ASIAN JOURNAL OF CIVIL ENGINEERING (BHRC) VOL. 18, NO. 1(2017)
PAGES 21-30

EXPERIMENTAL STUDIES ON CONCRETE ELEMENTS USING WASTE CARBON BLACK AS FILLER MATERIAL

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Received: 10 April 2016; **Accepted:** 17 July 2016

ABSTRACT

Concrete is the essential construction material used for many applications in the construction industry. Though it is used worldwide, it has its ill effects like the presence of pores and micro-cracks. These ill effects lead to acid intrusion and less resistance to atmospheric attack. As a result, its durability and strength get reduced. In this study attempt was made to investigate the effect of waste carbon black powder addition as filler material in concrete. Study on uniformity, surface hardness, split tensile strength, flexural strength and compressive strength of concrete specimens containing various percentages of carbon black were carried out. The effectiveness of using waste carbon black as filler in cylinders with rebar was also studied. From the experimental results, it can be seen that optimum percentage of 5% to 8% carbon black can be effectively used for enhancement of properties of concrete.

Keywords: Carbon black; filler; hardness; uniformity.

1. INTRODUCTION

Concrete is versatile construction material used in wide variety of applications. Concrete construction is expected to give trouble free service throughout its intended life. However, these expectations are not realised in many constructions due to pores in concrete, and these pores increase the permeability of concrete. The rate at which aggressive agents can penetrate to attack the concrete and the steel reinforcement is called as permeability. Permeability in concrete affects the durability of the concrete, and it will make the concrete vulnerable to external media attack such as water, chemicals, sulphates, etc. Hence, permeability is a very important attribute that needs to be achieved in any application.

The porosity of concrete can be reduced by adopting measures such as surface treatment

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using silanes, siloxanes, etc. and the addition of filler materials to concrete. Fillers are materials which are added to enhance the properties of concrete. These materials are used to reduce the porosity of the concrete. Some of the filler materials in use are Mica, Feldspar, Silica, Glass micro spheres, Flake glass, Talc, etc.

2. RESEARCH BACKGROUND

Many research works have been carried out by using various materials such as mica, silica, glass micro spheres, fake glass, etc. as filler in concrete. The effectiveness of using waste carbon black as filler in concrete has been previously studied since 1993. Goldman and Bentur [1] studied the influence of microfillers on the enhancement of concrete strength and proposed that carbon black is non-reactive inert material. They also commented that compressive strength is more of concrete with smaller particle size carbon black (0.073 and 0.025 micrometer) compared to the larger particle size of 0.33 micrometer. Goldman and Bentur [2] proposed that carbon black, non- reactive filler is highly effective in improving the mechanical performance of concrete. Their work indicated that improved mechanical properties are due to densification of the transition zone.

The present study investigated the use of waste carbon black as filler in enhancing the mechanical properties of concrete. Effect of carbon black on concrete cylinders with rebar is also studied by conducting Open Circuit Potential Test (OCP) and Chloride Ingress Penetration test.

3. MATERIALS USED

3.1 Carbon black

Carbon black used for the present study is finely divided powder. The specific gravity of carbon black was determined by density bottle approach, and it was once found to be 1.03. The pH value is 6 [3] and this indicates that carbon black is almost an inert material. The sources of carbon black are mainly from rubber industry, petrochemical plant and oil plant [4]. The particle size of carbon black was determined by using particle size analyser, and graph as shown in Fig. 1, was extracted. The particle size of carbon black was found to be 0.05 micrometer.

3.2 Cement

For the present work 53 grade. The cement used is Portland pozzolanic cement (PPC), and specific gravity of cement is 2.74. The consistency of cement carbon paste was found to be 34%. The initial setting time of cement was more than 30 minutes and final setting time was less than 10 hrs.

3.3 Fine aggregate

The specific gravity was found to be 2.33, and the moisture content was found to be 1.15%. Fineness modulus was 3.544 and as per IS 383 – 1970 [5] fine aggregate used in the present work belongs to sand zone II.

3.4 Coarse aggregate

The specific gravity was found to be 2.78, and the moisture content was found to be 0.33%. The sieve analysis conducted and fineness modulus was 7.767. The bulk density of coarse aggregate used was 1.513 kg/m^3.

