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# Study on Corrosion Resistant In Geopolymer Concrete by Incorporating Various Admixtures

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***ABSTRACT***
*Cement is a material which has grown recently in years. Due to increase in the infrastructure projects the demand for concrete as a construction material has increased. Concrete is comprised of cement, aggregates, water and admixtures. Concrete is the most expended development material. It is viewed as progressively versatile, intense and reliable. Concrete is the second most expended material after water which requires bigger amounts of Portland concrete. The creation of the OPC makes dangers the earth because of emanation of $CO_2$ too mining additionally brings about unrecoverable loss of nature. By considering all these factors Geopolymer concrete was introduced. Geopolymer concrete may be a creative development material which is able to be delivered by the synthetic activity of inorganic atoms. Right now the fundamental impediment of fly debris based Geopolymer concrete are moderate setting of cement at encompassing temperature and the need of warmth relieving. All these factors are eliminated by addition of Ground Granulated Blast Furnace Slag (GGBFS) which shows considerable gain in strength. M30 grade of Geopolymer concrete specimens were heat cured for 24 hours at 90ºC. This paper was studied on mechanical properties by using cube and cylindrical specimen. The outcome of this study shows that Geopolymer solid blocks picks up quality inside 24 hours without water restoring at encompassing temperature. Additionally, the quality of Geopolymer concrete were surveyed which expanded in increment in level of GGBFS in a blend separately. It was seen that the Mix ID F60 invigorated most extreme compressive of 46.67 N/mm$^2$.*

***Keywords:*** *Geo polymer concrete, Fly ash, GGBS, Compressive strength, tensile strength*

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## I. INTRODUCTION

The enormous increase in population growth causes necessitates the huge infrastructure developments, which in turn raises the demand for concrete would be increase. The worldwide concrete consumption is estimated about 8.8 billion tons per year. The production of cement is associated with various environmental issues related to emission of greenhouse gases. During the assembly of 1 ton of cement, one ton of carbon-di-oxide is released to the atmosphere and rising the greenhouse effects within the global environment. The carbon dioxide contributes 65% of global warming. Further, when the cement concrete is exposed to the environment it get deteriorated and causing additional environmental problems.

Although the use of cement is still unavoidable, several efforts are in progress to supplement it in concrete in order to reduce the global warming issues. Geo-polymer concrete incorporating with supplementary cementing materials like Fly Ash can overcome the performance of cement concrete for their mechanical properties. Compared to Portland cement, Geopolymer is energy efficient and environment friendly. It has been established that the Fly Ash can be utilized effectively in low value application such as mine filling, embankment formation, structure fillings, manufacturing of PPC.

## II. LITERATURE REVIEW

SujayChetanNanavati [1], he investigates the concrete with various materials such as alkaline liquids, fly ash, aggregates and super-plasticizers. Substantial experimental research on the aspects such as mix design, curing etc. and their impact on properties of Geo-polymer concrete has been conducted, ever since on Geo-Polymer concrete which can prove to the sustainable construction material of the future and suggestions regarding the applications of Geo-polymer concrete are delineated at the end.

B.V Rangan [2], he proposed a study on fly ash-based geopolymer concrete, by identifying the effects of salient factors that influence the properties of the geopolymer concrete within the fresh and hardened states. He suggested a simple method for the look of geopolymer concrete mixtures by using the test results of assorted parameters considering short-term and long-term properties. In this paper, he illustrates the usage of the geopolymer concrete within the industry & the economic merits of the geopolymer concrete.

Davidovits [3], he verifies the results of geopolymer concrete by adding the proportion of alkaline liquid in materials such as fly ash and rice husk ash to produce binders. Because the chemical change that takes place during this case could be a polymerization process.

Francis N. Okoye [4], he analyzed, the effect of silica fume on durability properties of fly ash based geopolymer concrete by immersing the cubes in 2% sulphuric acid and 5% sodium chloride solutions. A control mix & M40 mix was casted for comparison. In specimens, chemical attack & its resistance was evaluated visually, by measuring change in the weights and percent losses in compressive strength at different intervals of time. Percent losses in compressive strengths in control specimen (M40), GPC3 in 2% $H_2SO_4$ and GPC3 in 5% NaCl at 90 d were found. He concludes that thus the resistance of concrete incorporating silica fume in sulphuric acid and chloride solution was significantly higher than that of the control.

