EXPERIMENTAL STUDY ON HARDENED CONCRETE BY USING STEEL FIBERS WITH MINERAL ADMIXTURE

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ABSTRACT

Concrete is probably the most extensively used construction material in the world. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption by the use of supplementary materials. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. Fly Ash and silica fume is a new mineral admixture, whose potential is not fully utilized. Moreover only limited studies have been carried out in India on the use of silica fume for the development of high strength concrete with addition of steel fibers. The study focuses on the compressive strength performance of the blended concrete containing different percentage of silica fume and Fly Ash and steel fiber as a partial replacement of OPC. The cement in concrete is replaced accordingly with Silica fume content was use from 0% to 10% in the interval of 2% in weight basis and also fly ash content was use from 10% in weight basis. So to improve the strength of concrete steel fibers were added 0.5%, 1%, 1.5%, 2% by weight of steel fiber. Concrete cubes are tested at the age of 3, 7, and 28 days of curing. Finally, the strength performance of Fly ash and silica fume blended fiber reinforced concrete is compared with the performance of conventional concrete. From the experimental investigations, it has been observed that, the optimum replacement Fly ash and silica fume to cement and steel fiber without changing much the compressive strength is 10% - 8 % & 1.5 % respectively for M25 grade Concrete.

Keywords: Cement, Hardened Concrete, Steel Fiber, Fly Ash and Silica Fume.
I. INTRODUCTION

Inspired from the ancient application of techniques artificial fibers are commonly used nowadays in order to improve the mechanical properties of concrete. Especially Synthetic (Polypropylene, polyester etc.,) glass, nylon, asbestos, carbon and steel fibers used in concrete caused good results to improve numerous concrete properties. In general, tensile, flexural, impact, deformation capability, loads bearing capacity after cracking and toughness properties of concrete are considerably ductility and flexural toughness [1]. For long term, strength and toughness and high stress resistance, steel fiber reinforced Concrete (SFRC) is increasingly being used in structures such as flooring, housing, precast, tunneling, heavy duty pavement and mining. Generally, aspect ratios of steel fibers used in concrete mix are varied between 50 and 100. The most suitable volume fraction values for concrete mixes are between 0.5% and 1.5% by volume of concrete [2].

Newly developed admixtures allow lowering the water/binder ratio to very low levels without loss of workability. By incorporation of super plasticizers, the strength development of fly ash concrete can be accelerated to achieve the desired performance at early ages by adding accelerating agents such as metakaolin, slag, silica fume etc. The initial interest in the use of silica fume was mainly caused by the strict enforcement of air-pollution control measures in various countries to stop release of the material into the atmosphere. Silica fume is a pozzolanic material which is a by-product of the silicon smelting process. It is used to produce silicon metal and ferrosilicon alloys which have a high content of glassy-phase silicon dioxide (SiO2) and consist of very small spherical particles.

Silica fume is known to produce a high-strength concrete and is used in two different ways: as a cement replacement, in order to reduce the cement content (usually for economic reasons); and as an additive to improve concrete properties (in both fresh and hardened states). Therefore, utilization of silica fume together with fly ash provides an interesting alternative and can be termed as high strength and high performance concrete. In general, the character and performance of fiber reinforced concrete changes with varying concrete formulation as well as the fiber material type, fiber geometry, fiber distribution, fiber orientation and fiber concentration [3].

During the viaduct construction between J.J hospital and Crawford market in Mumbai, Saini [3] has undergone a research work based on high performance concrete (HPC) of grade M75 where SF was added @ 10% by weight of cement to ensure durability of the structure. They found 28days compressive strength of HPC varied between 79.6 to 81.3 MPa indicating good control of quality of concrete. The purpose of this research is to study the effects of steel fibers on the workability, compressive strength, flexural tensile strength, splitting tensile strengths, modulus of elasticity of hardened concrete.