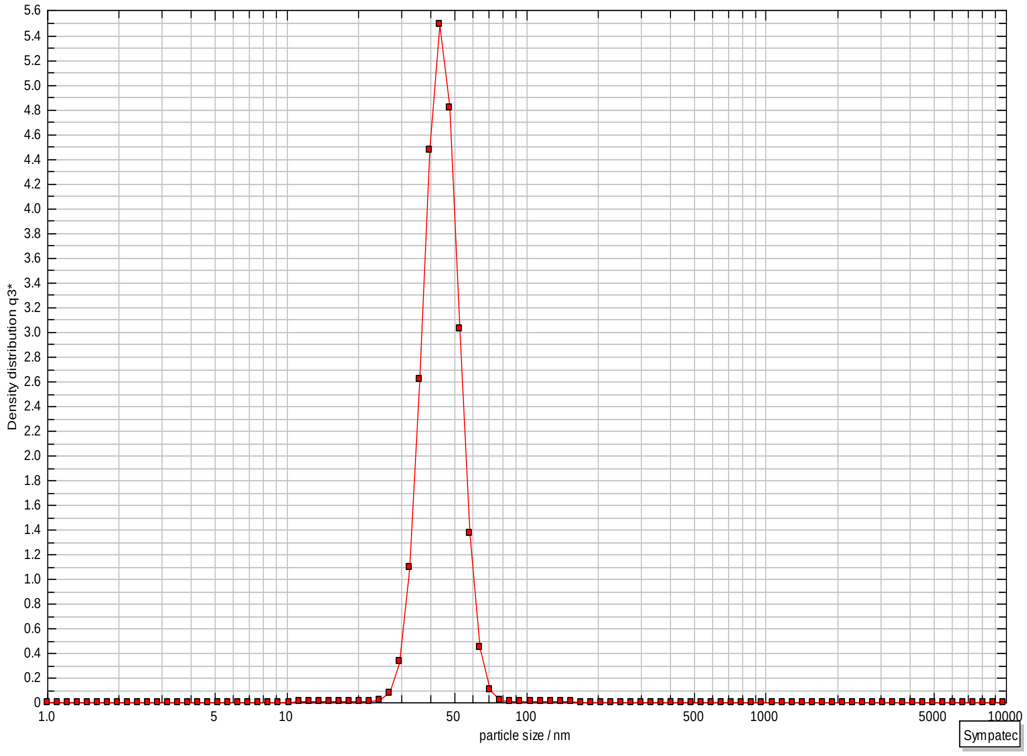

Figure 1. Result obtained from particle size analysis

4. PREPARATION OF SPECIMENS

Concrete specimens were cast with M20 grade of concrete. Concrete specimens were cast in the form of cubes (150 × 150 × 150 mm), cylinders (Height – 300 mm, Diameter – 150 mm) and prisms (500 × 100 × 100 mm). Concrete specimens for conducting the non-destructive test, compressive strength test, flexural strength test and split tensile test were cast with 0%, 2%, 5%, 8%, 10% and 12% of carbon black by weight of cement. Optimum % for the addition of carbon black in concrete was obtained from the above-mentioned tests results. For the optimum % obtained, concrete cylinders with rebar were cast. Concrete cylinders with rebar were used for conducting OCP test and Chloride ingress determination test.

In this study, the procedure followed under [1] was adopted for mixing concrete ingredients with carbon black. At first, aggregates were mixed dry. Then a small quantity of water (of the designed water-cement ratio) was added to the aggregates and mixed, further cement and the remnant of water were added. After mixing the concrete ingredients for few minutes, carbon black was introduced and mixed.

5. TESTING PROGRAMME

5.1 General

Influence of adding carbon black as filler material in concrete was studied by casting and testing the specimens. Flexural behaviour of PCC beam was studied by conducting flexural strength test. In addition to that, the tests conducted on concrete cubes were non-destructive testing using Ultrasonic Pulse Velocity (UPV), compressive strength test using Rebound hammer and the compressive strength test using compression testing machine. The tests conducted on concrete cylinders were split tensile strength test, OCP Test and chloride ingress determination test.

