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EFFECT OF PARTIAL REPLACEMENT OF CEMENT BY SILICA FUMES ON MECHANICAL PROPERTIES OF CONCRETE

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Abstract: ***The exposure of alumino silicate materials such as silica fume, fly ash rice husk etc., along with alkaline environment forms an environment friendly material called geopolymer. These materials not only contribute reduction in emission of carbon dioxide gas to the atmosphere but also these modern materials act as a substitute for cement to meet with the future demand. In this study an attempt has been made to produce silica fume based geopolymer concrete and to find out its strength characteristics by considering the parameters such as ratio of alkaline liquid (AL) to silica fume (SF), ratio of silicate to hydroxide (SiO_3/OH) and the age of geopolymer concrete with varying percentage of silica fume. The usage of mineral admixtures in the concrete not only enhances its strength properties but also durability. The strength is investigating finding the optimum use of mineral admixture (Silica fume of levels 0, 10, 15 and 20% at 7 days and 28 days of curing). Hence use of silica fume based geopolymer concrete is recommended for construction.***

Keywords: **Silica fume, Alkaline liquid, Geopolymer Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength**

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The usage, behavior as well as the durability of concrete structures, built during the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the ease of procuring the constituent materials of concrete. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production constituents leads to a mass of concrete have bred contempt. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Silica Fumes, Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, are some of the

pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. Addition of silica fume to concrete has many advantages like high strength, durability and reduction in cement production. The optimum silica fumes replacement percentage for obtaining maximum 28 days strength of concrete ranged from 10 to 20 %. Cement replacement up to 15% with silica fume leads to increase in strength, for M20 grade of concrete. In this paper suitability of silica fume has been discussed by replacing cement with silica fume at varying percentage and the strength parameters were compared with conventional concrete.

II. Experimental Investigations

2.1 Materials used

2.1.1 *Silica fume*

Silica fume is a by-product material obtained in the production of ferrosilicon industry and also from silicon metal. Typical particle size is <1µm. The specific gravity of silica fume used is 2.26. The presence of silica in greater percentage improves the microstructure of concrete. In the present work cement was replaced with silica fume of about 10; 15 & 20%.

2.1.2 *Cement*

The cement used for this study is Ultratech Ordinary Portland Cement (OPC) of 53 grade. The silica fume based geopolymer concrete is designed for characteristic compressive strength of 20 MPa. The fineness of cement by 90 micron sieve is 3%.

Table 2.1 Properties of Cement

Specific Gravity	Standard Consistency	Setting Time	Compressive Strength
3.14	30%	Initial: 127 min Final: 213 min	53.466 N/mm^2

2.1.3 *Fine aggregate*

The type of fine aggregate used for the present study is natural river sand and it was screened and washed to remove all organic and inorganic compounds before its use that are likely to present in it. Sand passed through 2.36 mm sieve and retained on 600 µ was taken for study.

Table 2.2 Properties of Fine Aggregates

Specific Gravity	Water Absorption	Bulk Density	Zone
2.662	0.847%	1.456 kg/lt	III

2.1.4 *Coarse aggregate*

Basalt Rock were crushed and used as coarse aggregate confirming IS: 383 1989. The aggregates were washed to remove dust & dirt and were dried to surface dry condition. The Flakiness and Elongation Index were maintained well below 15%.

Table 2.3 Properties of Coarse Aggregates

Specific Gravity	Water Absorption	Bulk Density	Impact Value
2.93	1.32%	1.35 kg/ lt	10.59%

2.1.5 *Alkaline liquid*

The alkaline liquid is soluble alkali metals usually sodium or potassium based. The sodium based liquid has more reactivity and it is easily soluble than potassium based solution. A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. The sodium hydroxide solids were a technical grade in flakes form with a specific gravity of 2.13 with 98% purity.