II. EXPERIMENTAL PROGRAM

Materials

A. Cement

Ordinary Portland Cement of Sanghi brand of 53 grade confirming to IS: 12269-1987 was used in present study. The property of cement is shown in Table 1.

Table 1: Properties of Cement

<table>
<thead>
<tr>
<th>Properties</th>
<th>Obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>3.15</td>
</tr>
<tr>
<td>Initial setting time</td>
<td>65 min</td>
</tr>
<tr>
<td>Final setting time</td>
<td>175 min</td>
</tr>
<tr>
<td>Consistency</td>
<td>30%</td>
</tr>
</tbody>
</table>
B. Silica fume

Silica Fume used was confirming to ASTM C (1240-2000) and was supplied by Fortune minerals and abrasives, Ahmedabad. Silica Fume is used as partial replacement of cement. The properties of Silica Fume are shown in Table 2.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Dark to Light Gray</td>
</tr>
<tr>
<td>Bulk density</td>
<td>450-650 g/cm³</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.22</td>
</tr>
<tr>
<td>Moisture content</td>
<td>1%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>92%</td>
</tr>
</tbody>
</table>

C. Fly Ash

Flyash obtained from Neyveli Lignite Corporation Thermal Power Plant I is used in the experimental investigation. The physical and chemical analysis of lignite ashes were carried out at Neyveli Lignite Corporation Ltd. The results were compared to Indian standard specification IS: 3812-1981. The physical and chemical properties are shown in the Table 3 was used in this investigation.

<table>
<thead>
<tr>
<th>Physical and chemical composition</th>
<th>Neyveli flyash</th>
<th>IS:3812-1981</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity(% of retained on 45/μm)</td>
<td>1.92</td>
<td>-</td>
</tr>
<tr>
<td>Fineness (By Blaine’s) cm²/gm</td>
<td>4668</td>
<td>3200 min</td>
</tr>
<tr>
<td>Bulk density gm/cc</td>
<td>0.94</td>
<td>-</td>
</tr>
<tr>
<td>SiO₂</td>
<td>46.3%</td>
<td>35.0% min</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>22.1%</td>
<td>-</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3.1%</td>
<td>-</td>
</tr>
<tr>
<td>CaO</td>
<td>13.3%</td>
<td>-</td>
</tr>
<tr>
<td>MgO</td>
<td>3.11%</td>
<td>5.00% max</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.9%</td>
<td>1.5%</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.78%</td>
<td>-</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.78%</td>
<td>-</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.44%</td>
<td>-</td>
</tr>
<tr>
<td>MnO</td>
<td>0.13%</td>
<td>-</td>
</tr>
<tr>
<td>BaO</td>
<td>1.18%</td>
<td>-</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.80%</td>
<td>2.75% max</td>
</tr>
<tr>
<td>LOI (Loss on ignition)</td>
<td>0.65%</td>
<td>-</td>
</tr>
<tr>
<td>SiO₂+Al₂O₃+Fe₂O₃</td>
<td>71.5%</td>
<td>70.00% min</td>
</tr>
</tbody>
</table>
D. Aggregate

Good quality river sand was used as a fine aggregate. The fineness modulus, specific gravity and dry density are 2.32, 2.68 and 1690 kg/m³. Coarse aggregate passing through 20mm and retained 10mm sieve was used. Its specific gravity and dry density was 2.7 and 1550 kg/m³.

E. Fibers

Steel fiber having low carbon and it’s both end were hooked were used. The steel fibers have a length of 30 mm, diameter of 0.50 mm, aspect ratio of 50, and density of 7.85 g/cm³. Collect from Stewols Pvt. Ltd. Nagpur.

F. Plasticizer

A commercial AC- Green Slump-GS-02 black cat Chemical Limited plasticizer From Nagpur was used to maintain the workability of fresh concrete. The dosage of hyper plasticizer was kept constant in mass basis; it was 1% of the binder content of concrete. The aim of keeping the amount of plasticizer constant is to neglect, if any, the influence of plasticizer on the properties of hardened concrete.