5.2 Open circuit potential test

Cylindrical reinforced concrete (1: 1.160: 2.941) specimens of size 150 mm diameter and 300 mm height were cast with and without carbon black powder. Open Circuit Potential test was conducted as per ASTM C876 [6]. All the specimens were taken out after 28 days of curing and then dried. Before immersing the specimens in 3.5% NaCl, the potential of the reinforced bar was measured against saturated calomel electrode (SCE) using a high impedance volt meter. Then the specimens were subjected to 3.5% NaCl solutions to induce accelerated corrosion. The potential readings had been measured periodically. The research was continued for 60 days. The measurements were changed once in a week due to induced accelerated corrosion. Potential measurements were carried out for both control specimens and carbon black specimens at an ambient temperature of 32+1°C. Table 1 depicts the relationship between Open Circuit Potential Values and the probability of corrosion.

Table 1: Relation between for OCP values and probability of corrosion

Open circuit potential (OCP) values (mV vs. SCE)	Corrosion condition (As per ASTM C876)
< - 426	Severe corrosion
< - 276	High (< 90% risk of corrosion)
- 126 to - 275	Intermediate corrosion risk
> - 125	Low(10% risk of corrosion)

5.3 Chloride ingress determination test

This test was used to determine the amount of chloride penetrated into the cylindrical specimen after conducting open circuit potential test. The cylindrical specimen was divided into two portions after conducting open circuit potential test. Concrete from the core of cylindrical specimen was collected and crushed. The crushed concrete was sieved through 425 micron sieve. 20 gram of crushed concrete passing through 425 micron sieve was taken. 100 ml of distilled water was added to the crushed sample and kept in a shaker for 1 hour. After 1 hour of shaking, the sample was filtered and the solution was collected for chloride test. The burette was filled with silver nitrate (0.02N) solution. 50 ml of solution was taken in the conical flask and 2 ml of potassium chromate was added. The yellow colour solution was formed. The amount of chloride penetrated into the cylindrical specimen was determined by titrating the solution against silver nitrate solution using potassium chromate 5% as an indicator. The amount of chloride penetrated into the cylindrical specimen was determined by the Equation (1).

$$Chloride(mg/L) = \frac{(ml \times N) Silvernitrate \times 1000 \times 35.5}{Sample(ml)} \tag{1}$$

where, N is the Normality of Silver Nitrate

6. RESULTS AND DISCUSSIONS

6.1 General

The strength characteristics of M20 grade concrete cubes, cylinders and PCC beams made of various percentages of carbon black in surface hardness, uniformity, compression, were found by casting and testing the same. The results of tested specimens are discussed below.

6.2 Ultrasonic pulse velocity test

The results of ultrasonic pulse velocity test are shown in Table 2. From the Table 2, it is noticed that quality of concrete cubes with 2%, 5%, 8% and 10% of carbon black is good. This shows that uniformity of concrete is maintained with the addition of carbon black.

Table 2: Ultrasonic pulse velocity test results

% of Carbon Black	Time (Microsecond)	Distance Travelled (m)	Velocity (km/s)	Quality of concrete (IS 13311) [7]
0%	33.55	0.15	4.85	Excellent
2%	32.39	0.15	4.63	Excellent
5%	34.89	0.15	4.30	Good
8%	36.32	0.15	4.13	Good
10%	43.10	0.15	3.48	Good
12%	45.73	0.15	3.28	Medium

6.3 Rebound hammer test

Rebound hammer test was conducted as mentioned in the previous section and test results are as shown in Table 3. Test results show that concrete specimen with 5% shows fairly good surface characteristics when compared to control specimens. The test result shows that addition of carbon black as filler in concrete increases the surface hardness of concrete. Among concrete specimens with carbon black, 5% shows the best performance.

6.4 Compressive strength test

Compressive strength test results are given in Table 4. From the observations, it is inferred that 2%, 5% and 8% carbon black specimens have attained greater strength compared to control specimen. This may be due to densification of the transition zone [2]. The addition of carbon black beyond 8% reduces the compressive strength value since carbon black imparts brittle characteristics to concrete.

