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# Effect on Mechanical Properties of Concrete by Partial Replacement of Fly Ash and Silica Fume

Dr. Sanjeev Kumar Gupta*, Salvant Raj**, Malkiyat Singh***
**(Associate Professor, Department of Civil Engg., Govt. College of Engineering and Technology, Jammu, J&K, India)*
*Email: skgcivil70@gmail.com)*
*** (Assistant Professor, Department of Civil Engg., Govt. College of Engineering and Technology, Jammu, J&K, India)*
*Email: salvant.raj@rediffmail.com)*
**** (Lecturer, Department of Civil Engg, Govt. College of Engineering and Technology, Jammu, J&K, India)*
*Email: malkiyat40@gmail.com)*

**ABSTRACT**
In the present study the effect of addition of fly ash and silica fume with different proportions in concrete on mechanical properties has been studied. In this study 8 different mixes were prepared, in which mixes of fly ash and silica fume at different ranges ( CM, 0FA30SF, 5FA25SF, 10FA20SF, 15FA15SF, 20FA10SF, 25FA5SF, 30FA0SF ) are replaced by weight of cement and strength properties are determined for 7 days and 28 days of curing. The replacement of silica fume at 30% by wt. of cement gives higher values of compressive strength and split tensile strength. Lower values were observed when fly ash replacement by weight of cement in concrete gets increased. Mix with 15% FA 15% SF and 5% FA 25% SF was found to increase the compressive strength and split tensile strength when increase in the fly ash replacement by weight of cement result in the decrease in compressive strength at 7 days and 28 days of curing. Mix with30% FA has lower strength.. At 28 days, mix with 20%FA10%SF, 25%FA5%SF and 30%FA0%SF result in decrease in strength as compared to the normal mix. Flexural strength of concrete with replacement by fly ash and silica fume by weight of cement in different proportions were found increases for 7 days of curing and for 28 days its goes decreasing. Mixes with proportions of 0%FA30%SF, 10%FA20SF and 30%FA have higher values of strength as compared to normal mix after 7 days of curing. At 28 days mixes with very lower values of split tensile strength as compared to normal mix are 20%FA10%SF and 25%FA5%SF.

***Keywords -*** Compressive Strength, Cement, Fly Ash, Silica Fume.

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## I. INTRODUCTION

Fly ash being employed in concrete from the past times also has a vital role in improving the strength properties of concrete. In the earlier ages, fly ash has not much influence on strength because strength goes on decreasing but at later ages, properties tend to increase. Hence this is also utilized in concrete structures where strength at earlier ages is not an issue. Silica fume is also a byproduct which is waste and it is use in concrete as it is very small spherical particles and used to produce high strength concrete. In this present study we use silica fume as a cement replacement in order to less cement content.

Fly ash is powder resembling or a fine residue that result from the ignition of crushed coal in electric power plant. Objective of fly ash used in concrete to reduction in cement content, reduction in heat of hydration, improve workability, gain in strength in concrete. Fly ash increased the workability when part of the cement is replaced by fly ash which results in increase in the compaction factors of the concrete. It may also result in reduction in segregation and bleeding. Fly ash is fine in nature so, it increase in compressive strength. Various experimental work show that the cement

paste having high content of fly ash may act as new combined material in as reactive aggregate which are fixed in the mixture and cracks generally transmitted around the fly ash particles. Periods studies also show that fly ash containing cement or concrete with high modulus of elasticity, lower shrinkage and creep when matched with the properties of OPC.

## II. RESEARCH METHODOLOGY

The aim of the experimental program is to compare the properties of concrete by partial replacement of fly ash and silica fume with varying percentages in concrete by weight of cement. The basic tests carried out on concrete samples are discussed in this paper, followed by a brief description of concrete mix design and curing.

