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Application of Fly Ash and Silica Fume Towards the Performance of Concrete

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Abstract- Cement is a material that has the ability to hold concrete together. It binds coarse aggregate with fine aggregate. The use of supplementary cementitious materials is fundamental in developing low cost construction materials for use in developing countries. In this study, the physical and chemical properties of silica fume and fly ash are studied and the effect of replacing cement by silica fume and fly ash to compare the effect of presence of the replacement material on the strength of specimens to the conventional specimens are investigated. The suitability percentage of replacement by silica fume and fly ash, cubes cylinders and prisms are casted and tested. Various mix proportions are to be designed such as normal concrete mix, Silica fume and fly ash (5, 10, and 15 %) is determined. It is found that Addition of admixtures to the concrete increases the strength of high performance concrete. The effect of silica fume, fly ash in the High Performance Concrete is studied. High strength fibre reinforced concrete mix has been produced with addition of condensed Silica fume and flies ashas mineral admixtures. By the addition of fly ash in high strength concrete with different percentage of mineral admixtures, the flexural strength has been improved in all the mix.

Keywords:- Cement, fine aggregate, pozzolanic, fly ash, Silica fume, durability, workability, strength.

I. INTRODUCTION

Cement is a material that has the ability to hold concrete together. It binds coarse aggregate with fine aggregate. Over one billion tonnes of cement are produced per year. It is expected that the demand for cement will increase significantly. To this point, there is no alternative material for cement. Cement is a fine powder essentially controlling concrete properties of strength and hardness.

There are several types of cement; however Portland cement is the most cement type that is used across the world. Portland cements are made out of a mixture of limestone and clay rock as these rocks contain the raw materials of cement production as calcium carbonate ($CaCO_3$) Iron oxide (Fe_2O_3) Aluminium oxide (Al_2O_3) and Silicon dioxide (SiO_2). These rocks get crushed and blended then heated to a clinker in a kiln. Clinker is cooled and then ground into a fine powder. A small proportion of gypsum is added at the final grinding stage to produce a dry powder (Portland cement).

Silica fume (SF) is a by- product of the smelting process in the silicon and ferrosiliconindustry. The reduction of high-purity quartz to silicon at temperatures up to 2,000oC produces SiO_2vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting ofnon-crystalline silica. By-products of the production of silicon metal and the ferrosilicon alloyshaving silicon contents of 75% or more contain 85–95% non-crystalline silica. The by-product of theproduction of ferrosilicon alloy having 50% silicon has much lower silica content and is lesspozzolanic. Therefore, SiO_2 content of the silica fume is related to the type of alloy being produced.Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust.

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It is very fine no crystalline silica manufactured by electric arc furnaces as a by-product of the production of metallic silicon or ferrosilicon alloys. The raw materials are coal, quartz, and woodchips. The smoke that produced from furnace operation is stored and sold as silica fume rather than being land filled.

II. LITERATURE SURVEY

R.M.Karthikeyan et al (2017) obtain high durability and high strength concrete by replacing cement with 40% & 50% of fly ash and 10% of Silica fume &Metakaolin. As Per ACI method the various mix designs are prepared for various proportions. Respective tests are conducted. Based on the results, 50% replacement of fly ash and 10% of silica fume with cement gave better compressive strength.

Tejas P. Pawar et al (2017)investigate effect of silica fume &fiberorientation of sisal fiber on performance of concrete, which ultimately solve the problemsof waste disposal & reduces global warming. Here in the experiment an attempt has beenmade to increase the strength of concrete by replacing cement partially with silica fumeand sisal fibers at varying percentage in a design mix of M30 and M40.

K. Chandrasekhar Reddy & K. Arjun (2017) find the suitability of silica fume and metakaolin combination in production of concrete. It deals with M30 grade concrete by replacing cement with Silica Fume (0%, 5%, 10%, 15%) and Metakaolin (0%, 5%, 10%, 15%). Later combinations of Metakaolin and Silica Fume at highest strength of SF were carried. The current work focuses on studying mechanical properties of concrete in which silica fumes or metakaolin are replaced. The combinations will be compared with conventional concrete and results were be tabulated.

Syed Abuthahir and Nirmalkumar (2017)reviews the work carried out on the use ofsilica fume (SF) and Metakaolin (MK) as supplementary cementing materials as a partial replacement for cement. Theliterature demonstrates that both SF and MK are effective and causes significant improvement in various properties ofthe concrete in both fresh and harden state.

