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An Experimental Investigation on Mechanical Properties of Concrete by Partially Replacing Cement with Silica Fume and Fly Ash

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***Abstract*— This paper summarizes the research work on the properties of Silica Fumes (SF) and Fly Ash (FS) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with SF and FA by weight at 0% (nominal), 5%, 10%, 15%and 20% as various combinations. The project work involves the determination of compressive strength and flexural strength at different levels of replacement. This research work was experimentally carried out to investigate the effects of introducing Silica Fume and Fly Ash as a Partial Replacement of OPC to determine whether the replaced Concrete can be used as a Structural Concrete at suitable replacement percentages. Mix proportion of M25 is adopted.**

In this study cement is replaced with SF and FA and specimens were casted with a water cement ratio of 0.5 and the compressive strength and flexural strength of specimen were found out. The results obtained were compared with the result obtained for OPC having same mix and same water cement ratio

Keywords—Silica fume, Fly Ash, Compressive strenth, Flexural strength

I. INTRODUCTION

OPC is used in concrete as binders for making the civil structures. The production of cement results in emission of many greenhouse gases in atmosphere, which are responsible for global warming. Hence, the researchers are currently focused on use of waste material having cementing properties, which can be added in concrete as partial replacement of cement, without compromising on its strength and durability. This will result in decrease of cement production thus reduction in emission in greenhouse gases, in addition to sustainable management of the waste. The properties of concrete mainly depend on the constituents used in concrete.

The waste product like fly ash, silica fumes which has cementetious properties were used as partial replacement material for cement. These pozzolanic admixtures can used for reducing the Portland cement content in mortar and concrete production. The positive effects exerted by such pozzolanic materials on properties of concrete are very beneficial for the future demands of cementetious materials. The blend prepared by using fly ash and silica fumes at some particular proportions can produce concrete with adequate strength and thereby we can limit the use of cement, without compromising the strength.

The benefits of using either fly ash or silica fume in concrete in partial replacement for Portland cement are fairly well established. However both materials have certain short falls. Silica fume, while imparting significant contributions to concrete strength and chemical resistance can create increases in water demand, placing difficulties and plastic shrinkage problems in concrete and present handling difficulties in the raw state if not properly used. Deficiencies associated with the use of fly ash in concrete depend on the nature of fly ash being considered.

This paper presents a study on mechanical properties of concrete made with fly ash and silica fumes.

II. SCOPE

Scope of the project is to find out the optimum percentage of FA and SF to get maximum compressive strength and to find out the flexural strength.

III. OBJECTIVES

Objectives of this work are as follows

- To promote the use of waste materials as binding agent in concrete without compromise in strength.
- To reduce the emission of greenhouse gases into atmosphere.
- To reduce the cost of production of concrete.

IV. MATERIALS USED

- *Cement*

Ordinary Portland cement of grade 53 is ued. The properties of the Ordinary Portland cement (OPC) used in this study are tabulated in TABLE I.

TABLE I: PROPERTIES OF CEMENT

Properties of cement	Value
Fineness	2%
Consistency	30%
Specific gravity	3.15
Initial setting	40 minute

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- *Fine aggregate*

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. M – Sand is used as Fine aggregate

- *Coarse aggregate*

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are used. The Flakiness Index and Elongation Index were maintained well below 15%.

- *Water*

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Pure potable water is used for mixing

- *Fly Ash*

Fly ash is composed of the non-combustible mineral portion of coal. Particles are glassy, spherical 'ball bearings' finer than cement particles. It is a pozzolonic material which reacts with free lime in the presence of water, converted into calcium silicate hydrate (C-S-H) which is the strongest and durable portion of the paste in concrete.High calcium fly ash (ASTM class C) from NLC limited ,Neyveli, India was used in this investigation.