## III. EXPERIMENTAL DETAILS

Various physical tests on cement, sand and aggregate were conducted in laboratory and their values are calculated and checked as per IS code recommended values. Physical test on cement fineness, consistency, initial and final setting times, soundness and compressive strength while for sand some basic test are conducted such as sieve analysis, fineness modulus and specific gravity of sand is calculated. On the other hand aggregates test are also conducted like sieve analysis, impact test, crushing strength values and abrasion test. At the end the test on hardened concrete were carried out.

## IV. MATERIAL USED

For the entire experimental program, following materials were used.

**A) Cement:** Ordinary Portland cement OPC 43 grade (ACC) used as per IS code 8112-1989. Basic component and composition of cement.

**Table 1 Basic Component of OPC**

| S. No. | Content | (%) |
|---|---|---|
| 1 | CaO | 60-67 |
| 2 | $SiO_2$ | 17-25 |
| 3 | $Al_2O_3$ | 3-8 |
| 4 | $Fe_2O_3$ | 0.5-6.0 |
| 5 | MgO | 0.5-4.0 |
| 6 | Alkalis | 0.3-1.2 |
| 7 | $SO_3$ | 2.0-3.5 |

**Table 2 Composition of Cement**

| S. No | Name | Oxides | % |
|---|---|---|---|
| 1 | Tricalcium Silicate | $3CaO.SiO_2$ | 45-55 |
| 2 | Dicalcium Silicate | $2CaO.SiO_2$ | 20-30 |
| 3 | Tricalcium Aluminate | $3CaO.Al_2O_3$ | 06-10 |
| 4 | Tetracalcium Aluminoferrite | $4CaO.Al_2O3Fe2O_3$ | 15-20 |

**Table 3 Physical Properties of OPC**

| Test | Values | IS code values |
|---|---|---|
| Fineness of cement | 7% | less than 10% |
| Consistency | 29% | 26% to 32% |
| Initial setting time | 34 min. | 30 minutes |
| Final setting time | 10 hours | 600 minutes |
| Soundness | 6mm | less than 10mm |
| Specific gravity | 3.12 | --------- |
| Compressive strength (MPa) | | |
| 7 days | 37.52 | 33 |
| 28 days | 44.12 | 43 |

**Table 4 Physical properties of fine aggregates**

| S. No. | Characteristics | Value |
|---|---|---|
| 1. | Type | Natural sand |
| 2. | Specific Gravity | 2.58 |
| 3. | Fineness Modulus | 2.55 |
| 4. | Grading Zone | Type III |

**Table 5 Physical properties of coarse aggregates**

| S. No. | Test | Values |
|---|---|---|
| 1 | Impact value | 17.80% |
| 2 | Crushing strength values | 24.22% |
| 3 | Abrasion test | 30.56% |
| 4 | Specific Gravity (10 mm) | 2.64 |
| 5 | Specific Gravity (20 mm) | 2.68 |

**B) Fly Ash:** ASTM- C 618-93 categorizes natural pozzolans and fly ash into the following three categories:- Class N Fly Ash, Class F Fly Ash and Class C Fly Ash.

**Table 6 requirements for fly ash and natural pozzolans for use as a mineral admixture in portland cement concrete as per ASTM C 618-93**

| Requirement | Fly ash classifications | | |
|---|---|---|---|
| | N | F | C |
| Chemical Requirements | | | |
| SiO2+Al2O3+Fe2O3, min% | 70 | 70 | 70 |
| SO3, max% | 4 | 5 | 5 |
| Moisture content, max% | 3 | 3 | 3 |
| Loss on ignition, max% | 10 | 6 | 6 |
| Physical Requirements | | | |
| Amount retained when wet sieved on 45mmsieve, max% | 34 | 34 | 34 |
| Pozzolanic activity index, with Portland cementat 28 days, min% of control | 75 | 75 | 75 |
| Pozzolanic activity index, with lime at 7 days,min (MPa) | 5.5 | 5.5 | --- |
| Water requirement, max% of control | 115 | 105 | 105 |
| Autocalve expansion or contraction, max | 0.8 | .8 | 0.8 |
| Specific gravity | 5 | 5 | 5 |
| Percentage retained on 45 mm sieve | 5 | 5 | 5 |

