Partially replacement of cement with flyash and silica fumes

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ABSTRACT

The concrete industries are facing the environmental impact of the cement production by the emission of carbon dioxide. Partial replacement of cement has been tried by low, medium and high volume with pozzolanic waste materials that include flyash, silica fume, rice husk ash, furnace slag having high silica and cementitious contents. Total replacement of cement is also of current interest by the emerging new material called geopolymer concrete. Among all the replacement materials for cement, flyash has been identified which is being produced in large quantities comparatively is recommended for use in concrete. A good quantum of research has been made on flyash utilisation including the development of geopolymer concrete but, most of them are confined to the utilisation of low calcium flyash called class C flyash. Only limited research has been done and reported about the utilisation of high calcium flyash called class C flyash which is the waste, based on lignite burning in thermal power stations. Class C ash being more cementitious in nature compared to class F ash, the high calcium content is a problem for the rebar corrosion and concrete deterioration. However, it is believed that if the microstructure is suitably modified with the incorporation of silica based additives to flyash based concrete it could be materialized with the development of bulk utilisation of high calcium flyash concrete.

Keywords — Flyash, Silica fumes, Compressive Strength, Workability;

INTRODUCTION

The impacts of substitute building technologies on energy and environment have made an inventive thinking to consume industrial wastes for meeting its demand. The greatest challenge of this century that the concrete industry faces is to achieve a sustainable pattern of growth. The task is formidable, but the ideas and experience show that it can be accomplished if we make a paradigm shift from the culture of accelerating construction speeds to the conservation of energy and material. Cement requires enormous heat in its manufacturing, making it expensive to the environment. For every ton produced, half a ton of CO2 is released by fuel burning and clinker forming, making responsible for more than 8% of all the greenhouse gases released. The net cement production in the world by 2015 is nearly 3 Billion Metric Tonnes and growing at 5% annually. The replacement of cement is a must and for the replacement materials among which flyash seems to be more effective.

Concrete constituents are becoming scarce and researchers are in search of alternatives for them. The replacement with flyash for Portland cement was realised as an effective means to reduce greenhouse gas emissions while also advance sustainable development. Consisting mostly of silica, alumina and iron, flyash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compoundsimilar to Portland cement. The spherical shape of the particles reduces internal friction thereby increasing the consistency of concrete and also mobility. The recent development of geopolymer concrete technology involves the 100 percent replacement of cement with ash materials. An activating solution is used to have polymerisation process, finally resulting in a hard concrete with other conventional ingredients. The main precautions associated with the use of flyash in concrete can include slower early strength development, extended initial setting time, difficulty in controlling aircontent, seasonal limitations during winter months, and quality control of flyash sources. The 28 days strength is reached normally in 40-45 days depending on the fraction of flyash used. This problem can be solved by adding admixtures to flyash concrete. Steam curing can also be recommended particularly for precast products. Flyash reacting with available lime and alkalis generate additional
cementitious compounds that act to block bleed channels, filling pore space, and reducing the hydraulic conductivity of hardened concrete (Mullick, 2005). The pozzolan reaction consumes Ca(OH)2 (calcium hydroxide), which is leachable, replacing it with insoluble calcium silicate hydrates (CSH). The increased volume of fines and reduced water content also play a role in reducing hydraulic conductivity. Flyash is a preconsumed supplementary cementitious material (SCM) which is a waste stream of a manufacturing process and there are mainly two types of flyash as class C and class F mentioned in the construction industries based on the CaO content. The bituminous, semi bituminous or lignite and coal based fed in the thermal power stations (TPS) contribute the different types of flyash. The development of natural lignite formation can be well understood (Stadhouders, 2010). Many authors distinguished the salient features between Class Cand F types of flyash in different countries which are very useful for realization.

OBJECTIVES
The salient objectives of the present study have been identified as follows:

1. The main objective of the present work is to develop structural concrete.
2. The determination of the possibilities of directly using the flyash replacing a high % of cement
3. The scope of the present work is limited to the feasibility study

NEEED FOR THE PROPOSED WORK
Necessity and importance of the study on bulk utilization of high calcium flyash in structural concrete.

i) Strength and durability characteristics
ii) Analysis and discussion on the investigation.
iii) Decrease the cost of making concrete.
iv) The qualitative and quantitative conclusion.

