STUDY ON STRENGTH AND DURABILITY OF BLENDED CONCRETE

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ABSTRACT

Cement Concrete is the most widely used material for various Constructions, properly Designed Concrete Results in Good Strength and Durability Properties. Even such well Designed and Prepared Cement Concrete Mixes under Controlled Conditions also have Certain Limitations Because of which The Properties of Concrete are Found To be in Adequate For Special Situations and for Certain Special Structures. Hence variety of mineral admixtures such as fly ash silica fume, Alcofine, met kaolin, GGBS rice husk ash, etc are used with partial replacement of the cement, Blended concrete leads to high strength and durable concrete for major applications in the constructions such as high rise buildings tall structures, nuclear power plants, etc. the essential need for additives both chemical and mineral is a must to improve the performance of concrete plain concrete possesses a very little tensile strength limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to propagation of such micro-cracks, eventually leading to brittle fracture of concrete. In the past, attempts have been made to improve the tensile strength of the Concrete. this was achieved by the addition of small, closely spaced and randomly oriented fibers, dispersed uniformly in the concrete mix.

Introduction:

Ordinary Portland Cement (OPC) is becoming an energy exhaustive and pricey constituent in the production of concrete, which is the most widely used construction material. It is expected that the cement requirement will grow threefold to about 3.5 billion tonnes by the year 2015. Although the requirement is vast, the raw materials required for the cement production is relatively less. In addition to the expensive process of cement production, the environmental impact due to the emission of Carbon dioxide (CO2) is alarming, since it is the major source for global warming. Bhanumathidas and Mehta (2001) have estimated that to produce one ton of cement, nearly 1.5 tonnes of earth minerals are consumed and one ton of CO2 is emitted in the atmosphere.

One of the efficient methods to conserve the natural resources and reduce the impact on the environment is to go for SCMs, wherein the quantity of OPC can be saved. Since most of the SCMs are waste materials, which are pollutants when dumped in the lands, blending of them in concrete becomes a safe and effective disposal method. Some of the waste materials which improve the properties of concrete are fly ash, Ground Granulated Blast furnace Slag (GGBS), silica fume, RHA, LP, copper slag and so on.

•SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMs)

Blended cement has replaced OPC to a major extent, in lieu of its increased durability and lesser cost. In addition there is reduction in green house gases in the manufacturing of cement, thereby reducing pollution. The new ACI
318-08 Building Code gives the limitation on the quantity of supplementary cementitious materials, expressed as a percentage of the total cementitious materials, as follows:

1. Fly ash or other C618 pozzolans – max: 25 percent
2. Total of fly ash or other pozzolans and silica fume – max: 35 percent
3. Combined fly ash, pozzolan and silica fume – max: 50 percent with fly ash or pozzolan not exceeding 25 percent and silica fume not exceeding 10 percent
4. Ground granulated blast-furnace slag – max: 50 percent
5. Silica fume – max: 10 percent

**Binary blending of Fly ash**

Fly ash, which was once an environmental pollutant, has now found a good place in the construction industry, mainly in production of blended cement. Fly ash is one of the residues generated during combustion of coal and comprises the fine particles that rise with the flue gases. Generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants. Depending upon the source of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata. It is often used as SCM in concrete production. Owing to its pozzolanic properties, fly ash is used as a replacement for some of the Portland cement content of concrete.

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Class C fly ash is produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO).

**Binary blending of LP**

Lime and limestone powder was the oldest material used for construction purpose. It was used as a binding material as well as filler. Lime mortar and concrete was prepared by mixing water with hydrated lime (calcium hydroxide) and aggregate. The setting of lime mortar is caused by loss of water and hardening taking place through the reaction of hydrated lime with atmospheric CO2 to form CaCO3, which is the binding material. Since lime mortar has comparatively low strength properties, lesser durability and retarded setting time, an alternate binding material was sorted for, which was the reason for the emergence of PC.

Limestone decreases the size of gel pores which is related to higher hydration rates. Hence, the use of limestone in cement produces a material that is structurally adequate to be used in construction. It was clearly observed from the visual inspection that the mortar specimens with higher replacement levels of Limestone Filler (LF) suffered more pronounced deterioration in both sulphate solutions, when compared to those without LF. A low proportion (<10%) of LF causes no significant changes in sulphate resistance of parent PC, while a large proportion (>15%) may worsen sulphate performance. Upto 20% of the cement could potentially be substituted by
limestone (or other fillers) to economize on the usage of PC clinker and to reduce the energy and the deleterious emissions associated with its production.