**C) Silica Fume:** Silica fume used in concrete of powder form. The manufacture supplier of silica fume is KGR Agro Fusion Pvt. Ltd Ludhiana. Silica fume have $SiO_2$ 95%-98% according to ASTM CI1240**.**

**Table 7 Specifications of Silica Fume**

| S. No. | Content | Values |
|---|---|---|
| 1 | $SiO_2$ | 95%-98% |
| 2 | $Al2O_3$ | 0.03% |
| 3 | Carbon | < 1% |
| 4 | CaO | 0.05% |
| 5 | MgO | 0.10% |
| 6 | FeO | 0.02% |
| 7 | $TiO_2$ | 0.03% |
| 8 | LOl | < 2% |
| 9 | Moisture | 0.1% to 3% |
| 10 | Bulk density | 550 kg/ to 700 $kg/m^3$ |

**D) Chemical Admixture:** Conplast SP500, the admixture supplied by Fosroc India Pvt. Limited is used in our research work. It is a extremely efficient super plasticizer for concrete. It meets the needs for super plasticizer according to BS 5075 Part 3, ASTM C-494Type A and Type F and IS: 9103-1999 (amended 2003).The amount of the super plasticizer is set based on the needs for workability. The scientific data associated to the super plasticizer used is provided in Table 5.10. This information is supplied by the manufacturers.

**Table 8 Technical data of admixture**

| S. No. | Characteristics | Value |
|---|---|---|
| 1. | Colour | Brown |
| 2. | Specific gravity | 1.20 |
| 3. | Air entrainment | Minimum 1% |
| 4. | pH | 7 to 8 |

## V. METHODOLGY

Mix design by which we select the suitable ingredients of concrete and determine the proper amounts by which a objective of making concrete for required target strength , durability, workability and to make concrete economical. Making proportions of all ingredients of concrete make it more economical as well as quality. So for good performance of concrete the material is selected in proper proportions and appropriate mix is designed.

**A) Design of concrete mix:** For the design mix of concrete it should be prepared by keeping in view that compressive strength of concrete with adequate workability so that fresh concrete can be properly mixed, placed and compacted. Proportions of concrete mix were get by using IS code 10262-2009. Steps to be followed for proportion of concrete mix:

1. Selection of ingredients –cement, supplementary cementing materials, aggregates, water and chemical admixture.
2. Quantities of all ingredients to meet an economical concrete.

3. Quality control.

n this study, Mix Design is done by using IS10262- 2009.

### B) Design Mix Parameters:

Mix Grade = M35
Type of cement = ACC OPC 43 grade
Workability = 100-120 mm slump
Method of concreting = By pumping
Exposure condition = Moderate
Max. Aggregate size used = 20mm
Water / cement = 0.40
Fly Ash replacement = 0.5, 10, 15, 20, 25, 30% by wt. of cement.
Silica Fume replacement = 0,5, 10,15,20,25,30% by wt. of cement
Admixture = Coneplast

**Table 9 Mix proportions**

| Unit of batch | Cement (Kg) | Fine Aggregate (kg) | Coarse aggregate (kg) | | Water | Admixture |
|---|---|---|---|---|---|---|
| | | | 10mm | 20mm | | |
| Cubic meter | 370 | 749 | 431 | 647 | 170 Lt | |
| Ratios | 1 | 2.02 | 1.16 | 1.74 | 0.45 Lt | 0.8 % |

**C) Mix Composition:** Eight batches mixes are prepared as shown below in table.5.12. Fly Ash and Silica Fume at different proportions in concrete by replacement with cement at (0,5, 10, 15, 20, 25, 30) with varying percentages of two supplementary cementing materials.

