Study on Strength Characteristics of Eco-Friendly Geopolymer Concrete Blended with Silica Fume

P R Kishore[1], B J Sushma[2], A S Kumar[3]

[1]*Assistant Professor & HOD, Civil Engineering Department, Aditya Engineering College, Surampalem, A.P, India*
[2]*Assistant Professor, Civil Engineering Department, Aditya College of Engineering, Surampalem, A.P, India*
[3]*Assistant Professor Civil Engineering Department, Aditya Engineering College, Surampalem, A.P, India*

---***---

Abstract - *For the preparation of concrete, the material used for binding are ordinary Portland cement (OPC). The production of OPC emits air pollutants like CO2 results in environmental pollution. Geopolymer Concrete (GPCs) is one of the types of concrete which can be prepared by mixing geopolymer paste with the aggregates. The geopolymer paste can be formed by polymeric reaction of alkaline liquids with the Silicon (Si) and Aluminum (Al) presents in by–product materials such as fly ash (FA), silica fume, metakaolin, etc. The advantages over geopolymer concrete includes the elimination of water curing, good mechanical and durability properties, eco-friendly and alternative to OPC based concrete. The investigation of the compressive strength and split tensile strength of the Geopolymer concrete produced by replacement of FA with SF (Silica fume) 0%, 5%, 10% and 15% by mass of FA with 8molar NaOH solution is carried out in the study. In this study sodium hydroxide (NaOH) and sodium silicate (Na2Sio2) is used as alkaline liquid for geopolymerisation process. The test on compressive strength and split tensile strength is carried out at the ages of 7 and 28 days under sun heat after curing of specimen in oven for 24 hours at a curing temperature of 90°c and 150°c.*

Key Words: Geopolymer, Concrete, fly ash, silica fume, Sodium Silicate, Sodium hydroxide.

1. INTRODUCTION

Concrete plays a major role in the human life. It has become in such a way that the usage of concrete become second only to water around the world. The preparation of concrete constitutes the OPC as binding materials. The production of OPC emits the CO2, results in environmental pollution and considered as 7% of the world carbon dioxide is attributable to cement industry only. Due to the environmental pollution and usage of natural resources like limestone, the production of cement should be reduced. It is said that one ton of CO2 releases for every ton of OPC manufactured, so the utilisation of cement must be reduced.

The utilisation of concrete for constructing the various shapes is increasing day by day. As the production of eco-friendly concrete overcome this problem by replacing the cement with the by-product of industry as fly ash, silica fume, slag, etc. The increasing production of fly ash creates a lot of problem in disposal and also provides opportunity to utilise as a substitute for OPC to prepare concrete. As only 5% of the fly ash is used in the construction industry for the manufacture of brick and concrete and rest of fly ash is used for land filling.

The alternative utilisation of silica fume in construction industry has been emerged in geopolymer concrete in recent years. The geopolymer technology utilise all grade of silica fume which reduce the stock of waste silica fume materials. The present study considered silica fume utilisation in production of geopolymer concrete. Geopolymer technology was first coined by Davidovits in 1970s to name the three dimensional alumino-silicates structures, which is a binder produced form the reaction of source materials rich in silicon (Si) and aluminium (Al) with an alkaline liquid. The source materials rich in silicon (Si) and aluminium (Al) may be the industrial by product as fly ash, silica fume, slag, etc. and the alkaline liquid used are sodium hydroxide and sodium silicates. The alkaline liquid is mainly used to dissolve the Si and Al atom and helps in the formation of geopolymer paste as binder which binds the loose coarse and fine aggregates for the preparation of geopolymer concrete.

2. MATERIALS AND METHODS

2.1 Fly Ash (FA)

In this study Class F fly ash were used. The fly ash meets the ASTM C618: Class F fly ash specifications. Some of the ASTM characteristics specifications are:

- High fineness, good particle size distribution
- The product has low energy consumption and high production efficiency.

2.2 Silica Fume (SF)

The silica fume meets the ASTM C 1240-93 specifications. There are some characteristics for the SF such as materials characteristics that confirm to the requirement of ASTM C1240, which involve physical and chemical requirements.

2.3 Fine Aggregates

In the present study locally available fine aggregates are used. The BS812, (1984) [5] describes the method for the size distribution of samples of aggregates by sieve analysis. The sample used for the test is taken in accordance with the procedure describe in clause 5 of BS812: part 102 :(1984)

[5]. The samples of aggregates must be washed before the test to remove other materials such as clay and dirt and keep oven dried and then sieve analysis was done.

2.4 Coarse Aggregates

In the present study the locally available coarse aggregates are used. The ASTM C33 [4] recruitments for coarse aggregate demands to use sizes between 5 and 20 mm and for this investigation three types of 6.3, 12.5 and 20mm were chosen for the suitable of manufacture of geopolymer concrete.

