Carbon Black as an Additive in Conventional Concrete

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Abstract— In this experimental investigation an attempt was made to minimize the presence of pores in conventional concrete using carbon black powder, a waste from rubber industry as filler. Carbon black filler material imparts the enhanced performance of concrete. To suggest the optimum percentage of carbon black to be added in concrete totally 18 number of concrete cubes, 12 number of concrete cylinders with carbon black of different percentage (0%, 2%, 5%, 8%, 12%, 15%) were cast. Study on morphology, surface hardness, uniformity, compressive strength, tensile strength and water absorption were carried out on carbon black concrete specimens. A Comparison is made with test results to arrive at valid conclusion. It can be observed that the specimens with 2% and 5% carbon black show good performance with respect to control specimens.

Keywords— Carbon black, Concrete, Pores in concrete, Compressive strength, Permeability, Morphology of Concrete

I. INTRODUCTION

Concrete is the most widely used man made construction material in the world. It is obtained by mixing cementitious materials, water and aggregates in required proportions.

Being a versatile material, presence of pores in concrete proves to be a major problem since ever it was discovered. Pores in turn attract water that leads to various ill effects such as freezing and thawing, acid intrusion, decreased resistance to chloride ion, reduced compressive strength etc. By considering this problem, a study is made to minimize the pores present using carbon black powder, a waste from rubber industry as filler. Due to their extreme small size they can fill the pores thereby it is expected to achieve the following benefits:

- Increase in density of concrete thereby increase in strength and resistance to atmospheric attack
- Decrease in permeability of concrete

A. Carbon Black

Carbon black is virtually pure elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. Its physical appearance is that of a black, finely divided pellet or powder. It is a waste from rubber industry, finds difficulty in disposal. Normally these rubber wastes are dumped into soil creating soil pollution and contamination of water table. By using carbon black as filler in concrete we can reduce this problem to a great extent. Thereby reusing the waste usefully and making it eco-friendly to environment.
The specific gravity of carbon black was determined by density bottle method and it was found to be 1.33. The pH value was found to be 6. This indicates that carbon black is almost an inert material. Figure 1 shows the picture of carbon black.

II. EXPERIMENTAL PROGRAM ON CARBON BLACK CONCRETE

This experiment includes the casting of 18 number of concrete cubes of 150x150x150 mm size and 12 number of concrete cylinders of 150x300 mm size. Hence a total of 30 concrete specimens were cast with different percentage of carbon black for conducting various tests. Concrete cubes were cast with the carbon black filler of 0%, 2%, 5%, 8%, 12% and 15% in the amount of cement. Concrete cylinders were cast with the carbon black of 0%, 2%, 5% and 8% in the amount of cement. M20 Grade of concrete is used for analysis. In this study, hand mixing was done. Since carbon black was finding difficulty in blending with the ingredients of concrete, to obtain a cohesive mix different mixing procedure was adopted. The coarse aggregates, fine aggregates and water were taken by weight basis and mixed manually on a water tight platform. Water was added gradually until all the materials were mixed to get uniform mix. After 10 minutes the cement and the remnant of water were added. After 2 minutes of mixing, carbon black was introduced and mixed for 3 additional minutes.

Fig. 2 Carbon black Concrete Cubes

III. EXPERIMENTAL SETUP AND TESTING OF SPECIMENS

To study the performance of carbon black concrete the following tests were conducted on carbon black concrete specimens.

- Compressive strength test on concrete cubes using compression testing machine
- Non destructive Compressive strength test on concrete cubes using Rebound Hammer
- Ultrasonic Pulse Velocity test to find the Uniformity of concrete
- Water absorption test to study the permeability of concrete.
- Morphology of concrete specimens is studied using Scanning Electron Microscope(SEM)
- Split tensile strength test on concrete cylinders using compression testing machine

IV. RESULTS AND DISCUSSION

A. Compressive strength test

To determine the compressive strength of concrete cubes, The specimen was placed in the compression testing machine after curing. The load was applied gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen failed. The maximum load at which the specimen failed was recorded. Fig. 3 shows the Experimental Setup of Compressive Strength Testing. The result of compressive strength of concrete cubes is shown in Table I.
From the Table I and Fig. 4 it is clear that concrete specimen with 2%, 5% has given better results when compared to control specimen. This shows that carbon black filler increases the strength of concrete. Among all concrete cubes, 5% carbon black concrete shows the best result. This is due to densification of transition zone (Transition zone is a thin layer between bulk hydrated cement paste and the aggregate particles in concrete).

From 8% onwards the compressive strength value reduces since carbon black imparts brittle characteristics to concrete.

B. Rebound hammer test
This method is based on the principle that the rebound of elastic mass depends on the hardness of surface against which the mass strikes. The surface hardness and therefore the rebound is taken to be related to the compressive strength of concrete cubes. The results of rebound hammer test is shown in the Table II.
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Fig. 5 Experimental Setup for Rebound Hammer Test

### Table II

<table>
<thead>
<tr>
<th>% of Carbon Black</th>
<th>Rebound No</th>
<th>Compressive Strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>24.00</td>
<td>19.22</td>
</tr>
<tr>
<td>2%</td>
<td>25.50</td>
<td>21.85</td>
</tr>
<tr>
<td>5%</td>
<td>28.30</td>
<td>26.21</td>
</tr>
<tr>
<td>8%</td>
<td>22.17</td>
<td>17.48</td>
</tr>
<tr>
<td>12%</td>
<td>20.50</td>
<td>14.85</td>
</tr>
</tbody>
</table>

From the Table II and Fig. 6 it is clear that concrete specimen with 2%, 5% has given better results when compared to control specimen.