**Table 10 Detailed Descriptions of Concrete Mixes**

| Mix | Fly Ash (replacement by weight of cement) (%) | Silica Fumes (Replacement by weight of cement) (%) |
|---|---|---|
| CM | 0 | 0 |
| 0FA30SF | 0 | 30 |
| 5FA25SF | 5 | 25 |
| 10FA20SF | 10 | 20 |
| 15FA15SF | 15 | 15 |
| 20FA10SF | 20 | 10 |
| 25FA5SF | 25 | 5 |
| 30FA0SF | 30 | 0 |

## VI. RESULTS

### A) COMPRESSIVE STRENGTH:

For the compressive strength test cubes of size 150x150x150mm are tested at 7 and 28 days curing for all the batches of mixes. Out of six cubes three are tested for 7 days and rest three for 28 days of curing.

**Table 11 Compressive Strength Tested at the age of 7days and 28days**

| Mix | Compressive strength ($N/mm^2$) | |
|---|---|---|
| | 7days | 28days |
| CM | 24.4 | 36.4 |
| 0FA30SF | 39.5 | 47.5 |
| 5FA25SF | 36.7 | 39.75 |
| 10FA20SF | 28.3 | 38.4 |
| 15FA15SF | 32.4 | 40.6 |
| 20FA10SF | 25.2 | 36.4 |
| 25FA5SF | 23.13 | 34.2 |
| 30FA0SF | 20.11 | 31.5 |

The replacement of fly ash and silica fume in the concrete increases the compressive strength as compare to the normal. Replacement of 30%SF by weight of cement give higher strength values. As the fly ash addition increases there is decrease in compressive strength values and lower are obtained when fly ash and silica fume are 20%FA5%SF, 25%FA10%SF and only 30%FA0SF while mixes with 15FA15SF it increase the strength values but after going to mix 20FA10SF again values start decreasing.

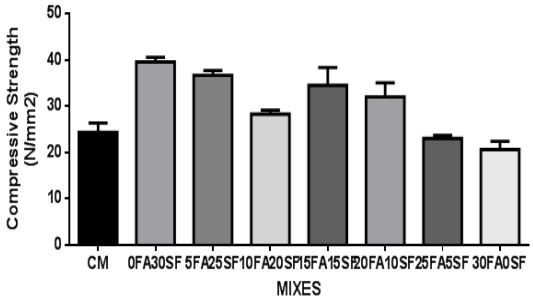



**Fig.1** Compressive Strength at the age of 7 days

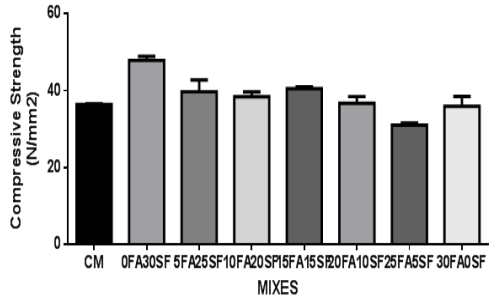



**Fig.2** Compressive Strength at the age of 28 days

**Fig.3** Split Tensile Strength at the age of 7 days

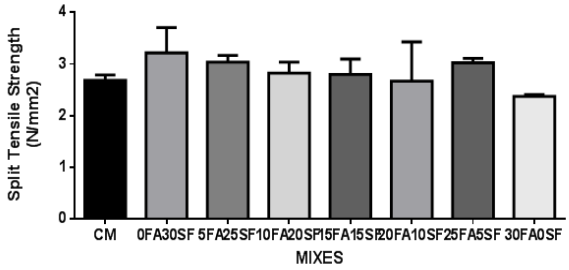



**Fig.4** Split Tensile Strength at the age of 28 days

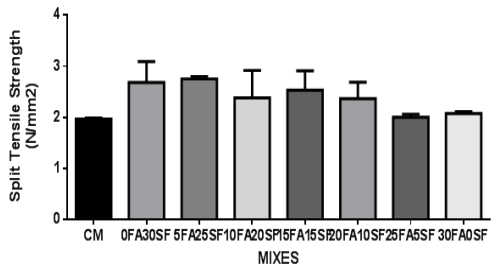
**B) SPILT TENSILE STRENGTH:**

Six cylinders of sized 150x300mm are casted for the spilt tensile strength and tested at 7and 28days of curing for all batches of mix. Three are tested at 7 days of curing and values shown in below table.