• Binary blending of RHA

RHA from the parboiling plants is posing a serious environmental hazard and ways are being thought of to dispose it. This material is actually a pozzolan since it is rich in Silica and has about 85% to 90% silica content. A good way of utilize this material is to use it for making ‘High Performance Concrete (HPC). RHA is a good pozzolans, which increase the durability and strength of concrete with increase in aging.

In the conversion of rice husk to RHA, the combustion process removes the organic matter and leaves the silica rich residue. However, such thermal treatment of the silica in the husk results in structural transformations that influence both the pozzolanic activity of the ash and its grind ability. When rice husk is first heated, weight loss occurs up to 100oC due to evaporation of absorbed water. At 350oC, the volatiles ignite, causing further weight loss and the husks commence to burn. From 400oC, to 500oc, the residual carbon oxidizes, and the majority of the weight loss occurs in this Period. The silica is still in an amorphous form. Above 600oC, in some cases the formation of quartz may be detected. As temperature is increased, the conversion to other crystalline forms of silica progresses with the formation of first crystobalite and next at higher temperatures, tridymite. Prolonged heating at temperatures beyond 800oC produces essentially crystalline silica. Uncontrolled combustion of husks as fuel for making clay bricks or for steam generation in parboiling rice plants produces ash, which is not completely amorphous. Due to the crystalline components in the ash, it is referred to as hard burnt ash. In order to obtain ash of acceptable reactivity with lime, it has to be ground for periods as long as seven hours if the ash crystalline ash or, as little as fifteen minutes if the ash is amorphous. The reactivity of the ash is related to its surface area and the amount of amorphous silica.

• SIGNIFICANCE OF THE STUDY

Quaternary mixes were developed and evaluated to meet certain strength and durability requirements related to companion control, binary and ternary mixes developed in this investigation. The cement mix systems utilized were obtained from addition of fly ash, RHA, and LP as SCMs to OPC and PPC. Based on the different cement mix systems combining the afore-mentioned SCMs, scores of concrete samples were derived. Mix design variables were taken as the amount of RHA and LP that can be added as replacements to modify two control mixes that were respectively obtained from an ordinary PC and a blended PC. The concrete samples, of various configurations were subjected to a range of test methods to evaluate the feasibility of their performance underscored by the mix system under various strength and durability conditions. The results obtained were ascertained from the micro structural studies of the blended cement matrix. The microstructural characteristics are also evaluated by adapting various surface analytical studies such as Particle size analysis.

• SCOPE OF THE STUDY

Basic strength characteristics, such as compressive strength, split tensile strength, flexural strength, density and durability studies of concrete are the main focuses in this research in order to study the influence of blending fly ash, RHA and LP on the quality and performance
of concrete. This study also aims at determining the most suitable mix proportion that can produce concrete of desirable strength without compromising on engineering performance and quality. The results of this study will lead to the reduction of the usage of cement, further sustainable development in the concrete industry and reducing harmful impact on the environment.

MATERIAL PROPERTIES

- **Cement**

OPC-43 Grade was used as per IS 8112 with specific gravity 3.15. The percentage of water required for standard consistency is 29.57%. The initial and final setting times for cement were 30 minutes and 320 minutes. The percentage of cement particles passing through IS 90 micron sieve is 96.4%. Chemical compositions and physical properties of OPC are given in Table 1.1(a) & (b).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon-dioxide (SiO2)</td>
<td>2</td>
</tr>
<tr>
<td>Aluminium Oxide (Al2O3)</td>
<td>5</td>
</tr>
<tr>
<td>Ferric Oxide (Fe2O3)</td>
<td>4</td>
</tr>
<tr>
<td>Calcium Oxide (CaO)</td>
<td>6</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>0</td>
</tr>
<tr>
<td>Sulphur tri oxide (SO3)</td>
<td>2</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>2</td>
</tr>
</tbody>
</table>

**Bogue’s compound Composition**

- Tricalcium Silicate (C3S) 4
- Dicalcium Silicate (C2S) 2
- Tricalcium Aluminate 8
- Tetra Calcium Alumino 1

Table 1.1(a) Chemical composition of OPC

<table>
<thead>
<tr>
<th>Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 days compressive strength (N/mm²)</td>
</tr>
<tr>
<td>Fineness (m² / Kg)</td>
</tr>
</tbody>
</table>

- **Aggregate**

The Fine Aggregate used was river sand passing through 4.75 mm sieve, falling under zone III as specified in IS 383-1978 and with specific gravity 2.60. Coarse aggregates used were crushed angular aggregates of nominal size 20mm, with specific gravity 2.60 and bulk density 1636Kg/m3. Locally available water conforming to IS456-2000 was used for concreting and curing. Rebars of size 12mm dia. and 70mm length was used.