## III. MATERIALS & ITS PROPERTIES

### A. Materials

### 3.1. Fly Ash

Geopolymer concrete can be manufactured by using the calcium (Class F) Fly Ash obtained from coal based thermal power plants. Fly Ash based Geopolymer is used as binder, instead of Portland or other hydraulic cement paste, to produce concrete. It develops bonding between aggregates and materials forming Geopolymer concrete, with or without the presence of admixtures. The properties and composition vary widely, not only between different plants but from hour in the same plant Fly Ash obtaining from cyclonic separators Fly Ash obtained from electro static precipitator. The principal constitutes are normally silicon dioxide, sulphur trioxide. Chemical composition and physical properties of Fly Ash is given in Table 1&2.

**Table 3.1 Chemical composition of Fly Ash**

| Content | Percentage |
|---|---|
| $SiO_2$ | 55.36 |
| $Al_2O_3$ | 26.49 |
| $Fe_2O_3$ | 10.86 |
| CaO | 1.34 |
| $Na_2O$ | 0.37 |
| $K_2O$ | 0.8 |
| $TiO_3$ | 1.47 |
| MgO | 0.77 |
| $P_2O_5$ | 1.43 |
| $SO_3$ | 0.2 |

**Table 3.2 Physical Properties of Fly Ash**

| Property | Content |
|---|---|
| Colour | Differs for various plants |
| Particle Size & Fineness | Passes 40micron sieve |
| Specific Gravity | 2.4 - 2.8 |

### 3.3. Silica Fume

Silica fume, additionally referred to as micro silica, is associate amorphous (non-crystalline) organism of Silicon-di-Oxide and silicon dioxide. it's associate ultrafine powder collected as a by-product of the semiconducting material and Ferro-Silicon alloy production and consists of spherical particles with a mean particle diameter of 150 nm. However, the production process, particle characteristics and fields of application of Silica Fume are all different from those of Fumed Silica. Silica fume is a fume may be a by-product within the carbothermic reduction of high-purity quartz with chemical element materials like coal, coke, wood-chips, in arc furnaces within the production of semiconducting material and ferrosilicon alloys. The chemical composition of Silica Fume is presented in Table 3.

**Table 3.3Chemical composition of Silica Fume**

| Items | Range |
|---|---|
| Fineness | 312 $m^2$/kg |
| Soundness | 1.0 mm |
| Initial Setting time | 260 |
| Insoluble residues | 0.51 % mass |
| Magnesia content | 9.47 % mass |
| Sulphide sulphur | 0.63 % mass |
| Sulphide content | 0.23 % mass |

**3.4. Ground Granulated blast-furnace slag (GGBFS)**

GGBFS is obtained by extinction liquefied iron slag (a by-product of iron and steel-making) from a furnace in water or steam, to supply a glassy, granular product that's then dried and ground into a fine powder.

**Table 3.4 Physical properties of GGBFS**

| Component | Bituminous |
|---|---|
| $SO_2$ | 95 |
| $SO_3$ | 13.5 |
| CL | 1.8 |
| Total Alkali | 39.2 |

**3.4. Aggregates**

Conventional Coarse and Fine aggregates, which are used by the concrete industry, are suitable to manufacture Geo-polymer concrete and also an aggregate grading curve which is currently used in concrete practice are also applicable.

**3.5. Alkaline liquid**

The most widely recognized basic fluid utilized in Geopolymerization is a blend of Sodium Hydroxide or Potassium Hydroxide and Sodium Silicate or Potassium Silicate. The Silicon and Aluminum in the low calcium (ASTM class F) Fly Ash respond with a soluble fluid, which is a blend of sodium silicate and sodium hydroxide arrangements, to shape the Geo-polymer glue that predicament the total and the other unreacted materials. The sodium hydroxide with 97-98% virtue in pellet structure is industrially accessible were broken down in water to make an answer with wanted focus. Table 5 gives the physical and chemical properties of Sodium Hydroxide pellets.

