# Effective Utilization of Industrial Waste in Concrete (100% Replacement of OPC)

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**Abstract— Concrete is the second most used material after water in would but for preparing concrete is most essential & for preparation of one ton of cement high amount of co2 is released which results in global warming . At the beginning of 21st century we replaced cement partially. The main aim of this research is replace cement fully to reduce cement production hence we replaced cement by fly ash & GGBS. Fly ash is completely industrial waste. In this research we study M30 grade concrete at which maximum compressive strength can achieve in second phase we replace fly ash 10%, 20%& 30% by GGBS for achieving more strength and utilize industrial waste.**

**Index Terms- Fly ash, Fully replaced, GGBS (Ground Granulated Blast Furnace Slag), industrial waste.**

## I. INTRODUCTION

*A. General*

In world normally concrete is used in construction because of its abundant resources is handling greater compressive strength ,durability and according to USGSS [united states geological survey] latest study 285.83 million tones cement is produced only in India .when contributes in greenhouse gases in the form of co2.In India production of fly ash is increases tremendously .according to survey in world 780million tones fly ash is produced and we utilized just 17 to 20% fly ash in concrete remaining 80%fly ash faces problem of disposal which requires several acres of priceless land .fly ash is very light in weight because of that fills easily and can create hazardous health problems such as asthma bronchitis soOur study depend on replacement of OPC by fly ash fully. I this we preferred for utilization of industrial waste like fly ash and GGBS effective. For preparation of fly ash based geo polymer concrete the reaction is polymerization. In which NoaH and Na2Sio3 is used activator and binder respectively. Our study on M30 grade concrete in which proportion is 1:1.82:3.87 and fly ash to binder ratio 0.35 and water to geo polymer binder ratio is 0.211.

*B. Flyash*

Fly ash is divided mainly into two categories based on its calcium content. Astm class f fly ash (low calcium fly ash) is mainly pozzolanic (i.e., they react with calcium hydroxide in moist condition to produced cementitious compounds), whereas class c fly ash (high calcium fly ash) has higher fraction of calcium oxides, which give them cementitious characteristics. Class c fly ash is often marketed directly in many countries and finds easy application in concrete as a part replacement of cement. In high calcium fly ash, the alumino- silicate glass has a lot of calcium in it which makes the fly ash much more reactive and hence gives high early age strength.

Low calcium fly ash has about 80% less reactive alumino-silicate glass with 20% being non-reactive crystalline minerals. Class f fly ash (most indian fly ash falls in this category) is primarily used as a cement replacement under certain conditions of quality in terms of chemicals composition, particle size distribution and loss of ignition(which is an indicator of carbon content). Other applications of class f fly ash are in the area of alkali activated concrete, blended cements, ternary blends including fly ash and slag or silica fume or lime.

Table no. 1: chemical compositions of fly ash

| Sr. No. | Chemical composition | Pozzocrate-60 % | Specification as per Is 3812-1981, (%) |
|---|---|---|---|
| I | $Sio_2$ + $al_2o_3$ + $fe_2o_3$ | 92.78 | 70 min. By mass |
| 2 | $Sio_2$ | 58.26 | 35 min. By mass |
| 3 | $Al_2o_3$ | 33.37 | ---- |
| 4 | $Fe_2o_3$ | 01.21 | ---- |
| 5 | Mgo | 1.56 | 5 max. By mass |
| 6 | $So_3$ | 0.66 | 3 max. By mass |
| 7 | $Na_2o$ | 0.54 | 1.5 max. By mass |
| 8 | Cao | 0.62 | ---- |
| 9 | Total chlorides | 0.03 | 0.05 max. By mass |
| 10 | Loss of ignition. | 0.87 | 5 max. By mass |

*C. GGBS*

GGBS composition depends upon the raw material which is used in iron production. In GGBS the silicates & aluminates impurities are greater from ore & coke which lowers the viscosity of slag. In case of pig iron production, consisting limestone foresterite or in some cases dolomite. In blast furnace, the slag floats on the top of iron & at the bottom for separation. After cooling of that waste material results in an unreactive crystalline material, consisting of aluminates, silicates & magnese. To cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet streams of water or air under pressure. Alternatively, in the pelletization process the liquid slag is partially cooled with water and subsequently projected into the air by a rotating drum. In order to obtain a suitable reactivity, the obtained fragments are ground to reach the same fineness as Portland cement.