- *Silica Fume*

Silica fume used was confirming to ASTM- C (1240-2000) and was supplied by "ELKEM INDUSTRIES" was named Elkem – micro silica 920 D. The Silica fume is used as a partial replacement of cement. The chemical composition of silica fume contains more than 90 percent silicon dioxide, Other constituents are carbon, sulphur and oxides of aluminium, iron, calcium, magnesium, sodium and potassium

- *Super plasticizer*

Ceraplast 300 is is used as water reducing admixture. Cera-Chem Pvt Ltd, Chennai has developed Ceraplast 300 M which is compatible with blended cements, especially with slag cements. Ceraplast 300 M is a new generation, high grade, and high-performance superplasticiser.

V TEST AND RESULTS

The specimen of standard cube of size 150mmx150mmx150mm was used to test the compressive strength of concrete. The beam specimen of size 100mm x 100mmx 500mm was used to find out the flexural strength. Three specimens were tested for 7, 14 & 28 days with each combination of silica fume and fly ash replacement. Total 15 cubes and 15 beams were casted. The materials are weighted and mixed by hand mixing. Water cement ratio adopted was 0.5. The concrete was filled in different layers and each layer was compacted. The specimens removed from mould after 24 hrs and it is cured in clean water for 7, 14 & 28 days and then tested for compressive strength and flexural strength as per Indian Standard. Compression testing machine is used for testing the compressive strength of the specimens. Flexural testing machine was used in flexural strength test.

Various combinations of silica fume and fly ash used in replacement of cement is as shown in the TABLE II

TABLE II. VARIOUS COMBIATIONS OF SILICA FUME AND FLY ASH

Combination	Silica Fume	Fly Ash
I	20	0
II	15	5
III	10	10
IV	5	15
V	0	20

A. Compressive Strength Test Results

Cubes casted were tested in compression testing machine and the breaking load for each specimen was noted. FIG I shows the cubes testing in compression testing machine.

Figi: Cubes Testing In Compression Testing Machine

The compressive strength of concrete cubes after 7 days, 14days and 28 days of curing was shown in the TABLE III.

Combinations	Compressive Strength(N/mm^2)		
	7th day	14th day	28th day
I	22.00	23.34	25.55
II	23.34	24.00	26.50
III	24.44	25.50	32.00
IV	22.67	23.00	28.00
V	20.32	22.78	24.4

Table Iii. Compressive Strength of Specimen

Compressive strength of conventional specimen is also found out after 7th day, 14th day and 28th day of curing. The result obtained are shown in TABLE IV

TABLE IV. COMPRESSIVE STRENGTH OF CONVENTIONAL SPECIMEN

Days of testing	Compressive strength(N/mm^2)
7th day	19
14th day	22
28th day	27.33

The results obtained for various combinations of silica fume and fly ash was plotted in a graph and the graph obtained is as given below. FIG II shows the graph representing the compressive strength of specimen during various days of curing.

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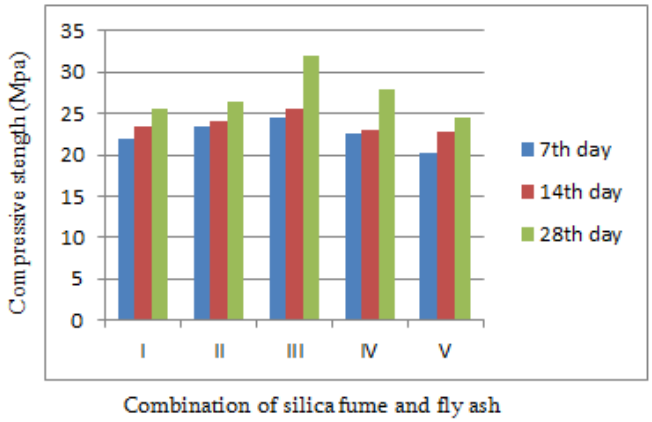
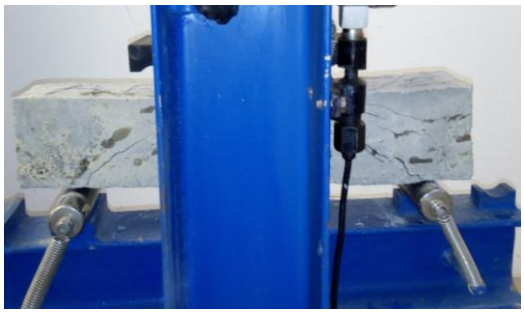


