Mechanical and Durability Properties of Concrete by Adding Bottom Ash as a Partial Replacement of Fine Aggregates

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Abstract— the natural resources of the sand are getting depleted gradually. Mining of sand also leads to various environmental hazards. The demand for the protection of the natural environment and the ban on mining in some areas is further aggravating the river sand. Bottom ash is a byproduct of composition of pulverized coal composed mainly of silica, alumina and iron with small amounts of calcium, magnesium sulphate. This paper presents the experimental investigation carried out to study the effect of use of coal bottom ash as a partial replacement of fine aggregate. An experimental program is planned in which controlled concrete of grade M30 is used. Fine aggregate is replaced with bottom ash by 10%, 20%, 30%, 40%, 50% and the properties like compressive strength, tensile strength, flexural strength, RCPT, Sulphate Attack Test, Optimum Replacement are studied. Test results show that bottom ash can be used as an effective replacement of fine aggregates. Workability decreases with the increase of bottom ash content. The compressive strength, tensile strength, flexural strength was effective up to 30% replacement level. Therefore 30% of the fine aggregates maybe replaced with bottom ash effectively.

Key words: Bottom Ash, Compressive Strength, Split Tensile Strength, RCPT, Sulphate Attack Test, Optimum Replacement

I. INTRODUCTION

Concrete is a material with great strength and has a very long life. It has emerged as the very basic construction material for the needs of the twenty-first century. Concrete being durable, is easy to prepare and fabricate from readily available constituents. Energy is the backbone of modern civilization of every country and the electric Power from thermal power stations is a major source of energy, in the form of electricity. In India, over 75% of electricity generated in India, is by combustion of fossil fuels, out of which nearly 55% is produced by coal-fired plants. This results in the production of more than 100 tons of ash every day. Most of the ashes are disposed to an open area available near the plant or by pumping into dumping yards which causes the pollution in water bodies and loss of productive land.

The continuous reduction of natural resources and the environmental hazards due to the disposal of coal ash has reached tremendously. The use of coal ash in normal concrete is a new dimension in concrete and if it provides satisfying results it can be used as the major constituent of concrete which helps in the decrement of the ash content and also reduces the usage of natural resources. This paper presents the experimental investigation carried out to study the effect of use of bottom ash as a replacement of fine aggregates. Although, fly ash obtained from the chimneys are being generally used as replacement of cement and in the manufacture of cement, the study on the use of bottom ash has been very limited.

II. MATERIALS AND MIX PROPORTIONS

The materials used for the concrete are the available locally and the properties of the materials are tested.

A. Cement

OPC of 53 Grade locally available is used in this investigation with specific gravity 3.15 and initial and final setting time of 30 and 590 minutes.

B. Fine Aggregate

Sand used is either round or angular in grains and it is found mixed in various grades of fineness. River sand is usually used. In this project, the locally available sand around Tiruppur of zone II is used. The fine aggregate are conformed to the provisions of Indian standard specification with the fineness modulus 3.22 and specific gravity 2.4.

C. Coarse Aggregate

Coarse aggregate is used to reduce the drying shrinkage and other dimensional changes. The size of the aggregate used is 20 mm nominal size from the local source was used. Coarse aggregate crushed angular aggregate should be sound, free from deleterious materials and must have crushing strength at least 1.5 times that of concrete. The properties of coarse aggregate includes the specific gravity 2.66 and fineness modulus of 7.81.

D. Bottom Ash

The Bottom ash is collected from Sree Rengaraj Ispat Industries, Perundurai. They are collected from the 30MW power plant. Nearly 5000 tons of the bottom ash are produced during the power generation process. The washed bottom ash is collected and made to dry in the sunlight. The dried bottom ash is then sieved and the desired size is taken for the replacement of sand. The physical and chemical composition of the bottom ash are studied.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Colour</td>
<td>Grey</td>
</tr>
<tr>
<td>2</td>
<td>Specific gravity</td>
<td>2.24</td>
</tr>
<tr>
<td>3</td>
<td>Ph</td>
<td>7-10</td>
</tr>
<tr>
<td>4</td>
<td>Fineness modulus</td>
<td>2.82</td>
</tr>
</tbody>
</table>

Table 1: Physical properties of bottom ash

E. Water and Plasticizer

Water is generally used for making concrete. Water should be free from acids, oils and other organic impurities. It reacts chemically with the cement to form a cement paste and it serves as a lubricant in the mixture of fine aggregates and cement.

Conplast SP430 (G) is used as the chemical admixture where a high degree of workability and its retention are required. It facilitates production of high quality concrete.
F. Mix Proportions

This study consists of six mixes of concrete with different proportions of bottom ash. The different proportions include 0%, 10%, 20%, 30%, 40%, 50% of replacement of fine aggregates on which experimental investigations were carried out. The mixes were named as CC, C1, C2, C3, C4, C5.

Mix design is a process of selecting suitable ingredients and determining their relative proportions with the objective of producing concrete of having certain minimum workability, strength and durability as economically as possible. Concrete mix has been designed based on Indian Standard Recommended Guidelines IS 10262: 2009.