LITERATURE REVIEW
The information presented here are a worldwide collection of research activities. The research works reported are mostly on the utilisation of low calcium (class F) flyash only. The reported work on high calcium (class C) flyash is comparatively very much limited. Flyash was first recognized as a mineral admixture for concrete in the 1930s, flyash has been the subject of worldwide study as researchers work to maximize its economical and environmental benefits (Ramesh et al. 1997). Investigations have focused on the physical, chemical and mineralogical characteristics of fly ash and their specific correlation to the performance of concrete. A complete review of the advantages of fly ash as a mineral admixture to concrete, including strength development and improved chemical resistance durability is available. A review of the current international standards on fly ash usage is provided, in addition to an extensive reference list and a complete survey of various other fly ash products, such as bricks, mineral wool, and gypsum wallboards, as well as the use of fly ash in waste management. Lignite if formed from peat is exposed to pressure and heat over long periods of time (Stadhouders, 2010). The longer the exposure period, the lower the moisture and ash content of the resulting coal and the higher its fuel quality. Lignite is a young type of coal, and is therefore considered to be of a low-rank fuel quality. Lignite is not a homogeneous product. There are quality variations within and between the lignite layers (Adamidou et al. 2007). These differences also translate in the LFA quantities and composition. Large variations in the composition make processing more complicated. To control the burning process within the lignite power plant a constant blend of various lignite qualities is fed into the plant. This consequently also ensures a more constant composition of the LFA. Major environmental concern associated with fly ash is the mobilization of trace elements that may contaminate water. To better evaluate proper use of fly ash, determine appropriate disposal methods, and monitor post disposal conditions, it is important to understand the speciation of trace elements in fly ash and their possible environmental impact. The speciation of selenium, arsenic, and zinc was determined in five representative class C fly ash samples by Yun Luo et al (2011). This work demonstrates that residual carbon in fly ash may reduce potential selenium (Se) mobility in the environment by
retaining it as less soluble elemental Se instead of Se(IV). Further, suggests that arsenic (As) and zinc (Zn) in class C fly ash will display substantially different release and mobilization behaviors in aquatic environments. Release of As will primarily depend upon the dissolution and hydrolysis of calcium pyroarsenate and Zn release will be controlled by the dissolution of alkaline aluminosilicate glass in the ash.

Pistilli and Majko (1984) described the results of five different concrete mixes having class C fly ash containing 9-12%, 15% and 25-30% CaO and reported the optimised amount of fly ash as 20-50% replacement of cement. It is also reported that properly air-entrained, showed excellent freeze-thaw durability (85 to 95% relative durability factor [RDF]) and good air-void parameters even at high fly ash contents. The setting times for the fly ash mixtures were longer by 4 to 6 h in the presence of a water reducer and very high fly ash contents. Subasi (2009) investigated the estimation ability of the effects of utilizing different amount (0, 5, 10, 15 and 20%) of the class C fly ash in cement on the mechanical properties of mortar, like compressive and flexural tensile strength using artificial neural network and regression methods with using ash content and reported that the multilayer feed-forward neural network models prediction was better than regression techniques.

**Experimentation**

**Strength Characteristics**

1. Cube Compression
2. Cylinder Compression
3. Split Tensile Strength
4. Flexure Strength

**Workability Characteristics**

1. Slump value

The workability property is measured by conducting slump cone test in accordance with IS: 1199 – 1959. The trails are carried out to improve the workability and cohesiveness of the fresh concrete by incorporating a superplasticizer. Marsh cone test is carried out to select the better combination of water, cementitious materials and chemical admixtures.

**STRENGTH CHARACTERISTICS OF FRESH CONCRETE**

The details of total number of specimens for M30 grade with and without fly ash, silica fume and superplasticizer are given in the Table 4.12 to test for various strength and durability characteristics. The types of specimens cast for strength testing are presented.

<table>
<thead>
<tr>
<th>No</th>
<th>Properties (Specimen)</th>
<th>Age of Testing (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compressive Strength (Cube)</td>
<td>7, 14, 28</td>
</tr>
<tr>
<td>2</td>
<td>Split Tensile Strength</td>
<td>7, 14, 28</td>
</tr>
<tr>
<td>3</td>
<td>Flexural Strength</td>
<td>7, 14, 28</td>
</tr>
</tbody>
</table>

**MIX PROPORTIONING OF CONVENTIONAL M30 GRADE CONCRETE**

With the determined properties of the concrete constituents, concrete grade of M30 is designed by IS method as detailed in Table 4.10. Based on the trial mixes a correct proportion is arrived. The worked out quantities for various types of concrete are represented in Appendix E. Initially maintained w/c ratio of 0.42 is and then is reduced to 0.3% and the dosage of SP is adjusted.
Table 4.10 Mix Details of M30 grade Conventional Concrete by IS method