**Table 3.5  Physical and chemical Properties of Sodium Hydroxide**

| Items | Range |
|---|---|
| Appearance | Clear to overcast,Thick fluid |

| | |
|---|---|
| Odour | Odourless |
| Solubility | Fully (100%) |
| Specific gravity | 1.3-1.5 |
| pH | 11-12.5 |
| Boiling point | $102^0$C ($216^0$F) |
| Vapor pressure (mm Hg) | 18@ $20^0$C ($68^0$F) |

**Table 3.6 Physical and chemical properties of Sodium Silicate**

| **Items** | **Range** |
|---|---|
| Molecular weight | 40.00 |
| Absolute density, g/cm$^3$ | 2.13 |
| Melting point, C° | 318.4 |
| Boling point, C° | 1390 |
| Solubility in water, g/100g water | 42 at 0 C° |

**B. Mixing & Curing**

The solids constituents of the Fly Ash based Geopolymer concrete, for example the totals and the Fly Ash, were blended in dry state for around three minutes. The fluid piece of the blend, i.e., the Sodium Silicate arrangement the Sodium Hydroxide arrangement, included water (assuming any), and the super plasticizers (assuming any) were pre-blended and afterward added to the solids and blended at wet state for an additional four minutes. The resultant blends were normally durable. Relieving process will be done in various manners, for example dry restoring in the lab, stove or steam relieving in a chamber and encompassing relieving.

## IV. EXPERIMENTAL INVESTIGATION

**A. Preparation of specimens**

**4.1. Cube**

Cube moulds of size 150x150x150 mm were used. Completely utilizing a waste material and afterward appropriately oiled along its countenances. Concrete was then filled in form and afterward compacted utilizing a standard size of 60 cm length having a cross sectional territory of 25 mm$^2$.

**4.2. Cylinder**

Cylinder moulds of width 150mm and length 300mm were casted. The unrefined petroleum was applied as observed before along the inner surfaces of the mould for the easy removal of casted cylinder from the mould. Concrete was poured all through its length and compacted well.

**B. Mix proportion**

Fly Ash (Class F) was used in geopolymer concrete and fine aggregate was conforming zone III as per IS code 383-1970. Coarse aggregate passes through 20mm and retained through 10mm sieve and mix ratio of concrete is given below in Table 7. Table 8 gives the Mix ID used in this study for showing the variation of admixtures in the mix.

**Table 4.1 Mix Proportion**

| Sodium silicate ($kg/m^3$) | NaOH solution ($kg/m^3$) | Extra water ($kg/m^3$) | Fly ash ($kg/m^3$) | F.A ($kg/m^3$) | C.A ($kg/m^3$) |
|---|---|---|---|---|---|
| 239.64 | 95.86 | 11 | 550 | 600 | 838.3 |
| 0.61 | | 0.03 | 1 | 1.04 | 1.56 |

**Table 4.2Mix ID**

| Mix id | Fly Ash (%) | GGBS (%) | Silica Fume (%) |
|---|---|---|---|
| F100 | 100 | - | 2.5 |
| F80 | 80 | 20 | 2.5 |
| F70 | 70 | 30 | 2.5 |
| F60 | 60 | 40 | 2.5 |

**C. Testing of specimens**

In this, M30 grade of Geo-polymer concrete specimens were involved under compression and tension. Cubes and cylinders of Geo-polymer concrete are tested in hydraulic compression testing machine in accordance with Indian Standards. Specimens of cubes of size 150×150×150 mm and cylinders of size 150mm ×300 mm are used for determining the compressive strength and split tensile strength.

Compressive strength - depends on many factors such as nature of solid material, quality control during creation of cement and so on. Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test.

Split Tensile strength test - the tensile strength of concrete is one of the fundamental and significant properties. The Splitting tensile strength test on concrete cylinder is meant to decide the elasticity of concrete. The concrete is frail in pressure because of its weak nature and isn't required to oppose the immediate strain. The concrete creates cracks when tensile load is applied. Accordingly, it is important to decide the tensile strength of concrete.

