# Performance of Geopolymer Concrete with Silica Fumes & Fibres under Various Aggressive Environment

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## Abstract

The increase in industrial activities of core sectors for the production of large amount of waste products like silica fumes, dust, fly ash, blast furnace slag with consequent problem of disposal of waste. So for the beneficial use of this waste could help to minimize the risk of degradation of environment. This paper deals with the waste product generated from industries in term of fly ash and silica fume as a partial replacement of cement. In this fly ash and fibre is used in varying proportion such as 25%, 50% and fibres as 0.5%, 1% whereas silica fume as 10%. M-40 grade concrete is used an accordingly mix design is prepared. Tests are performed for testing the efficiency of concrete. Concrete beam of size 100*100*500mm is prepared for calculation of flexural strength using flexural testing machine (FTM), with curing at 28 days in normal water and 5% con. Sulphuric acid. It was found that flexural strength increased at 25% and 10% replacement of cement with Fly ash and silica fume.

**Keywords: Fly ash, silica fumes, fibres, flexural testing machine**

## I. INTRODUCTION

In the context of increased awareness regarding the ill-effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Construction industry is one of the major users of the natural resources like cement, sand, rocks, clays and other soils. The ever increasing unit cost of the usual ingredients of concrete has forced the construction engineer to think of ways and means of reducing the unit cost of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal problem.

Concrete is a mixture of naturally and easily available ingredients such as cement, sand, aggregate and water. Cement has occupied second place as most used material in world after water. The rapid production of cement creates big problems to environment. The first problem is emission of CO2 during the production of cement. According to the survey 1 tonne of carbon dioxide is release to the environment when 1 tonne of ordinary Portland is manufactured. As there is no alternative material which can totally replace the cement. But substantial energy and cost saving can be result when industrial by products are used as a partial replacement of cement. Fly Ash, Blast furnace slag, Rice husk ash, High Reactive Meta kaolin, Silica fume are some of the pozzolanic material which can be used as the partial replacement of cement in concrete.

## II. PROPERTIES OF MATERIALS USED

### *A. Fly Ash:*

FLY ASH used in the project was obtain from Koradi Thermal Power Station located at Koradi near Nagpur, Maharashtra. The power plant is one of the four major power plants in Vidarbha. It is operated by Maharashtra State Power Generation Company Limited (Mahagenco), a subsidiary of Government of Maharashtra owned by Maharashtra State Electricity Board (MSEB). The basic properties of fly ash were found and compare with ingredients of cement to determine the optimum replacement of cement with fly ash. Properties of fly ash is as given in table no-1

Fig. 1: Fly Ash

Table – 1
Properties of Fly Ash

| *Sr.No* | *ELEMENT* | *PERCENTAGE%* |
|---|---|---|
| *1* | *Calcium Oxide (CaO)* | *1.88* |
| *2* | *Silica-di-oxide ($SiO_2$)* | *61.39* |
| *3* | *Magnesium Oxide (MgO)* | *1.32* |
| *4* | *Aluminum ($Al_2O_3$)* | *31.86* |
| *5* | *Iron oxide($Fe_2O_3$)* | *1.11* |
| *6* | *Titanium dioxide ($TiO_2$)* | *1.52* |
| *7* | *Potassium (K)* | *0.40* |
| *8* | *Sodium oxide ($Na_2O$)* | *0.58* |
| *9* | *Copper (Cu)* | *1.4* |
| *10* | *Phosphorus (P)* | *0.19* |
| *11* | *Nitrogen (N)* | *0.09* |

### *B. Cement:*

Before preparing the mix design it is necessary to determine the physical properties of cement so that effective mix design can be prepared and proportioning of various ingredients can be smoothly carried out. Cement which is being used for the project work is ACC cement of 43 grade conforming to IS 8112 So various physical properties that have been determined are given in table no-2