Table 3: Rebound hammer test results

Specimen	Rebound Number	Compressive strength (N/mm^2)	Quality (As per IS 13311) [8]	% Increase in Compressive strength on control
0%	22.32	24.5	Fair	--------
2%	22.5	24.9	Fair	+ 1.632
5%	22.5	25	Fair	+ 2.04
8%	21.25	22.5	Fair	- 8.16
10%	21.7	21.25	Fair	- 13.27
12%	20.33	20	Fair	- 18.37

Table 4: Compressive strength test results

Specimens	Compressive Strength (N/mm^2)	% Increase in Compressive Strength on control
0%	27.30	--------
2%	28	+2.56
5%	29.30	+7.33
8%	29.67	+8.68
10%	24	-12.09
12%	20.78	-23.88

6.5 Split tensile strength test

Test results are as shown in Table 5. Split tensile strength test result shows that the tensile strength of carbon black concrete is lesser when compared to that of control specimen. Since carbon black imparts brittle nature in concrete, this makes the concrete weak in tension.

Table 5: Split tensile strength test results

% of carbon black	Split Tensile Strength (N/mm^2)	% Increase in tensile strength on control
0%	3.61	---------
2%	3.42	-5.263
5%	3.29	-8.864
8%	3.13	-13.29
10%	2.94	-18.56
12%	2.87	-20.50

6.6 Flexural strength test

Flexural strength test was carried out as per IS: 516 – 1959 [9]. After loading of PCC beam till its ultimate point, the distance between the line of fracture and the nearer support was measured. The distance was found to be greater than 13.3 cm for all the specimens with 0%, 2%, 5%, 8%, 10% and 12% of carbon black. Flexural strength is expressed as the modulus of rupture (f_b) and the test results are shown in Table 6.

Table 6: Flexural strength test results

Specimen	Ultimate load (N)	Modulus of rupture (N/mm^2)
Control Specimen	14750	7.375
2 %	9750	4.875
5 %	8000	4
8 %	7000	3.5
10 %	7000	3.5

Flexural strength test result is shown in Table 6 and behaviour of specimens under flexural loading is shown in Fig. 2. The addition of carbon black in concrete has reduced the flexural strength compared to control specimen. Load carrying capacity for PCC beam with 12% carbon black was less and these beams failed by brittle fracture. Even the performance of carbon black specimens was less compared to control specimen, the load versus deflection behaviour for carbon black specimens was found to be acceptable.

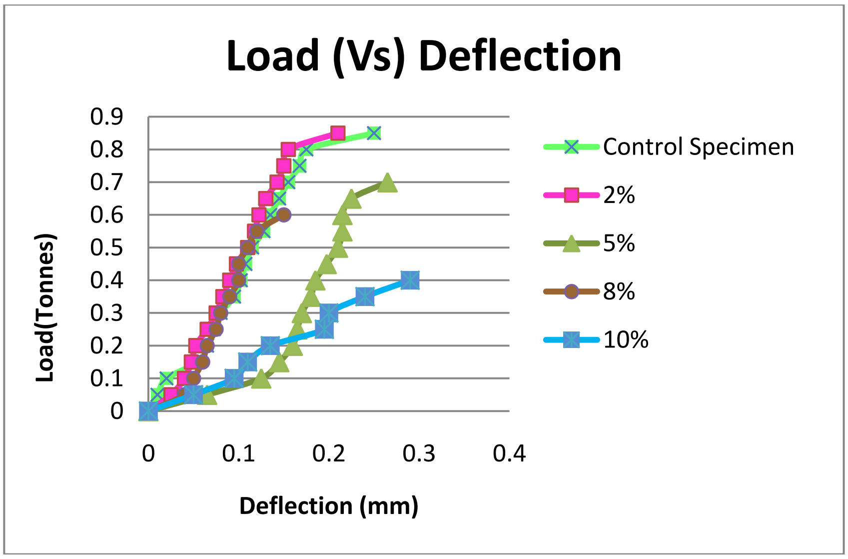

Figure 2. Load Vs. Deflection curve

6.7 Optimum percentage of carbon black

From the light of experimental results, it can be seen that concrete specimen with 5% and 8% carbon black shows good performance on control specimens. Concrete with 5% and 8% shows excellent performance compared to control as seen from the compressive strength test results. 5% to 8% addition is found to densify the weak link of the transition zone. However, its flexural strength values and split tensile strength are found to have the reduction in performance on control specimens. Reduction in performance may be due to imparting brittle characteristics to concrete by the addition of carbon black. The addition of carbon black beyond 8% is found to be not effective which can be seen from the reduction in performance of 10% and 12%. Optimum % of carbon black was found to be 5% to 8% from the test results.