III. MIXTURE COMPOSITION AND PREPARATION

Mix design is made for M25 grade concrete accordance with the Indian Standard Recommended Method IS 10262-1982. At the beginning of the mixture design, binder content 380kg/m³ (M25) and water–cement ratio 0.5 was kept constant and then, the volume of aggregate was determined for reference Portland cement concrete by assuming approximately 2% air is trapped in fresh concrete. The volume of aggregate was used to determine the aggregate weight. Fresh concretes containing 0.1% to 10% silica fume and 10% of fly ash as cement replacement in weight basis were prepared by modifying the reference Portland cement concrete. Fresh fiber reinforced concretes containing with different percentage of steel fibers (i.e. 0.5%, 1%, 1.5%, 2%) fiber in volume basis were prepared. Aggregate weight for a cubic meter was adjusted when blended cement or fiber introduced into concrete. The procedures for mixing the fiber reinforced concrete involved the following. First, the gravel and sand were placed in a concrete mixer and dry mixed for 1 min. Second, the blended cement and fiber were spread and dry mixed for 1 min. Third, the mixing water (90%) was added and mixed for approximately 2 min. fourth and the remaining mixing water (10%) and plasticizer were added and mixed 3 min. Finally, the freshly mixed fiber-reinforced concrete was cast into specimens mold and vibrated simultaneously to remove any air remained entrapped. After casting, each of the specimens was allowed to stand for 24 h in laboratory before demolding. To improve the Workability Super plasticizer is used in various percentages of silica fume and fly ash and steel fibers for M25 Grade of concrete

IV. TESTING METHODS

A. Workability

The workability of silica fume with steel fiber concrete has found to decrease with increase in silica & steel replacement so; it appeared that the addition of super plasticizer might improve the workability. Super plasticizer was added range of 0.75 to 1.80% by weight of cementsations materials for maintaining the slump up to 20mm.

B. Compressive strength

Series of cubes cube with a 150 mm side are casted using different percentage of Silica Fume (i.e. 2%, 4%, 6%, 8%, 10%) with different percentage of fibers (i.e. 0.5%, 1%, 1.5%, 2%). 
Specimens were for compressive strength and were measured 3, 7, 28 days and Compression test are conducted and results are obtained shown below

**Table 4: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (2% & 10%) with steel fiber**

<table>
<thead>
<tr>
<th>Fiber %</th>
<th>Compressive Strength (M25) N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
</tr>
<tr>
<td>0</td>
<td>20.24</td>
</tr>
<tr>
<td>0.5</td>
<td>13.23</td>
</tr>
<tr>
<td>1</td>
<td>14.34</td>
</tr>
<tr>
<td>1.5</td>
<td>15.24</td>
</tr>
<tr>
<td>2.0</td>
<td>16.83</td>
</tr>
</tbody>
</table>

**Figure 1: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (2% & 10%) with steel fiber**

**Table 5: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (4% & 10%) with steel fiber**

<table>
<thead>
<tr>
<th>Fiber %</th>
<th>Compressive Strength (M25) N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
</tr>
<tr>
<td>0</td>
<td>20.24</td>
</tr>
<tr>
<td>0.5</td>
<td>14.93</td>
</tr>
<tr>
<td>1</td>
<td>15.34</td>
</tr>
<tr>
<td>1.5</td>
<td>16.24</td>
</tr>
<tr>
<td>2.0</td>
<td>17.83</td>
</tr>
</tbody>
</table>
Figure 2: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (4% & 10%) with steel fiber

Table 6: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (6% & 10%) with steel fiber

<table>
<thead>
<tr>
<th>Fiber %</th>
<th>3 days</th>
<th>7 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20.24</td>
<td>28.64</td>
<td>38.64</td>
</tr>
<tr>
<td>0.5</td>
<td>15.12</td>
<td>25.90</td>
<td>40.56</td>
</tr>
<tr>
<td>1</td>
<td>16.21</td>
<td>26.88</td>
<td>42.53</td>
</tr>
<tr>
<td>1.5</td>
<td>17.56</td>
<td>28.79</td>
<td>43.24</td>
</tr>
<tr>
<td>2.0</td>
<td>18.34</td>
<td>31.95</td>
<td>46.38</td>
</tr>
</tbody>
</table>