The main components of blast furnace slag are CaO (30-50%), $SiO_2$ (28-38%), $Al_2O_3$ (8-24%), and MgO (1-18%). If increasing the CaO content of the GGBS results in raised slag basicity and an increase in compressive strength. The MgO and $Al_2O_3$ content show the same trend up to respectively 10-12% and 14%, after which no further improvement can be obtained. Such compositional ratios have been used to correlate slag composition with hydraulic activity; the latter being mostly expressed as the binder compressive strength.

Table no. 2: chemical compositions of GGBS

| Parameters | GGBS (%) | As per IS 12089-1987 (Reaffirmed 2008) |
|---|---|---|
| CaO | 37.34 | --- |
| $Al_2O_3$ | 14.42 | --- |
| Fe2O3 | 1.11 | --- |
| SiO2 | 37.73 | --- |
| MgO | 8.71 | Max. 17.0% |
| MnO | 0.02 | Max. 5.5% |
| Sulphide Sulphur | 0.39 | Max. 2.0% |
| Loss of Ignition | 1.41 | --- |
| Insoluble Residue | 1.59 | Max. 5% |
| Glass content (%) | 92 | Min. 85% |

## II. LITERATURE REVIEW

Davidovits introduced the term 'geopolymer' in 1978 to represent the mineral polymers resulting from geochemistry. Most of the literature available on this material deals with geopolymer pastes. Past studies on the properties and the behavior of fly ash based geopolymer concrete are extremely limited.

Davidovits, Djwantoro Hardjito, A. Palomo and a. Fernandez-jimenez, n.p. Rajamane, Barbosa, and Zhang Yunsheng and sun wei studded the geopolymer concrete using fly ash and or metakaoline as source material and activated by sodium hydroxide and sodium silicate solutions. Most of the past research on the behavior of geopolymetric material was based on binder paste or mortar using small size samples.

Joseph davidovits in developed amorphous to semi-crystalline three dimensional silico-aluminate materials in 1979 called as geopolymer. These are the mineral polymers resulting from geochemistry or geosynthesis. Geopolymerization is a geosynthesis that allows the products to exhibit the most ideal properties of rock- forming elements, i.e., hardness, chemical stability, etc. The author designated the geopolymers as poly (sialate) which is an abbreviation for poly(silico-oxo-aluminate) or (-si-o-ai-o-)n in which n is the degree of polymerization.

A. Palomo and a. Fernandez-jimenez studied the alkaline activation of industrial sub products like fly ash for making geopolymer concrete. For the production of the geopolymer concrete, an alkaline solution containing NaOH and sodium silicate ($na_2o$ = 32%, $sio_2$ = 5%, and $h_2o$ = 63%) were used. Concrete specimens were cast with solutions-to-fly ash ratio of 0.50 and 465 kg/$rn^3$ of fly ash. After casting the moulds in three layers, the samples were kept in an oven and cured for 20 hours at 85°c. It was observed that the concrete give good mechanical strength with in a very short period of time. The authors found that for fly ash based geopolymer binder, the main factors affecting its mechanical strength were curing temperature, curing time, and the type of activator, while the solution-to-fly ash ratio was not a relevant parameter. Increase in curing temperature increased the compressive strength. The type of alkaline activators that content soluble silicates resulted in higher reaction rate than when hydro-oxide was used as the only activators.