2.5 Sodium Silicate Solution

The sodium silicate solution is found in different grades in market. The chemical composition of the sodium silicate solution was Na_2O=14.7%, SiO_2=29.4%, and water 55.9% by mass and the ratio of SiO_2-to-Na_2O by mass is taken as approximately 2.

2.6 Sodium Hydroxide

The sodium hydroxide solids are taken in pellets form with 97% purity. The solution was prepared by dissolving pellets in distilled water. The sodium hydroxide solution can be used in the range between 8Molar to 16Molar.

3. TEST CONDUCTED

3.1 Sieve analysis test of fine aggregates

Table 1: Sieve Analysis of fine aggregates

Sieve Size (mm)	Weight Of Sieve(gm)	Weight Of Sieve + Sand Retained(gm)	Weight Of Sand Retained(gm)	∑ Retained %	Pass %
10.0	420.9	420.9	0	0	100
05.0	403	410.5	7.5	1.5	98.5
2.36	423.4	461.4	38	9.1	90.9
1.18	355.2	441.6	86.4	26.38	73.62
0.60	305.2	443	137.8	53.94	46.06
0.30	275.2	393.5	118.3	77.6	22.4
0.15	261.1	335.1	74	92.4	7.6
Pan	264.4	302.4	38	100	0
			∑=500		

4 MIXING

4.1 Alkaline Liquid

In this study, the alkaline liquid used is sodium silicate solution and sodium hydroxide (NaOH) solution. These solutions were prepared one day before the casting of cubes and cylinder because for a better chemical reaction between them and in order to obtain a better binding nature.

4.2 Mix proportion

The mix design is for 1:1.5:3. The ratio of alkaline liquid to fly ash is fixed to 0.35 and sodium silicate solution to the sodium hydroxide ratio is 2.5. The aggregate is taken as 77% mass of the concrete.

Table 2: Mix Proportions

Materials		*(kg/m3)*	*In Cube*	*In cylinder*
Coarse aggregates	20mm	277	0.935	1.47
	12.5mm	370	1.249	1.96
	6.3mm	647	2.184	3.43
Fine sand		554	1.87	2.94
Fly ash, Silica fume		408	1.377	2.16
Sodium silicate solution (SiO2/Na2O=2)		103	0.348	0.55
Sodium hydroxide solution		41 (8 Molar)	0.138	0.22
Extra water		None	-	-

5. RESULTS AND VALUATION

5.1 Compressive Strength test

The size of 150mmx150mmx150mm cube at the age of 7days and 28days was tested to determine the resistance of concrete under sun heat curing after curing of specimen in oven for 24 hours at a curing temperature of 90°c and 150°c.

Table 3: compressive strength cured at 90°c and 150°c

Materials %		*Compressive strength(MPa) cured at*			
Fly ash	Silica fume	90°c		150°c	
		7d	28d	7d	28d
100	0	9.91	17.29	10.32	16.56
95	5	10.18	18.25	10.46	16.68
90	10	12.09	20.4	11.28	21.27
85	15	9.66	16.20	13.29	23.02

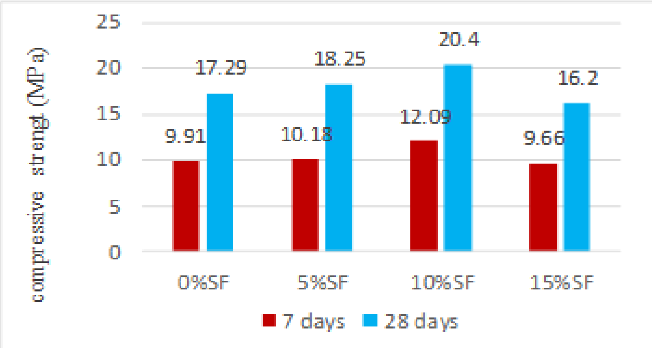

Fig.1 Graph showing compressive Strength (MPa) cured at 90^{0}c in oven

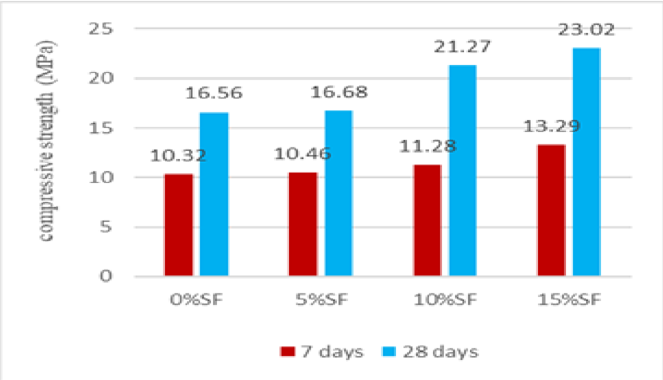

Fig.2 Graph showing compressive strength (MPa) cured at 150⁰c in oven

5.2 Split tensile strength test

The size of 150mmx300mm cylinder at the age of 7days and 28days was tested to determine the resistance of concrete under sun heat curing after curing of specimen in oven for 24 hours at a curing temperature of 90°c and 150°c.