2.2 Mix Proportion of Normal Concrete [By Mass]:

Table 2.4 Mix Proportion

Water	Cement	Fine Aggregates	Coarse Aggregate
0.50	1	1.46	3.1
191.6 lt	444.44 kg	666.67 kg	1481.48 kg

2.3 Mix Proportion of Geopolymer Concrete

For geopolymer concrete there is no specific method of design mix. In the present investigation normal concrete mixing method and the available literatures on GPCC are used. In order to achieve good strength same w/c ratio is adopted as in normal concrete.

Table 2.5 Mix Proportions of Geopolymer Concrete Per m^3

Nomenclature	w/c	Cement (Kg)	F.A. (Kg)	C.A. (kg)	Water (lt)	Silica Fumes (kg)	Alkaline Solution (kg)
MIX 1 (0%)	0.50	444.44	666.67	1481.48	4.8	0.0	0.0
MIX 2 (10%)	0.50	400.00	666.67	1481.48	4.8	44.44	13.33
MIX 3 (15%)	0.50	377.78	666.67	1481.48	4.8	66.67	20.01
MIX 4 (20%)	0.50	355.56	666.67	1481.48	4.8	88.89	26.68

2.4 Methodology

Preparation of Alkaline liquid

Sodium hydroxide (NaOH) and Sodium silicate (Na2SiO3) were used as alkaline liquids. The molarity of NaOH used for the present study was 14. The ratio of Na2SiO3 to NaOH selected was 1.5 and Alkaline liquid (AL) to Silica Fume (SF) ratio was taken as 0.30. A solution of 14M of sodium hydroxide is prepared by dissolving 560g of sodium hydroxide pellets in a litre of water and stored separately. For particular ratio of alkaline liquid to silica fume and sodium silicate to sodium hydroxide ratio was taken and mix the two solutions in the beaker one day before casting of specimens.

2.4.1 *Casting of Geopolymer concrete specimens*

Aggregates, Cement and SF have been mixed into the mixer machine in succession with appropriate proportions for dry mix and mixed by addition of water and alkaline liquid and then rotated sufficiently to achieve uniform mix. The concrete has been placed in 150 mm cube, 150 mm diameter × 300 mm high cylinder and 150 × 150 × 700 mm beam moulds and vibrated with standard vibrator. Curing time has been taken as 24 hours in mould at 20 – 24°C followed by underwater curing until the day of testing.

In the fresh state, compaction factor of each mix have been measured. In hardened state, 7 days & 28 days compressive strength of cubes, split tensile strength of cylinder and flexural strength of beam have been measured.

III TEST RESULTS

3.1 *Fresh State*

1) Mix Character: Due to superfine nature of SF particles, geopolymer concrete has shown more cohesiveness than standard ordinary Portland cement concrete.

2) Workability: It is defined as the property of freshly mixed concrete which determines the ease of homogeneity with which it can be placed and finished. In all the mix, the compacting

factor, i.e, workability decreases as percentage of SF is increased from 10% till 20%. Thus workability changes with varied dosage of silica fumes as a replacement.

3.2 *Hardened State*

Table and figure depicts 7 days and 28 days cube compressive strength. From the properties noted by concrete using silica fume replacing cement, it is observed that, there may be some loss of strength initially but the same improves effectively both with the age and addition of SF in place of cement. The compressive strength is up to 19.83 and 31.09 N/mm^2 at 7; 28 & 56 days respectively. It is seen that maximum strength is obtained at 15% replacement of silica fumes.

There is a significant improvement in the compressive strength of concrete because of high pozzolanic nature of silica fumes and its void filling ability.