A. Compressive strength

Compressive strength for normal concrete is found to be 20.4 $N/mm^2$. On the other hand, for Silica fume mixed Geo polymer concrete the compressive strength was to be found varied depending on the replacement of GGBFS in ratios of 20%, 30% & 40%. The compressive strength of the Geo polymer concrete demonstrated higher quality than comparing control concrete (F100). The greatest rate increment in quality is seen as 40.92% at F60. The significant perception is that the expansion of slag didn't influence the compressive strength of concrete yet expanded the compressive strength of Geopolymer concrete.

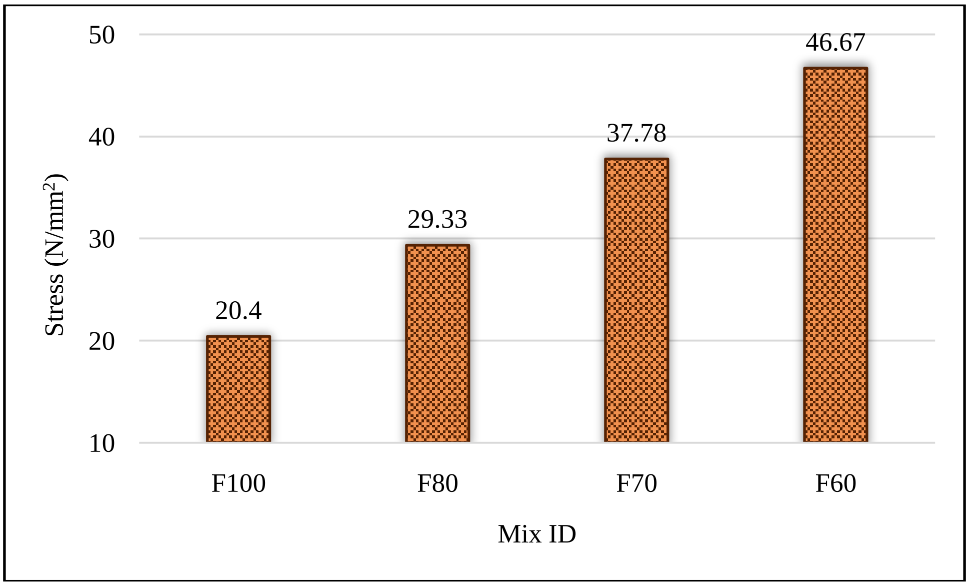


**Figure4.1 Compressive Strength of Specimens**

B. Split Tensile strength test

Here the ideal value is at 40% when GGBS is replaced with Binder. When GGBS replaced with Binder, the GGBS admixed Geopolymer concrete demonstrated higher split tensile strength esteems than relating F100. The rate increment in quality was seen as 11.2% at 40% substitution of GGBS. Subsequently, it was seen that the expansion of GGBS can influence the split tensile strength of concrete yet expanded the split tensile strength of admixed concrete up to 40% of GGBS.