Table – 2
Properties of Cement

| *SR.NO* | *Physical properties of cement* | *Results* | *Requirements as per IS-8112* |
|---|---|---|---|
| *1* | *Specific gravity* | *3.15* | *3.10-3.15* |
| *2* | *Standard consistency (%)* | *31.5 %* | *30-35* |
| *3* | *Initial setting time (hours, min)* | *40 min* | *30 minimum* |
| *4* | *Final setting time (hours, min)* | *380 min* | *600 maximum* |

### *C. Properties of Fine Aggregate and Coarse Aggregate*

Fine aggregates which are being used comprised of clean river sand with maximum size of 4.75mm conforming IS383-1970 with specific gravity of 2.6. Coarse aggregates used consisted of machine crushed stone angular in shape passing through 20mm IS sieve and retained on 4.75mm IS sieve with specific gravity of 2.9.

### *D. Water:*

Water plays a very important role for mixing of various ingredients; adequate quantity of water should be used for mixing because excess quantity of water may lead to many adverse effects such as bleeding. Water helps to carry out chemical reactions required for producing concrete and helps in formation of gel. The Water/Cement ratio used for M-40 grade concrete is 0.45.

### *E. Admixture:*

Admixture is a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. One such admixture which is being going to be used is super plasticizers, i.e. Viscoflux active. Use of super plasticizers permits the reduction of water to the extent up to 25 % without N

## III. CONCRETE MIX PROPORTION

Concrete Mix Design for M-25 grade concrete was prepared as per IS 10262: 2009 and accordingly concrete cubes and beams were prepared and test. Proportioning of various ingredients for M-25 grade concrete is as shown in the table no-3.

Table – 3
Concrete Mix Design for M-40 Grade

| *Mix* | *Cement (Kg/m$^3$)* | *W/C* | *Fine Agg (Kg/m$^3$)* | *Coarse Agg(Kg/m$^3$)* | *Fly-Ash (Kg/m$^3$)* | *Silica Fumes ( Kg/m$^3$)* | *Fibers (Kg/m$^3$)* |
|---|---|---|---|---|---|---|---|
| *N* | *443* | *0.42* | *648* | *1202* | *-* | *-* | *-* |
| *A* | *332* | *0.42* | *648* | *1202* | *110* | *-* | *-* |
| *B* | *221* | *0.42* | *648* | *1202* | *221* | *-* | *-* |
| *C* | *398* | *0.42* | *648* | *1202* | *-* | *44.3* | *-* |
| *D* | *287* | *0.42* | *648* | *1202* | *110* | *44.3* | *-* |
| *E* | *117* | *0.42* | *648* | *1202* | *221* | *44.3* | *-* |
| *F* | *285* | *0.42* | *648* | *1202* | *110* | *44.3* | *2.2* |
| *G* | *283* | *0.42* | *648* | *1202* | *110* | *44.3* | *4.4* |
| *H* | *174* | *0.42* | *648* | *1202* | *221* | *44.3* | *2.2* |
| *I* | *172* | *0.42* | *648* | *1202* | *221* | *443* | *4.4* |

## IV. TESTING PERFORMED ON HARDENED CONCRETE

### *A. Flexural Test:*

In order to determine the flexural test beams were casted of size 100*100*500 mm and flexural test was determined using Flexural Testing Machine. 28 days flexural strength for cubes cure in normal water and sulphuric acid was determined and compared with the conventional concrete. Outcomes of flexural testing are presented in table no-4 and table no-5.

Table – 4
Average Flexural Strength (Normal curing)