Fig Ii: Graph Showing Compressive Strength of Specimen

On analyzing the result obtained for various combination of silica fume and fly ash and compairing the same with the result obtained for conventional concrete we can say that optimum percentage of replacement of cement with fly ash and silia fume is combination III. The IIIrd combination is 10% of silica fume and 10% of fly ash and 80% cement. Conventional concrete is having a strength of 27.33 N/mm^{2,} when tested after 28th day of water curing whereas the concrete with the IIIrd combination gives a strength of 32N/mm^2. Thus we can say that, the mix with III$_{rd}$ combination can be used, without compromise in the strength of concrete.

B. Flexural Strength Of Beam

Flexural strength of the beams was tested with the help of flexural testing machine and the results obtained is shown in the TABLE V and the testing of beam in flexural testing machine is shown in FIG III..



Figiii: Beam Testing In Flexural Testing Machine

TABLE V. FLEXURAL STRENGTH OF BEAMS

Combination	Flexural strength(N/mm^2)		
	7th day	14th day	28th day
I	3.45	4.12	5.00
II	3.50	5.10	5.13
III	4.00	5.50	6.23
IV	3.40	3.95	5.11
V	3.44	4.00	5.00

Flexural strength obtained for conventional specimen is shown in the table TABLE VI

TABLE VI. FLEXURAL STRENGTH OF CONVENTIONAL BEAM

Days of testing	Flexural strength(N/mm^2)
7th day	4.13
14th day	4.45
28th day	5.67

The results obtained for various combinations of silica fume and fly ash was plotted in a graph. FIG IV shows the graph representing the flexural strength of specimen during various days of curing.

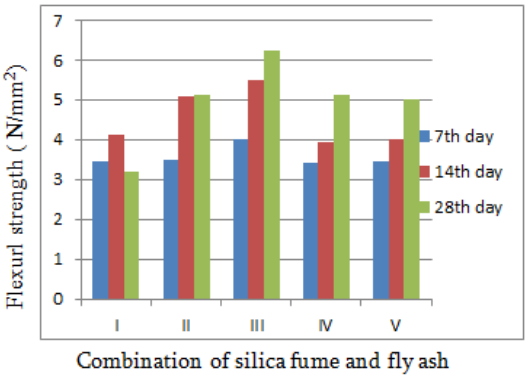


Fig Iv . Graph Showing Flexural Strength of Specimen

On analyzing the graph obtained it can conclude that the percentage which gives higher strength is combination III, ie 10% silica fume and 10% fly ash. That combination gives a flexural strength even more than the conventional concrete. There for we can conclude that the optimum percentage of replacement of cement with silica fume and fly ash for flexural strength is combination III.

VI CONCLUSION

Conclusions based on the results obtained for compression and flexural strength test are as follows;

Various combinations for replacement of cement with silica fume and fly ash are tested for various properties. In the fresh state the concrete is tested for finding the workability and found out that the mix is not workable without using super plasticizers. So water reducing admixture ceraplast 300 is used for obtaining the proper workability.

In hardened state the concrete is tested for finding out the characteristic compressive strength and the optimum combination of silica fume and fly ash is found out with the help of compression testing machine. The combination which the optimum compressive strength is IIIrd combination ie, 10% of silica fume and 10% of fly ash. This combination gives higher value of compressive strength than that of conventional concrete.

Flexural strength test was conducted in beams for finding out the optimum proportion for flexural strength. From the result obtained the optimum proportion obtained as IIIrd combination ie, 10% silica fume and 10% fly ash combination.

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From analyzing the results obtained mechanical properties of concrete can be improved by replacing cement with various combinations of silica fume and fly ash. But the combinations other than optimum combinations are found to be giving lesser values for compressive and flexural strength. Finally it can be conclude that silica fume and fly ash combination can be used as a partial replacement of cement but care should be taken to avoid the combination giving lower strength values.

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