Experimental Study on Strength Characteristics of Geopolymer Concrete Using Silica Fume

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Abstract— **The increases in the manufacturing of Portland cement several causes greater concern because of high carbon substance. This investigation focuses on entire removal of Portland cement for manufacturing of concrete. Geo-polymer concrete utilize an swap material as well as fly ash as binding material in position of cement. This fly ash react with alkaline solution (e.g. NaOH) and Sodium silicate (Na2SiO3) to shape a gel which binds the fine and coarse aggregates. fly ash as a supporting resource material and silica fume as replacements of fly ash by 5%, 10%, 15%, 20%. Concrete cubes of 150 X 150 X 150 mm were primed and cured under steam curing for 24 hours. Concrete cylinders of size 150 X 150 X 300mm and Concrete beams of size of 100 X100 X500 mm were also steam cured at 60°C. The silica fume was varied in fraction and outcome were compared with ordinary Geo-polymer concrete. And the respective strength get achieved.**

Index Terms— **Geo polymer, Fly ash, Silica fume, alkaline solution**

I. INTRODUCTION

Concrete usage around the world is second to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calculation of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete.

When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass, is a significant development. In 1988,Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash, rice husk ash. He termed these binders as geopolymer.

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In geopolymer, polymerization is a condensation polymerization in which water is released during chemical reaction and nature of reaction is endothermic. In geopolymerization, the polycondensation of alumino-silicate oxides (Si2O5, Al2O2) with alkali polysilicates (Sodium or Potassium silicate) takes place producing Si–O–Al bonds.

- Dissolution of Si and Al atoms from the source material through the action of hydroxide ions.
- Transportation or orientation or condensation of precursor ions into monomers.
- Setting or polycondensation/polymerization of monomers into polymeric structures.

II. PREVIOUS RESEARCH WORK

Several researches on strength characteristics of Geo Polymer concrete using silica fume have been studied and discussed in this paper.

Bakharev, 2005 Gourley & Johnson, 2005Song et, al., 2005 also reported the results of the tests on acid resistance of geoploymers and geopolymer concrete. By observing the weight loss after acid exposure, these researchrs concluded that geopolymers or geoploymenr concrete is superior to Portland cement concrete in terms of acid resistance as the weight loss is much lower. However, Bakharev and Song et. Al has also observed that there is degradation in the compressive strength of test specimens after acid exposure and the rate of degradation depended on the period of exposure. Test conducted by U.S. Army Corps of Engineers also revealed that geopolymers have superior resistance to chemical attack and freeze/thaw, and very low shrinkage coefficients.

Palomo et al (2004) reported the manufacture of fly ash-based geopolymer concrete railway sleepers. They found that the geopolymer concrete structural members could easily be produced using the existing current concrete technology without any significant changes. The engineering performances of the products were excellent, and the drying shrinkage was small.

Balaguru et al (1997) reported the result of the investigation on using geopolymers, instead of organic polymers, for fastening carbon fabrics to surfaces of reinforced concrete beams. It was found that geopolymer provided excellent adhesion to both concrete surface and in the interlaminar of fabrics. In addition, the researchers observed that geopolymer was fire resistant, did not degrade under UV light, and was chemically compatible with concrete.

Davidovits (1994) reported that the Geopolymer cement is also acid-resistant because unlike the Portland cement, geopolymer cements do not rely on lime and are not dissolved by acidic solutions. As shown by the tests of exposing the specimens in 5% of sulfuric acid and hydrochloric acid geopolymer cements were relatively stable with the weight lose in the range of 5-8% while the Portland based cements were destroyed and the calcium alumina cement lost weight about 30-60%.

Davidovits (1988), reported that geoplymer materials have a wide range of industries such as in the automobile and aerospeace, nonferrous foundries and metallurgy, civil engineering andplastic industries. The type of application of geopolymer materials is determined by the chemical structure in terms of the atomic ratio Si: Al in the polysialate.

III. METHODOLOGY

A. MATERIAL SELECTION

Materials used in this study were chosen according to the specification that meets the requirement. FA was obtained from Chennai Chemical composition of FA and SF is shown in Table 3.1.

SF was obtained with bulk density of 500-700 Kg/m^3.

Coarse aggregate used in this experiment is crushed and maximum size of 20 mm (BS 812-103.2 1989) while the fine aggregate used is natural Malaysian sand with the fineness modulus of 2.7, classified in zone 3. Fine aggregate was also sieved for the size less than 5mm.

Sodium silicate (Grade A53) used in a solution form mixed with 56.31% of water, 29.43% of SiO2 and 14.26% of Na2O. Sodium hydroxide used was in the form of pellets. Concentration of solution was 8M and in order to make 1 Kg of solution, 29.4% of pellets were added to the water.