M30 mix was considered for the conventional mix design, under severe exposure condition, placing of concrete by pumping, using a chemical admixture and a water cement ratio of 0.38 is considered. Based on trial with superplasticizer a free water content of 180 liters gave a slump of 100 mm. The tests carried out were for compressive strength on cubes, splitting tensile strength and flexural strength on standard specimens. Testing was carried out on conventional mix (control mix) without any replacement and on mixes with 10, 20, 30, 40 and 50% sand replaced by bottom ash. Testing was also carried out on mixes with 10, 20, 30, 40 and 50% sand replaced by bottom ash for replacement. The table 2 shows the various replacement of bottom ash with the sand for the mixes. The values are provided by the unit kg/m$^3$.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Cement (kg/m$^3$)</th>
<th>FA (kg/m$^3$)</th>
<th>BA (kg/m$^3$)</th>
<th>CA (kg/m$^3$)</th>
<th>Water (kg/m$^3$)</th>
<th>Admixture (kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>414.7</td>
<td>728.4</td>
<td>0</td>
<td>1214.8</td>
<td>157.6</td>
<td>4.147</td>
</tr>
<tr>
<td>C1</td>
<td>414.7</td>
<td>655.6</td>
<td>72.8</td>
<td>1214.8</td>
<td>157.6</td>
<td>4.147</td>
</tr>
<tr>
<td>C2</td>
<td>414.7</td>
<td>582.7</td>
<td>145.7</td>
<td>1214.8</td>
<td>157.6</td>
<td>4.147</td>
</tr>
<tr>
<td>C3</td>
<td>414.7</td>
<td>509.9</td>
<td>218.5</td>
<td>1214.8</td>
<td>157.6</td>
<td>4.147</td>
</tr>
<tr>
<td>C4</td>
<td>414.7</td>
<td>437.0</td>
<td>291.4</td>
<td>1214.8</td>
<td>157.6</td>
<td>4.147</td>
</tr>
<tr>
<td>C5</td>
<td>414.7</td>
<td>364.2</td>
<td>364.2</td>
<td>1214.8</td>
<td>157.6</td>
<td>4.147</td>
</tr>
</tbody>
</table>

Table 2: Mix proportions of the concrete mixes.

III. EXPERIMENTAL INVESTIGATION

A. Compression Strength Test

The compressive strength of the cubes are determined in the universal testing machine. The compressive strength had been evaluated from the peak load obtained by crushing the specimen. The Figure 1 shows the compressive test results of the cubes.

B. Split Tensile Strength

The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The split tensile strength had been evaluated from the peak load obtained by crushing the specimen. The Figure 2 shows the split tensile strength of the cylinder.

C. Rapid Chloride Penetration Test

The rapid chloride penetration test was performed as per ASTM C1202 to determine the electrical conductance of the conventional concrete and C3 mix and to provide a rapid indication of its resistance to the penetration of chloride ions. The test method consisted of monitoring the amount of electrical current passed through 51mm thick slices of 102mm nominal diameter of cylindrical specimen for duration of six hours. The RCPT apparatus consisted of two reservoirs. One reservoir was filled with 0.3N sodium hydroxide (connected to positive terminal) and other reservoir was filled with 3% sodium chloride (connected to negative terminal). A DC of 60V was applied and maintained across the specimen by using two stainless steel electrodes and the current across the specimen was recorded at 30mins interval for duration of six hours.

D. Sulphate Attack Test

Sulphate attack test was carried out by using the concrete cubes of size 150mmX150mmX150mm. After 28days of curing, the concrete cubes were dried at room temperature and the weight (W1) was noted. By adding 5% sodium...
sulphate (by volume of water) to 50 litres of distilled water the sodium sulphate solution was prepared. In this experiment, at 5% sodium sulphate (Na2SO4) solution the concrete cubes were immersed for a period of 3 months. After 90 days the observations were made. Then the cubes in normal room temperature for a period of 24hrs drying, the weight (W2) were noted. The sulphate attack is obtained from parameters such as loss in mass and loss in strength.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>W1(KG)</th>
<th>W2(KG)</th>
<th>%of weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>2.51</td>
<td>2.58</td>
<td>2.78</td>
</tr>
<tr>
<td>C3</td>
<td>2.49</td>
<td>2.57</td>
<td>3.21</td>
</tr>
</tbody>
</table>

Table 4: Weight loss due to sulphate attack

IV. CONCLUSION

The mechanical properties like compressive strength, split tensile strength and the durability properties for optimum replacement are obtained for the replacement of bottom ash in concrete for the various percentages (from 0-50%). The various discussions after obtaining these results are

- Bottom ash can be used as an effective replacement of natural sand.
- In the compressive strength bottom ash replaced concrete shows good results compared with the normal conventional concrete.
- The average maximum compressive strength obtained is 29.58 N/mm² and 34.30 N/mm² in 7 and 28 days and is found to be 17.06% and 9.7% more than the conventional concrete.
- The average maximum split tensile strength obtained is 2.66 N/mm² and 3.83N/mm² in 7 and 28 days and is found to be 10% and 6.38% more than the conventional concrete.
- The average maximum flexural strength obtained is 2.42 N/mm² and 3.78 N/mm² in 7 and 28 days and is found to be 8% and 7.3% more than the conventional concrete.
- However beyond 30% replacement of the bottom ash the strength fails.
- The chloride penetration is found to be moderate.
- The weight loss due to sulphate attack ie 30% replaced bottom ashed concrete is more than the conventional concrete.

REFERENCES