6.8 Open circuit potential test

The result of the open circuit potential test conducted on 0%, 5% and 8% of carbon black concrete specimens is shown in Fig. 3.

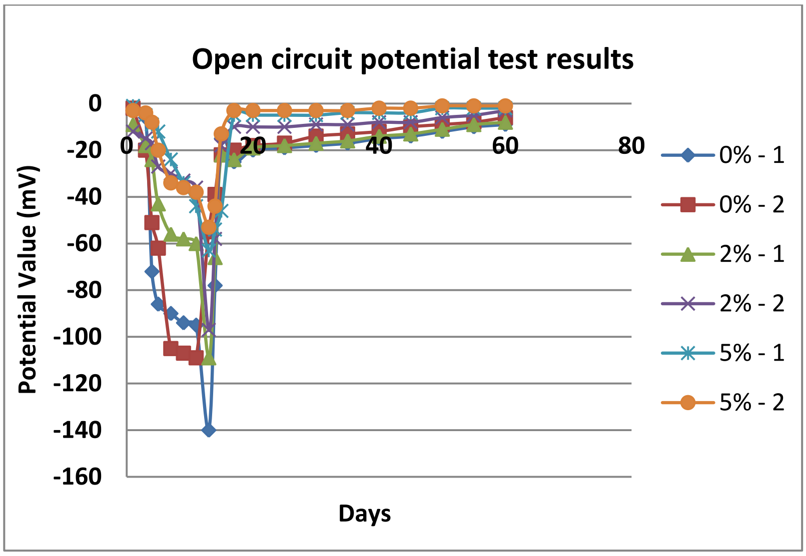

Figure 3. Open circuit potential test results

From Fig. 3, it is found that all the specimens are showing high negative potential values indicating the current condition of the rebar. Both the control and carbon black concrete showed the negative potential of more than -50 mV initially at 7 to 10 days. After that potential, the value of all specimens decreases simultaneously with increasing number of days. It is also noticed that the corrosion rate of carbon black concrete is less when compared to the control specimen. The trend in reduction of potential values for control specimen and carbon black specimen can be observed from the test results.

6.9 Chloride ingress determination test

The results of chloride ingress determination test for 0%, 5% and 8 % carbon black concrete specimens are as follows. Table 7 shows the amount of chloride penetrated into the specimen.

Table 7: Amount of Chloride penetrated into the specimen

Specimen	Volume of sample (ml)	Volume of silver nitrate solution (ml)	Mean value (ml)	Amount of chloride penetrated into the specimen (mg/L)
CS-1	50	11		
CS-2	50	12	11.5	163.30
5%-1	50	7.3		
5%-2	50	9.8	8.55	121.41
8%-1	50	10		
8%-2	50	11.3	10.65	151.23

From the observations made, it is inferred that the amount of chloride penetrated into the cylindrical specimen is much less in 5% and 8% in comparison to the control specimen. The test results show that chloride ingress is less in the cylindrical specimen with the optimum percentage of carbon black. Being very fine particle, carbon black has closed pores in concrete, and hence permeability of concrete has been reduced. From the test results, it is noticed that carbon black specimen has good resistance to corrosion.

7. CONCLUSION

From the present study, the following conclusions are arrived:

1. Non-destructive tests and compressive strength test results show that performance of 2%, 5% and 8% carbon black concrete is improved compared to control specimen.
2. Split tensile strength for 2% carbon black specimen is reduced by 5% compared to control specimen. With every 2% increase in carbon black, split tensile strength has been reduced by 4% approximately.
3. Flexural strength for carbon black specimens (2%, 5%, 8% and 10%) is less compared to the control specimens. The addition of carbon black has reduced split tensile strength and flexural strength compared to control specimens. This may be due to imparting of brittle characteristics to concrete by carbon black.
4. OCP test results and chloride ingress test results show improved performance for carbon black specimens. Being very fine particle carbon black has closed the pores present in concrete and hence, the permeability of concrete has been reduced. From the Open circuit potential test results and Chloride Ingress Determination Test results it can be seen that 5% and 8% carbon black addition is effective in RCC elements.

Hence, it is concluded that the addition of carbon black between 5% and 8% as a filler material will be very effective in enhancing the performance of concrete elements.

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