TABLE 3.1

CHEMICAL COMPOSITION OF FA & SF

Compounds	FA (%)	SF (%)
SiO_2	51.19	99.860
Al_2O_3	24	0.043
Fe_2O_3	6.6	0.040
CaO	5.57	0.001
MgO	2.40	0.000
SO_3	0.88	0.015
K_2O	1.14	0.001
Na_2O	2.12	0.003

The preliminary test of materials are specific gravity of cement, fine aggregate, coarse aggregate, fly ash, and manufactured sand. Fineness of cement and sieve analysis for sand. All the preliminary tests have been conducted and results are tabulated in table 3.2.

TABLE 3.2

RESULTS OF PRELIMINARY TEST

S.NO	MATERIALS	PROPERTIES	RESULTS
1	Cement	Specific gravity Fineness	3.15 98.03%
2	Fly ash	Specific gravity	2.45
3	Fine aggregate	Specific gravity Sieve analysis Fineness modulus	2.66 Zone II 2.708
4	Coarse aggregate	Specific gravity Fineness modulus	2.77 2.1

The mix design is in accordance with Indian mix design method. A sample of mix design was shown that the aggregates occupy the largest volume, (about 75-80% by mass) in GPCs. The silicon and the aluminum in the fly ash are activated by a combination of sodium hydroxide and sodium silicate.

Table 3.3

MIX PROPORTION VALUE

CONSTITUENTS	DENSITY (kg/mm^3)
Coarse aggregate	1294
Fine aggregate	554
Fly-ash	408
Sodium silicate	103
Sodium hydroxide	41
Super plasticizer	6.12

Table 3.4

MIX PROPORTION OF GPC WITH SILICA FUME

FA (Kg/m^3)	**SF (%)**	**SF (Kg/m^3)**	**Coarse Agg. (Kg/m^3)**	**Fine Agg. (Kg/m^3)**	**NaOH (Kg/m^3)**	**Na-Silicate (Kg/m^3)**
408	0	0	1294	554	41	103
387.6	5	20.4	1294	554	41	103
367.2	10	40.8	1294	554	41	103
346.8	15	61.2	1294	554	41	103
326.4	20	81.6	1294	554	41	103

IV. RESULTS & DISCUSSIONS

Compressive strength test results shows that In external exposure curing 20% replacement of SF shows the highest value i.e. 44.5 MPa at 28th day because greater temperature made it possible for Si and Al to dissolute in greater amount; resulting in greater strength. Incorporation of SF in the polymeric concrete and the different curing regimes had a significant influence on the compressive strength development. And results Of Compressive strength test results of fly ash-based polymeric concrete replaced by SF.

COMPRESSIVE STRENGTH OF GEO-POLYMER CONCRETE WITH SILICA FUME

Fig 4.1

Table 4.1

MIX	CUBE STRENGTH (N/mm^2)	
	7days	28days
GPC1	24	34.6
GPC2	25.3	35.4
GPC3	27.2	38.8
GPC4	29.4	42.2
GPC5	31.5	44.5

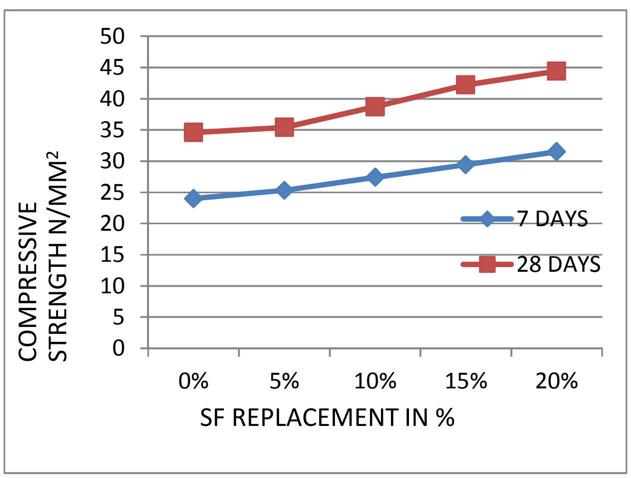

Fig 4.2

TENSILE STRENGTH OF GEO-POLYMER CONCRETE WITH SILICA FUME

Fig 4.3

Table 4.2

MIX	TENSILE STRENGTH (N/mm^2)	
	7days	28days
GPC1	1.40	2.40
GPC2	1.51	2.56
GPC3	1.66	2.81
GPC4	1.76	2.94
GPC5	1.90	3.07

