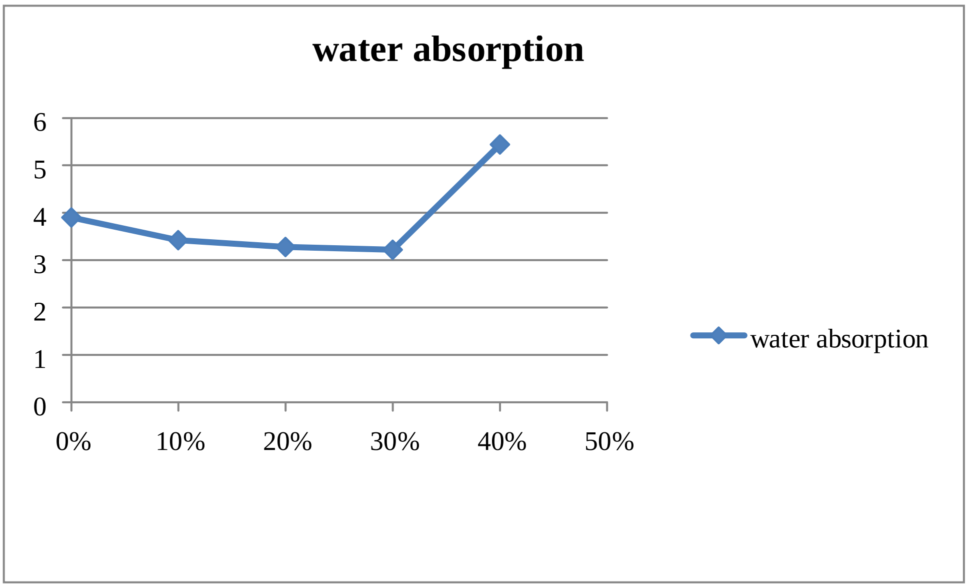

Fig 1.Water absorption (%) of SCC mixes with PET aggregate (%) at different curing periods

b.Influence of PET aggregate on Sorptivity of SCC specimen

The rate of water absorption at the curing periods of 28 days are shown in Figure 2. The initial rate of water absorption is shown in figure shown and it satisfied the criteria mentioned in ASTM C1585-13. Sorptivity values were reduced from 0%30% replacement of fine aggregate with PET aggregate. And also values were reduced with increasing the curing period. According to the acceptance criteria mentioned in the table 2, values are observed to be excellent in durability class (<6%) at all ages of curing. Reduction in sorptivity values up to 30% PET at all ages was primarily due to sufficient compaction attained, with the enhanced rheology of SCC by pozzolanic material fly ash and PET waste.

Table (2).Acceptance criteria suggested by Alexander et al.

Durability	Sorptivity limits(mm/√h)	Acceptance criteria
Excellent	<6	Highly acceptable
Good	6-10	Acceptable
Poor	10-15	Remedial measure required for acceptance
worse	>15	Rejected

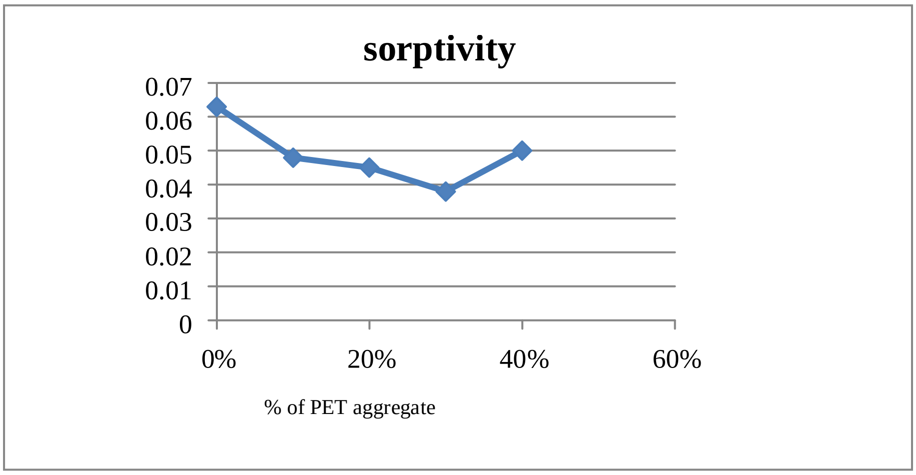

Fig 2.Sorptivity of SCC with respect to % variation of PET aggregate at different curing age

c.Effect of PET aggregate on compressive strength of SCC specimen

Compressive strength values of 28 are shown in Figure 3 and 4. Addition of ewaste PET for fine aggregate replacement in SCC mix reduced the strength. Strength reached target strength of M10 grade concrete up to 20% PET replacement. There was gradual decrease in compressive strength upto the expectable limits but strength from 10% PET was abruptly declined. Fly ash also absorbed the excess water available in the pore structure of matrix. Since PET restricted the water movement in SCC due to hydrophobic nature, it was additional to fly ash in delaying the hydration process. Thus SCC attained the compressive strength in longer duration.