| *Sr.No* | *Content* | *1$^{st}$ strength @ 28 days (N/mm$^2$)* | *2$^{nd}$ strength @ 28 days (N/mm$^2$)* | *3$^{rd}$ strength @ 28 days (N/mm$^2$)* | *Average (N/mm$^2$)* |
|---|---|---|---|---|---|
| *1* | *Normal concrete (N)* | *7.5* | *8.25* | *8.25* | *8* |
| *2* | *25% Fly ash (A)* | *9* | *8.25* | *9* | *8.75* |
| *3* | *50% Fly ash (B)* | *6.75* | *6.375* | *6.75* | *6.625* |
| *4* | *10% Silica Fume (C)* | *10.5* | *10.5* | *9.75* | *10.25* |
| *5* | *25% FA & 10%SF (D)* | *9.375* | *8.25* | *9.75* | *9.2* |
| *6* | *50% FA & 10%SF (E)* | *7.5* | *6.75* | *7.5* | *7.25* |
| *7* | *FA (25%) + SF (10%) + F (.5%) (F)* | *8* | *7.5* | *9* | *8.167* |
| *8* | *FA (25%) + SF (10%) + F (1%) (G)* | *8* | *8* | *9* | *8.33* |
| *9* | *FA (50%) + SF (10%) + F (.5%) (H)* | *7.5* | *6.75* | *7.5* | *7.25* |
| *10* | *FA (50%) + SF (10%) + F (1%) (I)* | *6.75* | *7.125* | *6.75* | *6.83* |

Table – 5
Average Flexural Strength (Acid curing)

| *Sr.No* | *Content* | *1$^{st}$ strength @ 28 days (N/mm$^2$)* | *2$^{nd}$ strength @ 28 days (N/mm$^2$)* | *3$^{rd}$ strength @ 28 days (N/mm$^2$)* | *Average (N/mm$^2$)* |
|---|---|---|---|---|---|
| *1* | *Normal concrete (N)* | *6* | *6.75* | *6.75* | *6.5* |
| *2* | *25% Fly ash (A)* | *7.5* | *7.5* | *8.25* | *7.75* |
| *3* | *50% Fly ash (B)* | *6* | *6* | *5.625* | *5.875* |
| *4* | *10% Silica Fume (C)* | *9* | *9.75* | *9* | *9.25* |
| *5* | *25% FA & 10%SF (D)* | *8.75* | *8.75* | *8* | *8.5* |
| *6* | *50% FA & 10%SF (E)* | *6.75* | *6* | *5.625* | *6.125* |
| *7* | *FA (25%) + SF (10%) + F (.5%) (F)* | *7.125* | *6.75* | *7.5* | *7.125* |
| *8* | *FA (25%) + SF (10%) + F (1%) (G)* | *7.5* | *7.125* | *7.125* | *7.25* |
| *9* | *FA (50%) + SF (10%) + F (.5%) (H)* | *6* | *6.375* | *6.375* | *6.25* |
| *10* | *FA (50%) + SF (10%) + F (1%) (I)* | *6.375* | *6* | *6* | *6.125* |

### *B. Weight OF Beam*

Weight of beam is to be checked after curing for 28 days in sulphuric acid and in normal water. The obtained result are given following table-

Table – 6
Weight of cube after curing

| *Sr.No* | *Content* | *Normal weight (Kg)* | *After acid test (Kg)* |
|---|---|---|---|
| *1* | *Normal concrete (N)* | *13.57* | *12.27* |
| *2* | *25% Fly ash (A)* | *13.44* | *12.37* |

| | | | | |
|---|---|---|---|---|
| *3* | *50% Fly ash* | *(B)* | *12.98* | *12.10* |
| *4* | *10% Silica Fume* | *(C)* | *13.35* | *12.55* |
| *5* | *25% FA & 10%SF* | *(D)* | *12.09* | *11.23* |
| *6* | *50% FA & 10%SF* | *(E)* | *13.33* | *12.26* |
| *7* | *FA (25%) + SF (10%) + F (.5%)* | *(F)* | *13.04* | *12.42* |
| *8* | *FA (25%) + SF (10%) + F (1%)* | *(G)* | *12.99* | *12.05* |
| *9* | *FA (50%) + SF (10%) + F (.5%)* | *(H)* | *13.45* | *12.62* |
| *10* | *FA (50%) + SF (10%) + F (1%)* | *(I)* | *13.23* | *12.06* |

## V. RESULTS AND DISCUSSION

### *A. Flexural Test:*

Result obtained by flexural testing machine is given in table no. 4 and table no. 5 after the curing was done in normal water and acid. The maximum increase in strength was obtain in mix C and D. In (Mix C) 10% silica fume was replaced by cement and in (Mix D) 25% fly ash and 10% silica fume is replaced by cement. Whereas same strength was obtain when curing was done in 5% sulphuric acid. Fig no.7 and 8 shows the variation in strength.