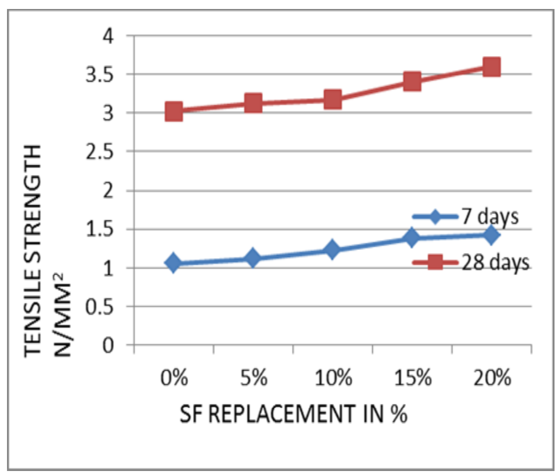

Fig 4.4

FLEXURAL STRENGTH OF GEO-POLYMER CONCRETE WITH SILICA FUME

Concrete specimen for flexural strength has cross sectional area of 100mm width with 100mm depth and length of 500mm concrete beam was casted and oven dried for 24hours at 60°c and compressive strength for 7 and 28 days were tested. Results are tabulated below in table 3.3.

Fig 4.5

Table 4.3

FLEXURAL STRENGTH OF GEO-POLYMER CONCRETE WITH SILICA FUME

MIX	FLEXTURAL STRENGTH (N/mm^2)	
	7days	28days
GPC1	1.06	3.025
GPC2	1.12	3.12
GPC3	1.23	3.17
GPC4	1.38	3.40
GPC5	1.42	3.6

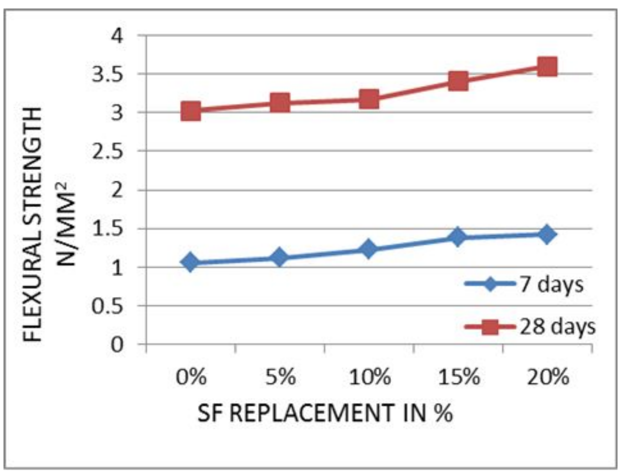

Fig 4.6

CONCLUSION

Based on the experimental investigation the following conclusions are listed below:

The test results of compressive strength shows that there is 9% increase in strength when silica fume is replaced up to 20 %.

The test results of tensile strength shows that there is 12% increase in strength when silica fume is replaced up to 20 %.

The test results of flexural strength shows that there is 10% increase in strength when silica fume is replaced up to 20 %.

REFERENCES

[1] M.F. Nuruddin, Sobia Qazi, N.Shafiq, A. Kusbiantoro,“ Compressive Strength &

[2] Microstructure of Polymeric Concrete Incorporating Fly Ash & Silica Fume”, Canadian Journal on Civil Engineering Vol. 1, No. 1, February 2010.

[3] Debabrata Dutta, Suresh Thokcham, Partha Ghosh and Somnath Ghosh.,(2010), “Effect of silica fume additions on porosity of fly ash geopolymer”, ARPN Journal of Engineering and Applied Sciences VOL. 5, NO. 10, OCTOBER 2010

[4] M. I. Abdul Aleem, P. D. Arumairaj, “GEOPOLYMER CONCRETE-A REVIEW”, International Journal of Engineering Sciences & Emerging Technologies, Feb 2012. ISSN: 2231 – 6604 Volume 1, Issue 2.

[5] Djwantoro Hardjito, Steenie E. Wallah, Dody M.J. Sumajouw, and B.V. Rangan. “FACTORS INFLUENCING THE COMPRESSIVE STRENGTH OF

[6] FLY ASH-BASED GEOPOLYMER CONCRETE” Civil Engineering Dimension, Vol. 6, No. 2, 88–93, September 2004 .

[7] Raijiwala D.B, Patil H, “GEOPOLYMER CONCRETE: A CONCRETE OF NEXT DECADE” Journal of Engineering Research and Studies.

[8] Djwantoro Hardjito, Steenie E. Wallah, Dody M. J. Sumajouw, and B.Vijaya Rangan, “On the Development of Fly Ash-Based Geopolymer Concrete”, ACI materials journal technical paper aci materials journal technical paper.