Compressive Strength Results of Cubes

No.	SF Percentage Replacing Cement	Avg. Compressive Strength (N/mm^2) 7 Days	28 Days
1.	0 %	15.83	21.75
2.	10 %	16.31	22.71
3.	15 %	19.72	29.24
4.	20 %	20.37	27.78

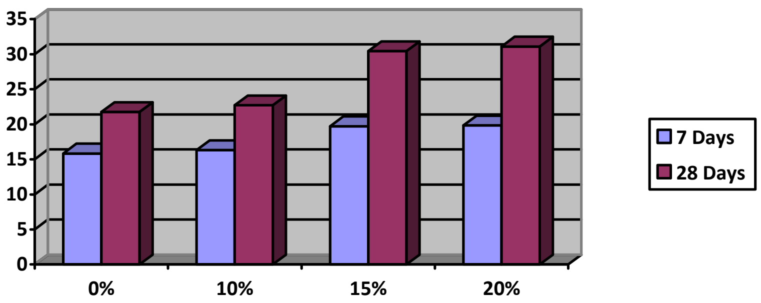
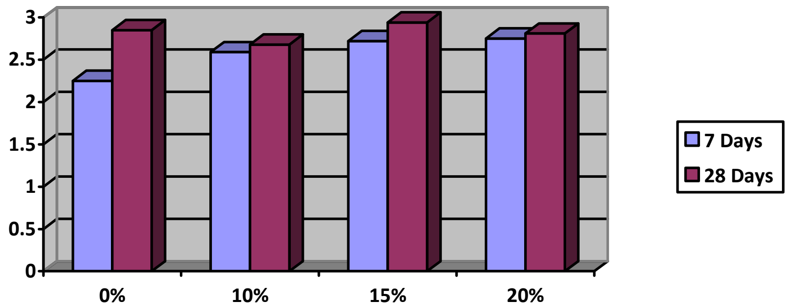


Fig.1 Compressive Strength Test Results

Split Tensile Strength Results of Cylinder

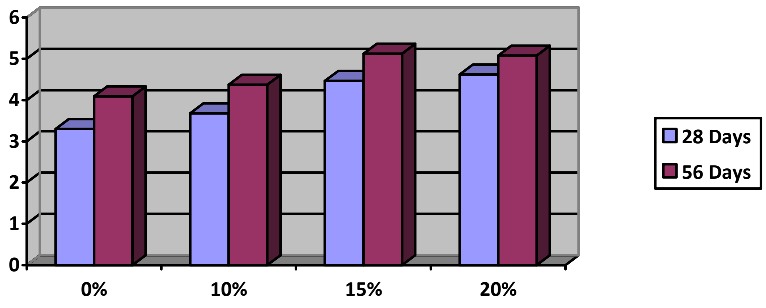
Sr. No.	SF Percentage Replacing Cement	Avg. Split Tensile Strength (N/mm^2) 7 Days	28 Days
1.	0 %	2.25	2.85
2.	10 %	2.59	2.68
3.	15 %	2.72	2.94
4.	20 %	2.75	2.81



Graph 2:- Split Tensile Strength Test Results

Flexural Strength Results of Beam

Sr.No.	SF Percentage Replacing Cement	Avg. Compressive Strength (N/mm^2) 28 Days	56 Days
1.	0 %	3.30	4.09
2.	10 %	3.68	4.37
3.	15 %	4.46	5.12
4.	20 %	4.62	5.08



Graph 3:- Flexural StrengthTest Results

IV Conclusions

It may be concluded that use of silica fume is a necessity in production of not only for high strength concrete but also for low/medium strength concrete as this material facilitate the adoption of lower water - cement material ratio and better hydration of cement particles including strong bonding amongst the particles. From the study it has been observed that maximum compressive strength is noted for 10% - 15% replacement of cement with silica fume and the values are higher than those of the normal concrete. Moreover with 15% of cement replaced by silica fume, the characteristic strength of higher grade of cement concrete namely M25 or M30 is achieved and consequently this SF concrete can certainly be used as a supplement to M20 grade. Lastly with good quality control, high early strength can be achieved in SF concrete which may be useful in various structural constructions such as high-rise buildings, bridges, chimneys, machine foundations, run ways etc.

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