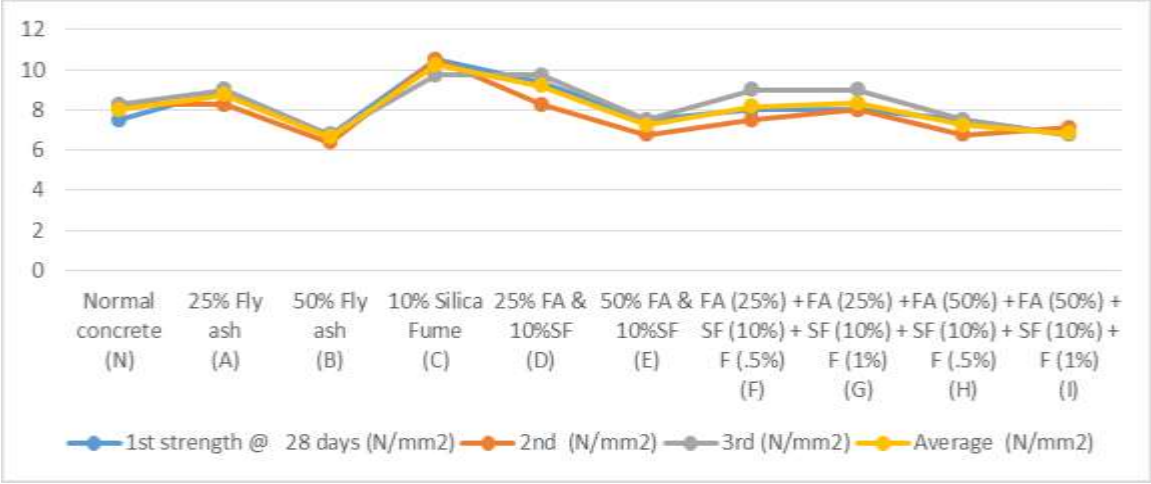


Fig. 7: Variation in strength by FTM (Normal curing)

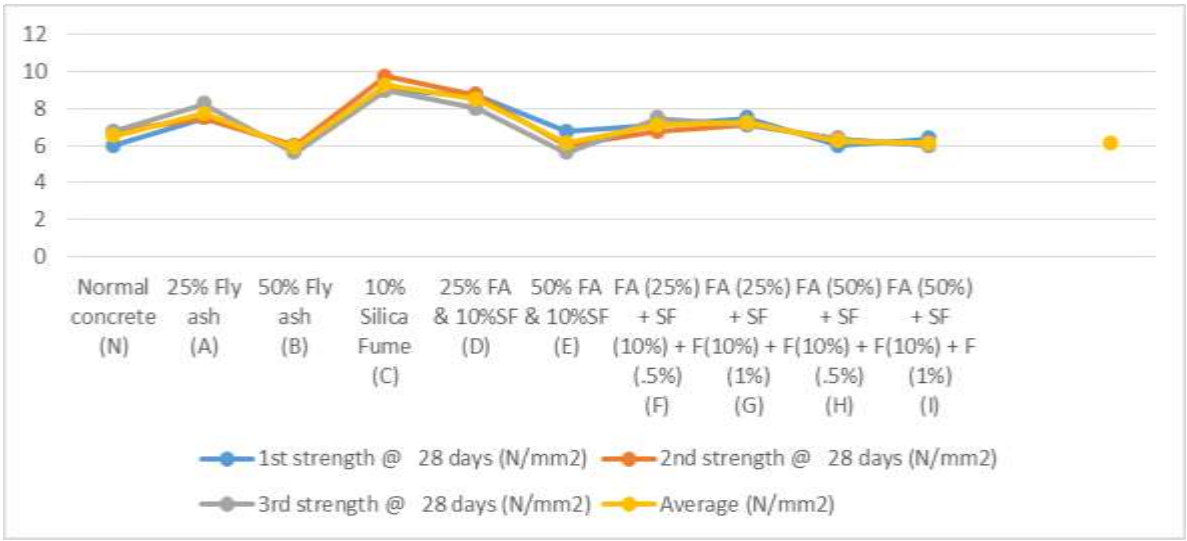


Fig. 8: Variation in strength by FTM (Acid curing)


Fig. 9: Variation in strength by FTM in normal and acid curing.