Sowmyashree T. et al (2017) investigated M30 grade of concrete is considered for the study. Here cement is constantly replaced with metakaolin by 15% and fine aggregate is partially replaced with WFS in various percentages such as 5%, 10%, 15%, 20% and 25% and using glass fibers 0.5% by weight of cement. The result shows that the concrete with 0.5% glass fibers, 15% constant replacement of cement by metakaolin and 10% replacement of fine aggregate with WFS gave maximum strength.

III. METHODOLOGY AND EXPERIMENT PLAN

1. Material Used:

In this experimental work, there are various materials used like...

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- fly ash
- Silica fume

2. Mix Design

Concrete mix containing silica fume and fly ash is designed, as per specification given under IS 10262: 2009. The concrete mix configuration is a procedure of selecting the suitable elements of concrete and deciding their most ideal extents which would create, at this very moment conceivable, concrete that fulfills the employment necessities, i.e. the concrete having a certain base compressive quality, the craved workability and strength.

Table 1. Mixture proportions of Silica fumefly ashconcretes.

<table>
<tr><th rowspan="2">Mix</th><th rowspan="2">SF %</th><th rowspan="2">fly ash %</th><th rowspan="2">SFI %</th><th colspan="7">Quantity (Kg/m^3)</th></tr>
<tr><th>C</th><th>SF</th><th>MK</th><th>SFI</th><th>CA</th><th>FA</th><th>Water</th></tr>
<tr><td>M1</td><td>0</td><td>0</td><td>0</td><td>504.21</td><td>0</td><td>0</td><td>0</td><td>1108.13</td><td>683.24</td><td>141.61</td></tr>
<tr><td>M2</td><td>5</td><td rowspan="2">5</td><td rowspan="2">2</td><td>478.99</td><td>25.21</td><td>25.21</td><td>120</td><td>1108.13</td><td>683.24</td><td>141.61</td></tr>
<tr><td>M3</td><td>10</td><td>453.78</td><td>50.42</td><td>25.21</td><td>120</td><td>1108.13</td><td>683.24</td><td>141.61</td></tr>
</table>

M4	15			428.57	75.63	25.21	120	1108.13	683.24	141.61
M5	5			478.99	25.21	50.42	120	1108.13	683.24	141.61
M6	10	10	2	453.78	50.42	50.42	120	1108.13	683.24	141.61
M7	15			428.57	75.63	50.42	120	1108.13	683.24	141.61
M8	5			478.99	25.21	75.63	120	1108.13	683.24	141.61
M9	10	15	2	453.78	50.42	75.63	120	1108.13	683.24	141.61
M10	15			428.57	75.63	75.63	120	1108.13	683.24	141.61

C-Concrete, SFi – fibres, SF- Silica fume, CA- Coarse aggregate, FA-Fine Aggregate

IV. RESULTS AND ANALYSIS

1. Mechanical Properties:

Mechanical properties such as compressive strength and flexural strength tests are evaluated.

1.1 Compressive Strength Test:

Compressive strength test usually gives an overall picture ofthe quality of concrete because strength is directly related tothe structure of the hydrated cement paste. Compressivestrength tests were performed on the cube specimens at the ages of 3,7 and 28days.

1.1.1 Effect of Silica Fume and Fly Ashat 3 Days on Compressive Strength:

The cube compressive strength results at 3 days fordifferent replacement levels such as 5%, 10%, and 15%of cement with fly ashand 10 % silica fume to the weight of concrete of round crimped typehaving aspect ratio 45.45 (length 25mm& diameter 0.55 mm)are presented in Table 4.1.

Table 2. Compressive Strength of M30 grade at 3days curing.

Mix	SF %	Fly ash%	SFI %	Compressive Strength MPa)
M1	0	0	0	20.36
M2	10	0		22.47
M3	10	5	2	24.56
M4	10	10		22.46
M5	10	15		21.62

SFI – fibres, SF- Silica fume.