Figure 3: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (6% & 10%) with steel fiber
Table 7: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (8% & 10%) with steel fiber

<table>
<thead>
<tr>
<th>Fiber %</th>
<th>Compressive Strength (M25) N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
</tr>
<tr>
<td>0</td>
<td>20.24</td>
</tr>
<tr>
<td>0.5</td>
<td>16.33</td>
</tr>
<tr>
<td>1</td>
<td>16.98</td>
</tr>
<tr>
<td>1.5</td>
<td>17.38</td>
</tr>
<tr>
<td>2.0</td>
<td>19.94</td>
</tr>
</tbody>
</table>

Figure 4: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (8% & 10%) with steel fiber

Table 8: Compressive Strength on M25 Grade of concrete containing silica Fume and fly Ash (10% & 10%) with steel fiber

<table>
<thead>
<tr>
<th>Fiber %</th>
<th>Compressive Strength (M25) N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
</tr>
<tr>
<td>0</td>
<td>20.24</td>
</tr>
<tr>
<td>0.5</td>
<td>14.27</td>
</tr>
<tr>
<td>1</td>
<td>14.89</td>
</tr>
<tr>
<td>1.5</td>
<td>15.37</td>
</tr>
<tr>
<td>2.0</td>
<td>17.95</td>
</tr>
</tbody>
</table>
V. RESULTS AND DISCUSSION

Effect of steel fiber, Fly ash and Silica Fume on compressive strength of concrete: Series of cubes are casted using different percentage of Silica Fume (i.e. 2%, 4%, 6%, 8%, and 10%) with different percentage of fibers (i.e. 0.5%, 1%, 1.5% and 2%). Compressive strength test is carried out on specimen cubes of concrete blended with various percent replacements to cement by Fly ash and Silica Fume & steel fiber (varying percentages) and conventional concrete at 3, 7 and 28 days of curing with compression testing machine. Optimized Results of Trial Mixes are as shown in tables from the results of trial mix, it is seen that the compressive strength of Concrete for all percentage remains nearly same at 7 days with replacement of cement by Fly ash and S F and found maximum for 10% and 8% slag & S F respectively replacement of cement. After testing the concrete (compressive strength) for M25 grade concrete separately for replacement of slag Fly ash, Silica Fume and steel fiber by cement respectively finally combined percentage of Fly ash, Silica Fume and steel fiber mix in which maximum strength is obtained was used to get optimized strength discussion: Results shown that initially addition of fibers in concrete containing Fly ash and Silica Fume decrease the compressive strength compared with Plain concrete. But at age of 28days curing it shows good results. Due to lower aspect ratio there is no problem of balling and handling is easily. As increasing volume of fibers it is observed that there is increased in compressive strength. Thus addition of Steel fibers, fly ash and Silica Fume increases the compressive strength up to 30% with different combination. Among all replacement of Silica Fume with steel fiber, 8%, fly ash 10% and Silica Fume with 1.5% volume of fiber is best combination.

VI. CONCLUSIONS

The results insure the effectiveness of minerals admixtures as fly ash, and silica fume to improve properties of concrete and to increase the resistance. The optimum dosage for partial replacement of cement by fly ash and silica fume is (10% and 8%) for the addition of steel fiber is 1.5%.

REFERENCES

[12] SUSAN, BERNAL; RUBY, DE GUTIERREZ; SILVIO, DELVASTO; ERICH, RODRIGUEZ. Escuela de Ingeniería de Materiales, Grupo de Materiales Compuestos, CENM, Universidad Del Valle. Ciudad Universitaria Meléndez, AA 2188, Cali, Colombia