Characteristics of Conventional M30 Concrete
With the design proportions of conventional M30 concrete, tests are conducted to for the workability and strength characteristics. Weigh batching and machine mixing are adopted for preparing concrete. Slump, compaction factor and flow table tests are conducted. Two mixes, one without plasticizer other with plasticizer are considered. The workability characteristics are presented in Table 4.11 and the views are presented in Appendix F.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Slump mm</th>
<th>Compaction Factor</th>
<th>Flow Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Plasticizer</td>
<td>46</td>
<td>0.80</td>
<td>10.10</td>
</tr>
<tr>
<td>With Plasticizer</td>
<td>48</td>
<td>0.86</td>
<td>11.30</td>
</tr>
</tbody>
</table>

Table 4.11 Workability Characteristics Conventional Concrete

RESULTS
Experimental Results
Compressive and Tensile Strength Tests
Cube specimens 100mm size and 100×200mm cylindrical specimens are tested for compressive strength in the respect to the age of curing in a standard manner as per as per IS: 516 – 1959. For each mix combination, three identical specimens were tested at the ages of 7, 14, 28 days. Results is presented As the compressive strength for cement replacement more than 60% is not satisfactory, the cement replacement of 50% and 60% are considered for further study.

<table>
<thead>
<tr>
<th>Mix</th>
<th>% Replacement of Cement with FA and Flyash with SF</th>
<th>Compressive strength for different curing days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7 Days</td>
</tr>
<tr>
<td>M1</td>
<td>0</td>
<td>28.05</td>
</tr>
<tr>
<td>M2</td>
<td>50</td>
<td>16.80</td>
</tr>
<tr>
<td>M3</td>
<td>10</td>
<td>16.41</td>
</tr>
<tr>
<td>M4</td>
<td>20</td>
<td>18.26</td>
</tr>
<tr>
<td>M5</td>
<td>60</td>
<td>12.32</td>
</tr>
<tr>
<td>M6</td>
<td>10</td>
<td>12.36</td>
</tr>
<tr>
<td>M7</td>
<td>20</td>
<td>14.80</td>
</tr>
</tbody>
</table>

Cube Compressive Strength Concrete without SP
Mix & % Replacement of Compressive strength for different curing days
<table>
<thead>
<tr>
<th>Mix</th>
<th>% Replacement of Cement with FA</th>
<th>Flyash with SF</th>
<th>7 Days</th>
<th>14 Days</th>
<th>28 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1S</td>
<td>0</td>
<td>0</td>
<td>29.40</td>
<td>32.90</td>
<td>39.40</td>
</tr>
<tr>
<td>M2S</td>
<td>50</td>
<td>0</td>
<td>16.87</td>
<td>20.19</td>
<td>34.80</td>
</tr>
<tr>
<td>M3S</td>
<td>1.2% SP</td>
<td>10</td>
<td>18.41</td>
<td>21.38</td>
<td>36.65</td>
</tr>
<tr>
<td>M4S</td>
<td>20</td>
<td>20.36</td>
<td>24.35</td>
<td>39.15</td>
<td></td>
</tr>
<tr>
<td>M5S</td>
<td>60</td>
<td>0</td>
<td>12.22</td>
<td>16.60</td>
<td>31.33</td>
</tr>
<tr>
<td>M6S</td>
<td>1.5% SP</td>
<td>10</td>
<td>12.36</td>
<td>18.02</td>
<td>32.85</td>
</tr>
<tr>
<td>M7S</td>
<td>20</td>
<td>15.80</td>
<td>17.30</td>
<td>36.36</td>
<td></td>
</tr>
</tbody>
</table>

Cube Compressive Strength of Concrete with SP

Compressive Strength Results

CONCLUSIONS

Compared with conventional cement concrete, the flyash based concrete is more workable and still more with the additions of silica fume. However, slump value is slightly reduced (0 to 20mm) with the intention of improving the strength which is indirectly proportional to the water-cement ratio. For M30 grade concrete even though studies are made for concrete with and without SP, the concrete with SP showed better overall performance in workability, strength and durability characteristics in general. Compared with conventional
cement concrete w.r.to cube compressive strength: Compressive strength of concrete for 50% and 60% cement replacement with flyash is satisfactory and other replacement levels are not so even with the addition of silica fume with the normal conditions.

SUGGESTIONS FOR FURTHER RESEARCH

Cement replacement up to 50% by weight of class C flyash is recommended with admixtures compulsorily and 10% of flyash replaced with silica fume. Cement replacement up to 60% by class C flyash is recommended for NLC flyash with admixtures compulsorily and 20% of flyash replaced with silica fume. Further, for more than 60% utilisation of flyash for replacing cement, substance like rice husk ash or nano-silica may be added in conjunction with silica fume which is the best additive for cement replacement.

REFERENCES