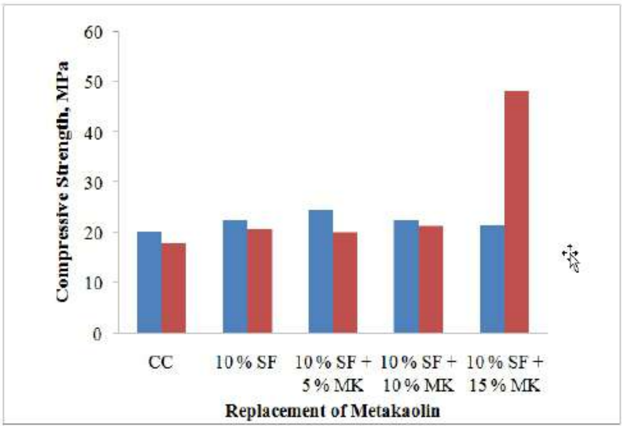

Fig 1. Compressive Strength of M60 grade concrete at 7 days curing.

The development of Compressive Strength at 7 days for the above differentmixes was plotted in the form of graph as shown in Fig. 4.1.The cube compressive strength was observed as 46.72 N/mm2for 15% SF, 10 % fly ashthere is an increase of strength by10.6% when compared to control specimen.

1.1.2 Effect of Silica Fumeand Fly Ashwith Steel Fibers at 14 Days on Compressive Strength:

Table 3. Compressive Strength of M60 grade at 14days curing.

Mix	SF %	fly ash %	SFI %	Compressive Strength Mpa)
M1	0	0	0	52.14
M2	5			52.55
M3	10	5	2	54.37
M4	15			55.53
M5	5			53.21
M6	10	10	2	55.40
M7	15			56.01
M8	5			52.76
M9	10	15	2	54.10
M10	15			55.23

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The cube compressive strength results at 14 days fordifferent replacement levels such as 5%, 10%, and 15%of cement with silica fume and fly ashare presented in Table 4.1.

From fig. 4.2, it is observed that at 10% replacement of cement by silica fume and fly ashcompressive strength increases over 0% silica fume, and fly ash. Further increase in silica fume by 15 % the compressive strength decreases.

Hence the maximum replacement of cement by admixture is 15% SF, 10 % fly ash. The cube compressive strength was observed as 56.01 N/mm2 for 15% SF, 10 % fly ashthere is an increase of strength by7.42% when compared to control specimen.

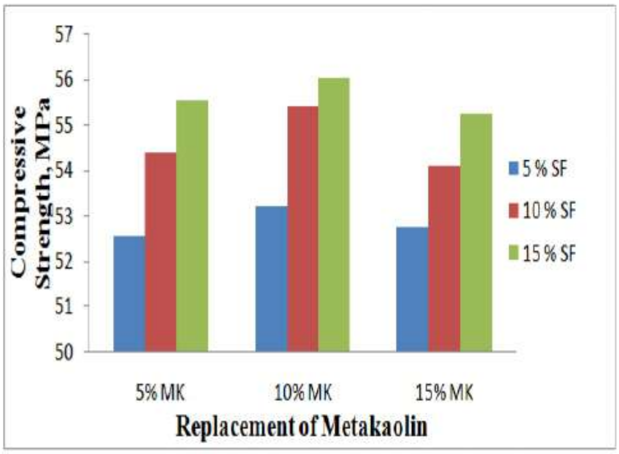

Fig 2. Compressive Strength of M60 grade concrete at 14days curing.

1.1.3 Effect of Silica Fumeand Fly Ashwith Steel Fibers at 28 Days on Compressive Strength:

Table 4. Compressive Strength of M60 grade at 28days curing.

Mix	SF %	fly ash %	SFI %	Compressive Strength (Mpa)
M1	0	0	0	62.12
M2	5			62.80
M3	10	5	2	64.92
M4	15			66.77
M5	5			63.52
M6	10	10	2	65.9
M7	15			68.78
M8	5			62.28
M9	10	15	2	64.52
M10	15			67.20

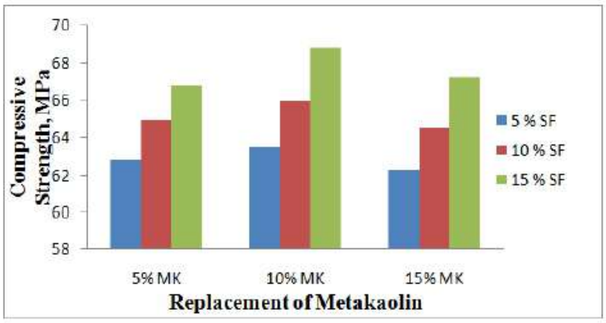

Fig 3. Compressive Strength of M60 grade concrete at 28 days curing.