The mix proportion for M30 concrete arrived by IS code method is given in Table 1.2.

**Table 1.2 Mix proportion for M30 concrete arrived by IS code method**

<table>
<thead>
<tr>
<th>Materials / m³ of concrete</th>
<th>Water</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse Aggregate</th>
</tr>
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<tbody>
<tr>
<td>(Kg)</td>
<td>191.6</td>
<td>399</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>0.48</td>
<td>1</td>
<td>1.3</td>
<td>2.</td>
</tr>
<tr>
<td>ix</td>
<td></td>
<td>53</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>

- **Fly ash**

The fly ash obtained was Class F with specific gravity of 2.12 with Blaine’s fineness of 305m²/Kg.

- **Rice Husk Ask**

The RHA was grey in colour with mean particle size of 25 microns and specific gravity 2.3 and
Blaine’s fineness of 315 m²/Kg. The chemical composition of RHA is given in Table 1.3.

Table 1.3 Chemical composition of RHA

<table>
<thead>
<tr>
<th>Compositions</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>90.2</td>
<td>1.5</td>
<td>2.1</td>
<td>0.8</td>
<td>1.2</td>
<td>0.6</td>
<td>0.1</td>
</tr>
</tbody>
</table>

TESTING METHODS

- **Compression Test**

The compressive strength of concrete was carried out as per IS516-1959. Concrete specimens of 150 x 150 x 150 mm cubes were cast with different types of blended cement concrete. After 24 hours the specimens were demoulded and subjected to curing for 28 days in ordinary tap water. After the curing period was over, the cubes were tested in the Compression Testing Machine (CTM) of capacity 2000kN, at the rate of loading of 140 kN/minute. Figure 3.14 shows the compression test setup on concrete cube specimen. The ultimate load at which the cube failed was taken. Tests were carried out on triplicate specimens and average compressive strength values were recorded.

- **Split tensile test**

Split tensile test was carried out as per ASTM C496-90. Concrete cylinders of size 150 mm diameters and 300 mm height were cast. During casting, the cylinders were mechanically vibrated using a table vibrator. After 24 hours, the specimens were removed from the mould and subjected to water curing for 28 days. After the specified curing period was over, the concrete cylinders were subjected to split tensile test by using universal testing machine. Tests were carried out on triplicate specimens and the average split.

- **Flexural strength test:**

Flexural strength test was carried out as per IS516-1959 by casting concrete beams of size 150 x 150 x 700mm size. After 24 hours, the specimens were removed from the mould and subjected to water curing for 28 days. After the specified curing period was over, the concrete specimens were subjected to flexural test by applying four point loading using UTM.
CONCLUSIONS:

The following conclusions can be drawn from this investigation

- For each 10% replacement of PPC with LP and RHA, there was an increase in compressive strength by about 12% which was not seen in OPC with 10%RHA and 10%LP. There was a drop in the compressive strength values beyond each 15% replacement of RHA and LP. Also there was a drop in compressive strength when unequal percentages of RHA and LP were added. Therefore, blending of RHA and LP were done in equal percentages for split tensile, flexure and durability tests.

- The quaternary system involving replacement of PPC with 10% LP and 10% RHA (PRL10) resulted in 40% more split tensile strength, 5% more flexural strength and 15% more bond strength of concrete than the control specimen, performing better than the ternary mixes. Therefore, the further durability tests were confined to PPC with replacement of LP and RHA.

- The water absorption results indicated that quaternary systems reduced the water absorption by about 15%, when compared to the control system.

SUGGESTIONS

- The utilization of SCMs in the construction industry has increased tremendously. There is a lot of potential for usage of fly ash, RHA and LP in concrete. However, the characterization of blending quaternary cement is not much established due to lack of systematic study and limited availability of data. The following suggestions are made for exploring effective utilization of quaternary blended cement in construction industry:
  - The quaternary blended cement performs well in strength and durability factors, which is evidenced in the microstructure also.
  - The addition of various types of fibres in the quaternary mix is expected to increase the tensile and flexural strength of the specimens. The study has a wide scope for future investigation

REFERENCES

1. ACI 318-05: Building Code Requirements for Structural Concrete and Commentary
6. ASTM C1202 - 10 Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration.

9. ASTM C78 / C78M -10 Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading).


11. ASTM G1 - 03 Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.