V. F. Barbosa, k. J. Mackenzie, & c. Thaumaturgoet reported that the optimum composition occurred when the ratio of $na_2o/sio_2$ was 0.25 and the ratio of $h_2o/na_2o$ was 10.0, based on tests performed on geopolymer pastes using calcined kaolin as the source material. The authors also stated that the water content plays an important role on the properties of geopolymer binders, besides the chemical composition of the oxides used as activators. Joseph davidovits reported that the industrial application of kaolinite with alkali began in the ceramic industry with olsen in 1934 and was later on reinvested in 1970 by the russian team berg and etal, but without any successful industrial implementation. The author found that the kaolinite, which is the component of clay, reacted with caustic soda at 150°c and polycondenses into hydrated sodalite. This basic innovation, the low temperature transformation from kaolinite into hydrosodalite, demonstrated the tremendous latent potential of this new mineral reaction.

S.V. Patankar and S.S. Jamkar studied the effect of partial replacement and full replacement of cement by low calcium fly ash in two phases. It was found that the compressive strength decreases with increase in replacement of cement by fly ash. Up to 40% replacement of cement, initial strength is less but strength at 60 days of curing is more or less similar to that of conventional concrete at 28 days of curing. Beyond 40% replacement of cement, workability and strength has been reduced and setting time increased. Beyond 60% replacement of cement, increases the water demand, difficulty in mixing, more time required for demoulding of cubes and reduction in the rate of gain of strength is observed.

In second phase, the authors studied the effect of various alkaline solutions-to-fly ash ratios by mass and the molarities of NaOH solution on compressive strength of geopolymer concrete. The fly ash used for experimental work contains $sio_2$-to- $al_2o_3$ in the proportion of 2.4: 1. The ratio of alkaline solution to fly ash was taken as 0.30, 0.35 and 0.4.0 for each 10m and 13m NaOH solution. The ratio of$na_2sio_3$-to- NaOH solution was kept constant at 2.5

Steam curing was done at 110°c for 2.5 hours just after demoulding the concrete cubes.

## III. MATERIALS & METHODS

### A. Quantity of Material for Preparation of Specimen:-

*a. Fixed Parameters:-*

Mix proportion ( M30 nominal ) = 1:1.82:3.37
$NaOH/ Na_2SiO_3$= 1:1
Concentration of $Na_2SiO_3$ solution (solid contents =50.93%, water content =49.07%)
Concentration of NaOH = 13.00 m
Type of fly ash used = p83 grade
Solution/fly ash ratio =0.35
Water/binder =0.35, 0.30, 0.25, 0.226

*b. Calculation for water/binder (0.35):-*

Weight of one cube = 9 kg approximately
Total cubes cast = 10
Mix proportion = 1:1.5:3
Fly ash in concrete = 16.5 kg
Sand required = 16.5 x 1.5 = 24.75 kg
Total aggregate = 16.5 x 3 = 49.5 kg
Coarse aggregate (20 mm) = 32.175 kg (65%)
Coarse aggregate (12.5mm) = 17.325 kg (35%)
Water/(fly ash + solids) = 0.35
($NaOH + Na_2SiO_3$) / 16.5 = 0.35
2NaOH = 5.775
NaOH by mass = 2.888 kg
$Na_2SiO_3$ by mass = 2.888 kg
Solid in NaOH (37.57%) = 1.085 kg
Solid in $Na_2SiO_3$ (50.93 %) = 1.471 kg
Total solids in solution = 2.556 kg
Water in NaOH = 2.888- 1.085 = 1.803 kg
Water in $Na_2SiO_3$ = 2.888-1.471 = 1.417 kg
Total water required = 3.220 kg
Water/(fly ash + solids) = 0.35
Water/(16.5 + 2.556) = 0.35
Water content = 6.670 kg
Net quantity of water required 6.670 – 3.220 = 3.450 kg

### B. Mixing, Casting and Compaction of Geopolymer Concrete:-

Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of portland cement concrete.

1. In the laboratory, the fly ash and the aggregates were first mixed together dry manually for about three minutes.
2. The aggregates were prepared in saturated-surface-dry (ssd) condition, and were kept in plastic buckets with lid.
3. The alkaline liquid was mixed and the extra water was added, if any.
4. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes.
5. The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.
6. Then ten cubes of size 150 x 150 x 150 mm were cast in three layers.
7. Each layer was well compacted concrete tamping rod of diameter 10 mm.
8. After compacting concrete, the top surface was leveled by using trowel and also struck the sides of mould by using hammer so as to expel air if any present inside the concrete and smoothen the sides.
9. The fresh concrete was cast and compacted by the usual methods used in the case of portland cement concrete (hardjito and rangan, 2005; wallah and rangan, 2006; sumajouw and rangan, 2006). Fresh fly ash-based geopolymer concrete was usually cohesive.
10. The workability of the fresh concrete was measured by means of the conventional slump test.