Table 4.2 and fig. 4.3 showed result of compressive strength of concrete with silica fume and fly ashusing M60 grade of concrete. It is observed that compressive strength increases with the increase of silica fume and fly ash as compared to the normal concrete. Compressive strength of concrete with silica fume is increased up to the 15 % and then decreases. The maximum values of compressive strength at 15% SF, 10 % fly ashare 68.78 N/mm2.

2. Flexural Strength Test Result:

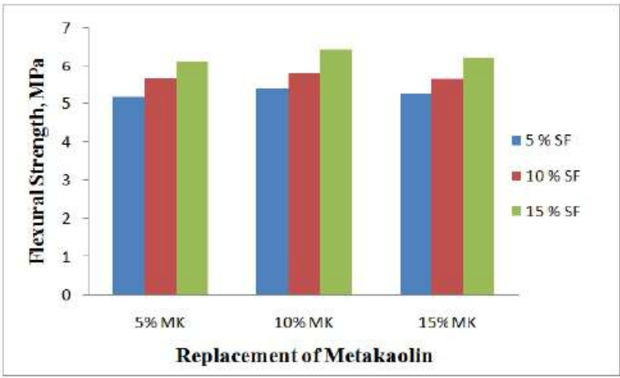

Fig 4. Flexural Strength of M60 grade at 28 days curing.

4.3 Split Tensile Strength Test Result:

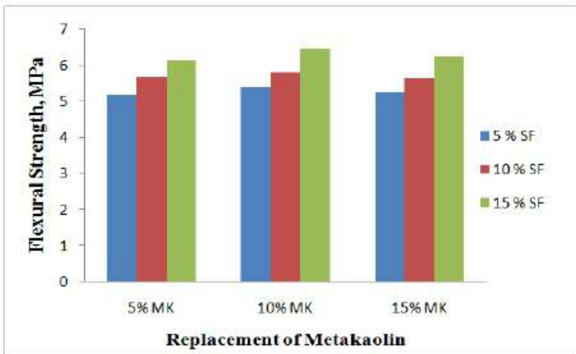

Fig 5. Split Tensile Strength of M60 grade at 28 days curing.

V. CONCLUSION

The purpose of introducing Silica fume and fly ash by partial replacing cement is to increase strength and performance of the concrete. And also strength and durability properties of concrete can be enhanced by introducing the fly ash.

The following conclusions could be drawn from the present investigation.

- Addition of admixtures to the concrete increases the strength of high performance concrete.
- The effect of silica fume, fly ash in the High Performance Concrete is studied.
- High strength fibre reinforced concrete mix has been produced with addition of condensed Silica fume and fly ashas mineral admixtures.
- By the addition of fly ashin high strength concrete with different percentage of mineral admixtures, the flexural strength has been improved in all the mix.
- From the experimental results it has been observed that the appreciable improvement in compressive strength and the flexural strength has been observed with 15% of silica fume, 10 % of fly ash and 2% of steel fibres.
- The compressive strength of high performed concrete at 7 days, 14 days and 28 days of curing with 5%, 10% and 15% of Silica fume and fly ash has been increased by 10.6 %, 7.42 % and 5.89 % and it is 46.72, 56.01 and 68.78 N/mm2.
- From the obtained results, 15% of silica fume, 10 % of fly ashand 2% of steel fibres can be taken as the optimum dosage, which can be used for giving maximum possible strength at the age of 28 days for steel fibre reinforced high performance concrete.
- The percentage increase in flexural strength at 28 days of 15% of silica fume, 10 % of fly ashover control specimen without silica fume and glass fibre is 29.63%.
- From the experimental results, the optimum percentage recommended as 15% of silica fume, 10 % of fly ashfor achieving maximum benefits in compressive, flexural strength.
- From the test of split tensile strength of M60 grade of control concrete is 5.23 MPa. The split tensile strength of concrete increases with all the proportions of fly ash (5%, 10% & 15%) and Silica Fume (5%, 10% & 15%), possesses higher Split Tensile Strength i.e. 7.19 MPa when compared to all other proportions and with further increase in the content of fly ash, The split tensile strength decreases.

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