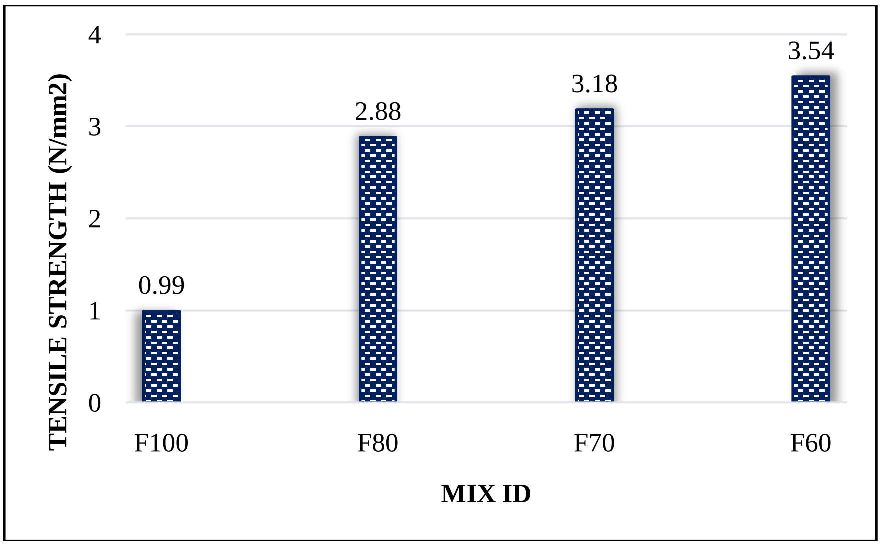


**Figure4.2 Split Tensile Strength of specimens**

C. Galvano static weight loss method (ASTM G1-03)

The least complex, and longest-settled, technique for estimating corrosion losses in plant and equipment is weight reduction examination. A gauged test (coupon) of the metal or combination viable is brought into the procedure, and later evacuated after a sensible time interim. The coupon is then cleaned of all consumption item and is rechecked.

**Table 4.2 Results for weight loss method**

| Mix id | Initial weight (gm) | Final weight (gm) | Average loss in weight (gm) | Corrosion resistant (mm/year) |
|---|---|---|---|---|
| F100 | 256 | 254 | 2 | 0.4113 |
| F80 | 256 | 255 | 1 | 0.205 |
| F70 | 256 | 255 | 1 | 0.205 |
| F60 | 256 | 255 | 1 | 0.205 |

D. Open circuit potential method

Corrosion of reinforcing steel is an electro-chemical process and the conduct of the steel can be described by estimating its open circuit potential. The more prominent the potential, higher the hazard that corrosion is occurring. An electrode forms one portion of the cell and the strengthening steel in the solid the other. Open circuit potential relates to a consistent state, in term of electrical flow, between metal (iron of steels) disintegration and the related decrease response, which prompts the development of particles hydroxyls (OH- from oxygen gas).It ought to be noticed that a flow is traded between disintegration zones and those of oxygen decrease. These zones can be various if metal has a huge contact zone with its encompassing medium.

Cylindrical reinforced Geo-polymer concrete specimens of size 150mm dia and 300 mm height were cast in triplicate with and without GGBFS. All the triplicate examples were taken out, and afterward dried. The capability of the inserted rebar was estimated against soaked calomel cathode (SCE) utilizing a high impedance volt meter before keeping the examples in 5%NaCl arrangements. . The potential readings were estimated occasionally.

**Table 4.3 Results of Open circuit potential test in mV**

| DAYS | F100 | F80 | F70 | F60 |
|---|---|---|---|---|
| 1 | -307 | -152 | -132 | -319 |
| 3 | -325 | -168 | -154 | -345 |
| 7 | -315 | -221 | -295 | -325 |
| 9 | -125 | -95 | -145 | -110 |
| 11 | -291 | -278 | -195 | -310 |
| 13 | -191 | -271 | -166 | -236 |
| 15 | -220 | -312 | -145 | -159 |
| 17 | -168 | -135 | -95 | -133 |
| 20 | -136 | -134 | -139 | -130 |

## V. CONCLUSION

In view of restricted test examination concerning the compressive and rigidity of cement the perceptions were made.

1. The mechanical properties of the Geopolymer concrete increases within 24 hours by curing at ambient temperature without water.
2. The need of warmth restoring of concrete was disposed of by consolidating GGBS and fly ash in a concrete mix.
3. Compressive strength of Geopolymer concrete was increased up to maximum of 15% and split tensile strength was also increased by 5% by addition of admixtures in concrete.
4. When percentage of GGBS is increasing, compressive and split tensile strength was found to be increasing gradually.
5. At long last, it was seen that the blend extents F60 invigorated most extreme compressive of 46.67 $N/mm^2$.
6. Accelerated corrosion test (weight loss method) reveals that the corrosion rate of uncoated rebar is somewhat lower. When the rebar is covered with zinc phosphate paint the corrosion rate was getting zero.
7. In Open circuit potential test, it was discovered that all the frameworks are demonstrating increasingly negative possibilities that - 270Mv versus Saturated calomel cathode (SCE) sign the dynamic state of the rebar. Yet, following 15 days SCE demonstrating the slight uninvolved state of rebar.

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