**Table 12 Split Tensile Strength Tested at the age of 7 days and 28 days**

| Mix | Split tensile strength(N/mm$^2$) | |
|---|---|---|
| | 7 days | 28 days |
| CM | 1.96 | 2.66 |
| 0FA30SF | 2.6 | 3.22 |
| 5FA25SF | 2.75 | 3.07 |
| 10FA20SF | 2.0 | 2.82 |
| 15FA15SF | 2.3 | 3.1 |
| 20FA10SF | 2.1 | 3 |
| 25FA5SF | 2.0 | 3.03 |
| 30FA0SF | 2.06 | 2.37 |

Split tensile strength for concrete having silica fume and fly ash at different proportions and there replacement by cement clearly showing in graph below that the split tensile strength increase with the increase in the fly ash and silica fume in concrete and having high strength as compare to the normal mix at 28 days of curing. Fly ash at 30% replacement by cement only without silica fume in concrete it gives the lower values of split tensile strength.




**C) FLEXURAL STRENGTH**

For flexural strength six specimens of size100x100x500mm casted and tested at 7days and 28 days curing Values are as shown in table for all mixes with different proportions of fly ash and silica fume.

**Table 13 Flexural Strength Tested at the age of 7 days and 28days**

| MIX | Flexural Strength(N/mm$^2$) | |
|---|---|---|
| | 7 days | 28 days |
| CM | 6.2 | 8.7 |
| 0FA30SF | 6.7 | 7 |
| 5FA25SF | 6.2 | 8.6 |
| 10FA20SF | 7.2 | 7.8 |
| 15FA15SF | 6.2 | 8.1 |
| 20FA10SF | 5.1 | 5.2 |
| 25FA5SF | 4.6 | 5.0 |
| 30FA0SF | 6.7 | 7.2 |

Replacement of fly ash and silica fume by weight of cement in concrete at different proportions results in decrease in flexural strength at 28 days of curing. At 5%FA25%SF mix have values which are near to the control mix values at 28 days of curing as it is clearly indicating in graph strength values are less than the normal mix values.

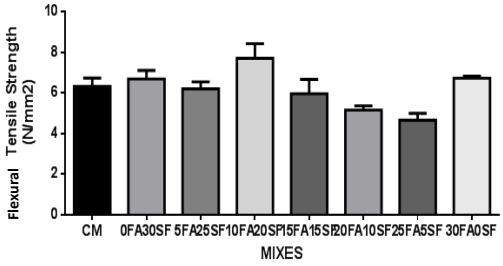



**Fig.5** Flexural Strength at the age of 7 days

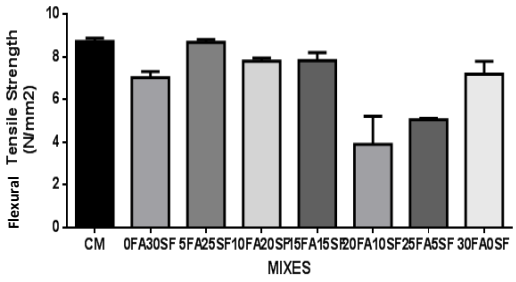



**Fig.6** Flexural strength at the age of 28 days

## VII. CONCLUSION

a) Maximum compressive strength was observed in mix 30%SF by replacement with cement but when there is increasing percentage of fly ash with silica fume it gives lower values of compressive strength at 20%FA10%SF, 25%FA5%SF, 30%FA then the normal mix at 28 days of curing.

b) Split tensile strength at 15%FA15%SF have more values as compared to the normal mix while it decrease with when replacement of cement with only fly ash at 30%.

c) Flexural strength for mix 10%FA20%SF have higher strength at 7 days curing then the normal mix whereas the flexural strength for 28 days curing is lower for all mixes at different proportions of fly ash and silica fume in concrete.

d) There is an increase in strength gain when supplementary materials were used.

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