### C. Curing of Concrete Specimens:-

After 24 hours of casting, all cubes were demoulded and then four cubes placed in an oven for thermal curing (heating) at temperature ($60^0$c, $90^0$c, $120^0$c) for duration 24 hours each respectively. After specified period of heating at required temperature, oven was switched off. To avoid the sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature in the oven for 24 hours. After 24 hours, specimens were removed from oven and then tested for compressive strength. Remaining six cubes placed in open to sky for sun dried curing for six days. After each day one cube was removed from there and kept it in room temperature for 24 hours so that no sudden temperature variation of cubes. After 24 hours, weight of each specimen was taken for determination of mass density and then tested for compressive strength.

### D. Testing on Geopolymer Concrete

Following test have been performed on the geopolymer concrete in the present investigation.

### E. Compressive strength test

The cubes were tested in compression in accordance with the test procedures given in the indian standards is-4031(part-vi)-1981 methods of testing concrete – determination of the compressive strength of concrete specimens (1981).

### F. Concentration of Solutions

*a. Concentration of Sodium Hydroxide:-*

Previous experimental work done by the researchers shows that the strength increases with increase in concentration of sodium hydroxide. In this project, the effect of various concentration of sodium hydroxide on workability as well as compressive strength was studied. For the investigation, 13 m solutions were used.

*b. Concentration of Sodium Silicate Solution:-*

It was observed that the effect of various concentrations of$Na_2O$ and $SiO_2$ in sodium silicate solution did not studied in the earlier investigation. It may be due to the availability of sodium silicate solution in the market. Therefore it is necessary to check the effect of various concentrations of $Na_2O$ and $SiO_2$ in sodium silicate solution on the strength of geopolymer concrete. The effect of various concentration of sodium silicate solution were studied in the preliminary investigation and then fixed the concentration of sodium silicate solution for the further experimental investigations.

### G. Type of Curing, Temperature and Age

Past studies on fly ash-based geopolymer concrete shows that the oven heating/curing gives good result compared to steam curing. It was found that the characteristics of the material were mostly determined by curing methods especially the curing time and curing temperature. Because the chemical reaction of the heat cured geopolymer concrete is due to substantially fast polymerization process, the compressive strength did not vary with the age of concrete. This observation is in contrast to the well known behavior of opc concrete, which undergoes hydration process and hence gains strength over time.

Earlier investigations have shown that the effect of age of mortar is not significant after 24 hours. In the present investigation, heating was done in oven at 60°c, 90°c, and 120°c for 24 hours.

## IV. RESULT

Table No. 3:- Compressive strength of geopolymer concrete of Water/ Binder ratio of 0.211 for oven curing at various temperature within 7 days

| Cube | Water / Cement-atious material ratio | ($Na_2SiO_3$ + NaOH) / Fly ash | Concentration of NaOH soln. (Moles) | Temp. ($^0$C) | Oven curing Time (Hrs) | Comp. Strength, (N/mm$^2$) |
|---|---|---|---|---|---|---|
| $C_1$ | 0.211 | 0.35 | 13.00 | 60 | 6 | 29.2 |
| $C_2$ | | | | 90 | | 31.21 |
| $C_3$ | | | | 120 | | 33.17 |

## V. CONCLUSION

As the curing temperature in the range of 60°C to 120°C increases, the compressive strength of fly ash-based geopolymer concrete also increases. Also it was seen that for Water/Binder ratio of 0.30 the results were promising. The slump value of the fresh fly-ash-based geopolymer concrete increases with the increase of extra water added to the mixture. Geopolymer concrete is economical compared to cement concrete.

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