$$\text{Split tensile Strength} = \frac{2\times P}{\pi\times D\times L}$$

Table 4: Split tensile strength cured at 90°c and150°c

Materials %		Split tensile strength(MPa) cured at			
Fly ash	Silica fume	90°c		150°c	
		7d	28d	7d	28d
100	0	1.11	1.61	1.63	2.81
95	5	1.29	1.95	1.83	2.74
90	10	1.57	2.31	1.94	3.80
85	15	1.67	2.47	1.95	3.69

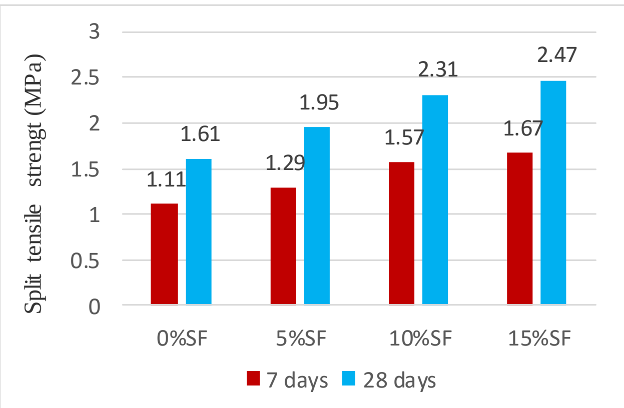

Fig.3 Graph showing Split tensile Strength (MPa) cured at 90⁰c in oven

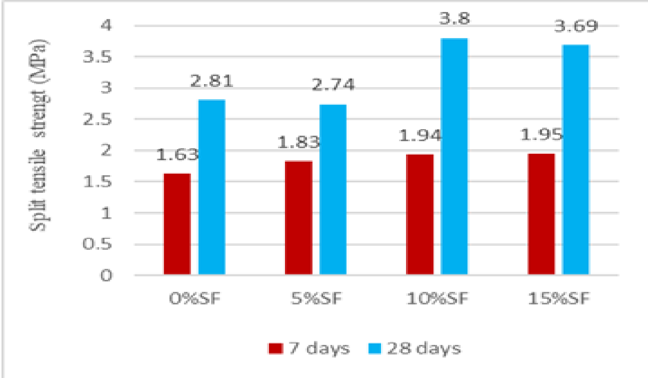

Fig.4 Graph showing Split tensile Strength (MPa) cured at 150⁰c in oven.

5.3 Density

The density of concrete mainly depends upon the unit of mass of aggregates used in the mixtures. The unit of density is kg/m³. The density of cube and cylinder cured in sun heat after curing of specimen in oven for 24 hours at a curing temperature of 90°c and 150°c.

Table 5: Density of cubes cured at 90°c and150°c

Materials %		*Density(kg/m3)of cubes cured at*			
Fly ash	Silica fume	90°c		150°c	
		7d	28d	7d	28d
100	0	2151	2183	2277	2337
95	5	2194	2256	2284	2342
90	10	2255	2296	2309	2415
85	15	2221	2245	2320	2452

Table 6: Density of cylinders cured at 90°c and150°c

Materials %		*Density(kg/m3)of cylinders curedat*			
Fly ash	Silica fume	90°c		150°c	
		7d	28d	7d	28d
100	0	2218	2256	2256	2326
95	5	2234	2305	2276	2347
90	10	2324	2380	2350	2461
85	15	2341	2448	2379	2580