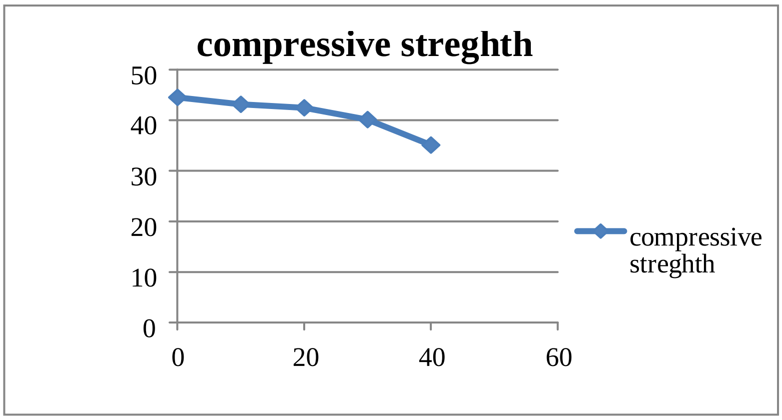

Fig 3.Compressive strength of SCC after 28 days water curing

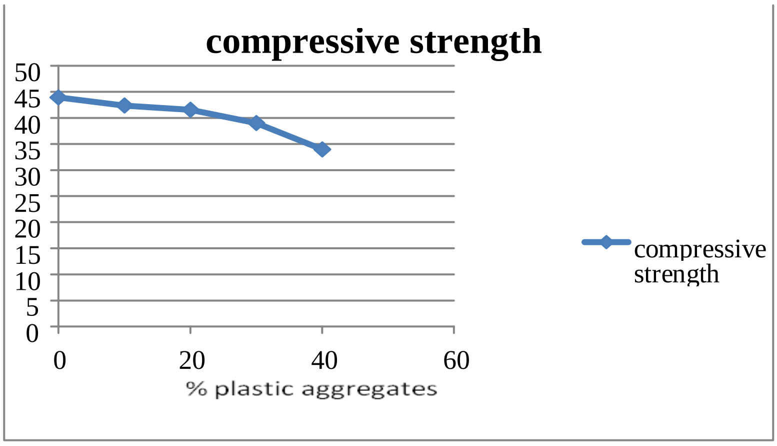

Fig 4.Compressive strength of SCC after 28 days 2% conc sulphuric acid curing

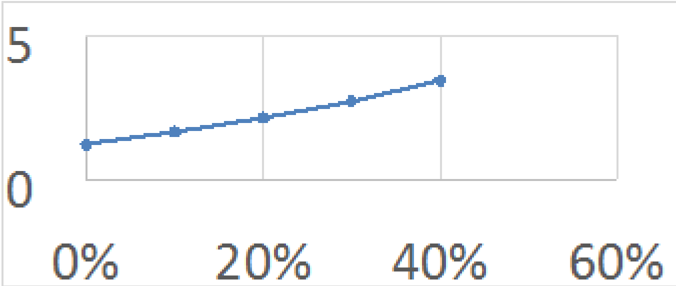

Fig 5. Graph showing % loss of compressive strength after sulphuric acid curing

4 CONCLUSION

The following conclusions are drawn with the effects of PET plastic waste, PET granules on self-compacting concrete:

- PET granules showed better resistance to water ingress up to 30% replacement due to hydrophobic nature but percentage of absorption increased at high volume replacement of PET.

- Porosity reduced up to 30% replacement of PET at all curing ages due to sufficient compaction available with enhanced rheology. Spherical shape of fly ash and PET filled all voids between aggregates obtaining continuous gradation among the matrix

- Since PET size, shape and inert nature reflects fine aggregate, PET took part in replacing sand for producing flow-able concrete. Due to smooth surface and spherical shape of PET, poor bonding at interfacial transition zone creates micro cracks and pores with increment in PET replacement. And availability of high amount of PET per unit volume also creates high porosity.

- Sorptivity also showed similar trend line of water absorption at all curing ages. The capillary suction of water ingress reduced due to smooth surface existed by the spherical particles of fly ash and PET.

- PET aggregate helped SCC efficiently to achieve excellent durable performance. It can be replaced for sand up to 30% with no hesitation for producing ecofriendly, economical and durable SCC.

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