### C. Ultrasonic pulse velocity test

The ultrasonic pulse velocity (UPV) is a non destructive method which is used to establish the homogeneity of the concrete and to find the presence of cracks, voids and other imperfections. The method is based on the principle that the velocity of an ultrasonic pulse through any material depends upon the density, modulus of elasticity and Poisson’s ratio of the material. Comparatively higher velocity is obtained when concrete quality is good. UPV test was conducted on concrete cubes to analyze the density, uniformity, homogeneity of carbon black concrete. The results of ultrasonic pulse velocity test are shown in the Table III.
D. Water Absorption Test for Concrete Cubes

Permeability of concrete is important when dealing with durability of concrete. It relates to the size of the pores in concrete, their distribution and most importantly their continuity. Water Absorption Test was conducted on Concrete Cubes to study the permeability of carbon black concrete. Three concrete cubes were immersed in clean water at room temperature for 24 hours. Then the cubes were removed from the water and allowed to drain for one minute and weighed. After weighing, all cubes were dried in a ventilated oven at 100 to 115°C and weighed. The weight loss was measured. The results of water absorption test is shown in the Table IV.

From the Table IV, it is clear that concrete specimen with 2%, 5%, 8% has better results when compared to control specimen. This shows that carbon black when used as filler in concrete decreases the porosity of concrete. Among concrete with carbon black specimens 8% shows the best result.

<table>
<thead>
<tr>
<th>% of Carbon Black</th>
<th>Dry weight (kg)</th>
<th>Wet weight (kg)</th>
<th>% increase in weight</th>
<th>% Increases in Water absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>8.98</td>
<td>9.15</td>
<td>1.89</td>
<td>-1.99</td>
</tr>
<tr>
<td>2%</td>
<td>8.44</td>
<td>8.54</td>
<td>1.18</td>
<td>-41.2</td>
</tr>
<tr>
<td>5%</td>
<td>8.32</td>
<td>8.40</td>
<td>0.962</td>
<td>-52.9</td>
</tr>
<tr>
<td>8%</td>
<td>8.64</td>
<td>8.70</td>
<td>0.694</td>
<td>-64.7</td>
</tr>
<tr>
<td>12%</td>
<td>7.48</td>
<td>7.90</td>
<td>5.61</td>
<td>+147.0</td>
</tr>
</tbody>
</table>

E. SEM analysis

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens.

The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using SEM techniques. In SEM analysis pore size of concrete specimens has been measured and the results are presented in the following Table V.

Fig. 9 Scanning Electron Microscope
From the morphology pictures, Table V and Fig. 13 it is clear that the pore size has been reduced in case of carbon black concrete when compared to control specimen. 5% has the minimum pore size than all other specimens. This indicates that carbon black is effective in filling the pores also in mortar specimens.

**TABLE V**

<table>
<thead>
<tr>
<th>% of Carbon Black</th>
<th>Pore Size (µm)</th>
<th>% Increase in pore size w.r.t Control Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>2%</td>
<td>10</td>
<td>-77.77</td>
</tr>
<tr>
<td>5%</td>
<td>6</td>
<td>-86.67</td>
</tr>
<tr>
<td>8%</td>
<td>20</td>
<td>-55.55</td>
</tr>
</tbody>
</table>
F. Split tensile strength test

Splitting tensile strength test was conducted on concrete cylinders to determine the tensile nature of carbon black concrete. The wet specimen was taken from water after 28 days of curing. The surface of specimen was wiped out. The weight and dimension of the specimen was noted. The cylinder specimen was placed on compression testing machine. The load was applied continuously without shock at a constant rate. The breaking load (P) was noted.

From the Table VI and Fig. 16 it is clear that the split 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 VI

<table>
<thead>
<tr>
<th>% of Carbon Black</th>
<th>Split Tensile Strength (N/mm²)</th>
<th>% Increase in compressive strength w.r.t Control Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>18.11</td>
<td>-</td>
</tr>
<tr>
<td>2%</td>
<td>13.58</td>
<td>-25.01</td>
</tr>
<tr>
<td>5%</td>
<td>15.84</td>
<td>-12.53</td>
</tr>
<tr>
<td>8%</td>
<td>11.32</td>
<td>-37.50</td>
</tr>
</tbody>
</table>

Figure 16 Split Tensile Strength Test Results

V. CONCLUSIONS

From the Experimental results it can be seen that concrete specimen with 2% and 5% carbon black shows good performance with respect to conventional concrete.

As seen from the morphology pictures taken by SEM, Concrete with 8% carbon black shows excellent closure of pores. As well as water absorption results are also better for 8% carbon black concrete. This is due to the densification of weak link of the transition zone. However it’s compressive and split tensile strength values are found to have reduction in performance with respect to normal concrete. This is due brittle characteristics imparted by carbon black on concrete.

Addition of carbon black beyond 8% is found to be not effective which can be seen from the reduction in performance of 12% and 15% specimens.

Hence it can be concluded that the addition of carbon black up to 5% as a filler will be very effective in concrete.

A. Suggestions for Further Study

- Investigating the performance of concrete with higher percentage of carbon as filler with the introduction of binders.

- Studying the performance of concrete by using carbon black as a replacement for cement.
VI. REFERENCES


[5]. Shaopeng Wu Liangtong Mo Zhonghe Shui, and Zheng Chen, “Investigation of the conductivity of asphalt concrete containing conductive fillers”.