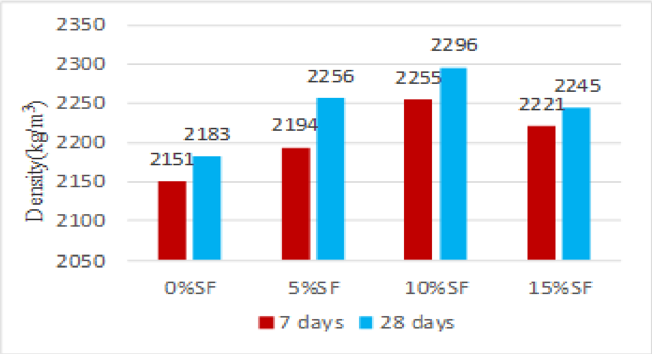

Fig.5 Graph showing density of cubes cured at 90^0c in oven

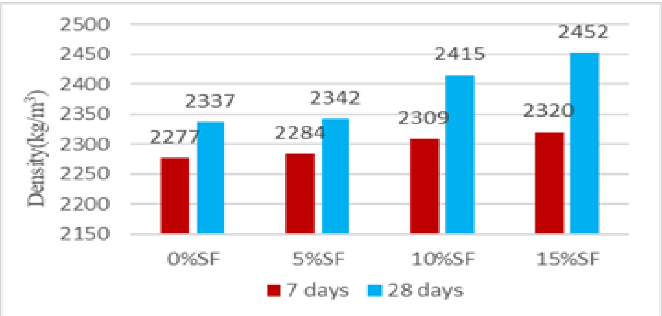

Fig.6 Graph showing density of cubes cured at 150^0c in oven

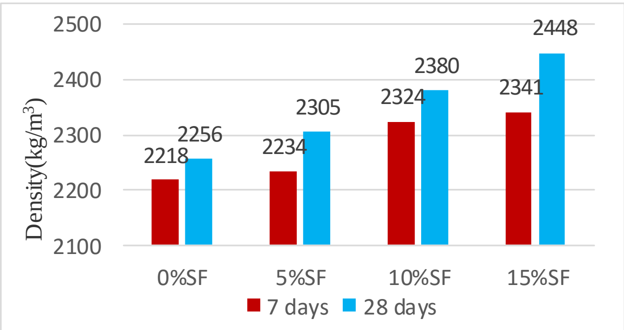

Fig.7 Graph showing density of cylinders cured at 90^0c in oven

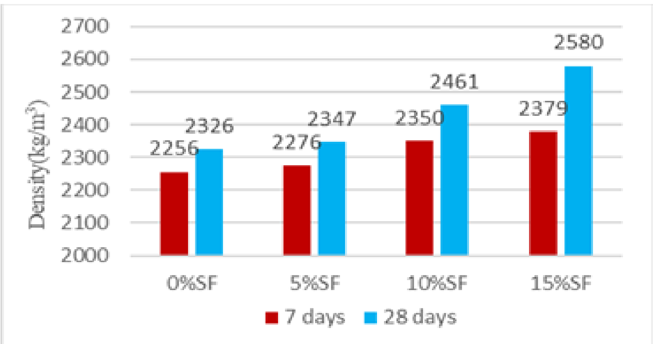

Fig.8 Graph showing density of cylinders cured at 150^0c in oven

6. CONCLUSION

The investigation performed on mechanical properties of geopolymer concrete can be concluded as

[1] Strength of the fly ash based geopolymer concrete increases with increase in curing temperature for a constant curing period.

[2] Optimal usage of silica fume reinforces the concrete in both compressive strength and Split tensile strength.

[3] The strength properties of geopolymer concrete mixes were studied by influencing silica fume. It has been concluded that the increasing quantity of silica fume up to 10% of fly ash increases the compressive strength of geopolymer concrete at a curing temperature of 90^0C and 150^0C.

[4] It has also been observed that the increasing quantity of silica fume increases the split tensile strength of geopolymer concrete at a curing temperature of 90^0C and 150^0C.

[5] The average density of fly ash-based geopolymer concrete is similar to that of OPC concrete.

[6] The geopolymer concrete mix can be produce easily with the equipment similar to those equipment used for preparation of conventional cement concretes.

[7] The geopolymer concrete utilize the industrial waste for preparation of binder in concrete. Thus, consumption can be increased and having both environment and economic benefits of using fly ash and silica fume.

REFERENCES

[1] American Society for Testing & Materials (2001) Specification for Coal Fly Ash and Raw or Calcinated Natural Pozzolan for Use as a Mineral Admixture in concrete. Philadelphia, USA: 4

[2] H.S. Wong, H. Abdul Razak, ―Efficiency of calcined kaolin and silica fume as cement replacement material for strength performance,‖ Cement and Concrete Research ,vol. 35,pp.696– 702, (2005). Terence C. Holland ―Silica user‘s manual‖, report no. FHWA- 1F-05. (2005).

[3] Amarendranath Deshini, Fineness of Densified micro silica and Dispersion in Concrete Mixes‖ Concrete-General, ODOT Item 499.03(2006).

[4] ASTM C 33 Aggregates are classified (fine or course) Annual Book of ASTM Standards: Concrete and Aggregates. 04.02 Philadelphia: American Society for Testing and Materials.

[5] BS 812: Part 102: (1984): Methods for sampling Testing Aggregates.

[6] BS 1881: Part 102: (1983) Method of normal curing of test specimens (20o C method).

[7] G. Prokopski , B. Langier, ―Effect of water/cement ratio and silica fume addition on the fracture toughness and morphology of fractured surfaces of gravel concretes‖, Cement and Concrete Research, vol. 30 pp. 1427± 1433 (2000).

[8] Malhotra, V.M. (2002) "High–Performance High–Volume Fly ash Concrete." ACI Concrete International 24(7): 1–5.