### *B. Weight of Beam:*

Result obtain after checking the weight of beam is given in table no.6 And the variation in loss of weight due to acid is given in fig no. 10.

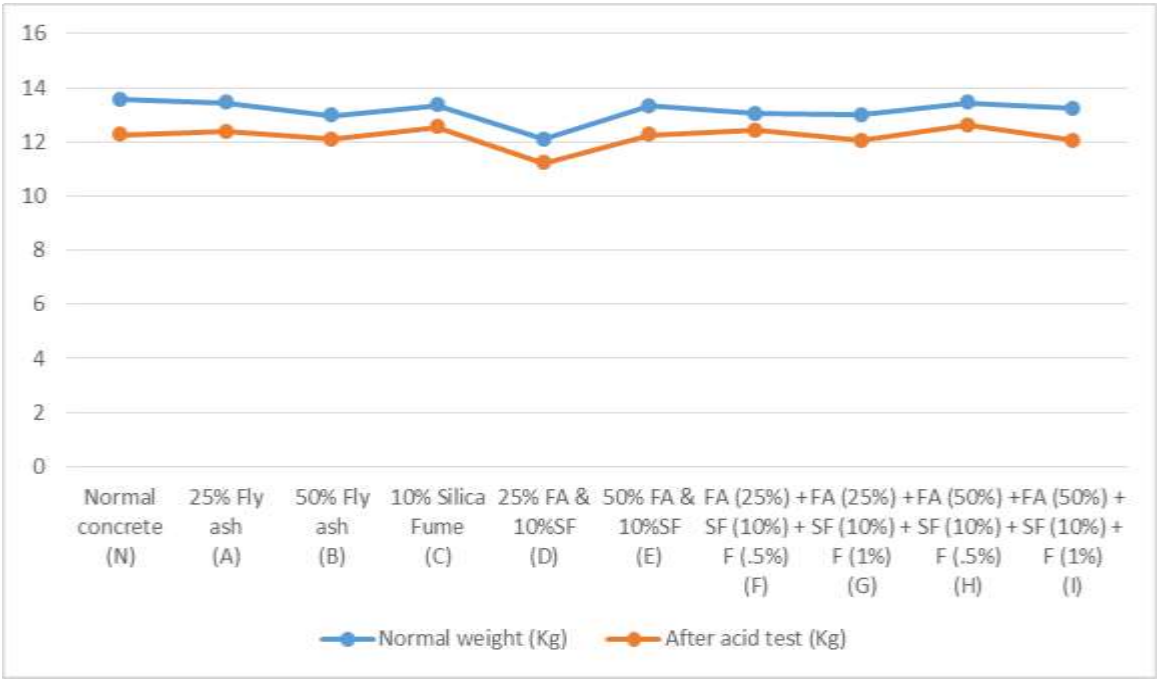


Fig. 10: Variation in weight due to Acid

## VI. CONCLUSION

- Near about 15% increase in flexural strength when 10% silica fume is replaced by cement as compare to conventional concrete. (Mix C)
- 10% increase in flexural strength when 25% fly ash + 10% silica fume is used. (Mix D)
- 5% increase is obtain when 25% fly ash is used after both natural and acidic curing. (Mix A)
- 10 to 12% decrease in flexural strength is found when it is cure for 28 days in acid as compare to normal curing.
- Near about 7 to 8% decrease in weight is found when curing is done acid as compare to normal curing.

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