International Journal of Futuristic Trends in Engineering and Technology
ISSN: 2348-5264 (Print), ISSN: 2348-4071 (Online)
Vol. 3 (05), 2016

Development of Geo-Polymer Concrete at Ambient Temperature

(Paper ID: 35ET3004201608)

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Abstract: The effect of the mechanical activation ofGGBFS on the properties of the geo-polymers cured at ambient temperature has been studied.*New generation concrete has been developed such as GEOPOLYMER CONCRETE. It use Ground granulated blast furnace slag (GGBFS).* This paper presents the laboratory tests conducted to investigate the mechanical properties of geo-polymer concrete. The experiments were conducted at different curing temperature of Ambient Temperature 60°C and 70°C using different source material such as GGBFS. The alkaline solution used for present study is sodium silicate and sodium hydroxide solution. Different molarities of sodium hydroxide solution 8M 10M and 12M are taken to prepare different mixtures. The compressive strength and split tensile strength have been determined at different curing period of 3,7,28 Days .The results show that Geo-polymer concrete with 100 % GGBFS gains maximum strength. Increase in the mechanical properties as increase in the temperature.

Keywords :Geo-polymer concrete, GGBFS (Ground granulated blast furnace slag), Sodium silicate, Sodium Hydroxide.

I. INTRODUCTION

Concrete is one of the most widely used construction materials and the Portland cement is a main component for making concrete. Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The production of cement generates large amount of carbon dioxide. Carbon dioxide could be reduced if the production of cement could be reduced. The production of one ton of cement emits approximately one ton carbon dioxide to the atmosphere, which leads to global warming conditions.[10] So, one of the ways to produce environmentally friendly concrete is to reduce the use of Ordinary Portland Cement by replacing cement with by-product materials such as GGBFS. One of the efforts to produce more environmentally friendly concrete is to replace the Portland cement in concrete with by-product materials such as GGBFS. [5] An effort to make environmentally friendly concrete is the development of inorganic alumina-silicate polymer, such as GGBFS that are rich in silicon and aluminum called

Geo-polymer, Synthesized from materials of geological origin or by-product materials such as GGBFS that are rich in Silicon and Aluminum. GGBFS (Ground Granulated Blast Slag) is a waste material Generated in iron or Slag Industries have significant impact on Strength and Durability of Geo-polymer Concrete

II. MATERIALS USED

A) Ground granulated blast furnace slag (GGBFS)

Geo-polymer concrete is produced by activating alumino-silicate based source material with an alkaline solution. Ground granulated blast furnace slags are used as one of the source material for geo-polymer binder. GGBS was obtained from JSW cements limited. Bellari, Karnataka. It was given to Laboratory for testing. Table1 shows the Chemical composition of GGBS.

Table 1. Properties of GGBFS

S. No	Chemical Composition	Percentage
1	Al2O3	**14.06**
2	Fe2O3	**2.80**
3	CaO	**33.75**
4	MgO	**7.03**
5	K2O	**0.69**
6	Na2O	**0.41**
7	SiO2	**31.25**

Fig. 1. GGBFS

B) Alkaline activator solution

A combination of sodium hydroxide solution (NaOH) and sodium silicate and sodium hydroxide were used as alkaline activator solution.The sodium hydroxide solution was prepared by dissolving the sodium hydroxide solids, in the form of pellets in distilled water. In order to avoid the effect of unknown contaminants in the mixing water, the sodium hydroxide pellets were dissolved in distilled water
.

In this study, the molar concentration of NaOH used is 12M. There are various molar concentration of NaOH but many of research paper shows that the maximum strength of concrete achieve in 12M, after 12M the strength is decreases, So in this investigation it is selected 12M.Since the molecular weight of Sodium Hydroxide is 40g, and in order to prepare 12M solution 12 x 40= 480 gms of Sodium Hydroxide was dissolved in 1000 ml of distilled water. The sodium silicate solution contained Na_2O =14.7%, SiO_2 = 29.4%, and 55.6% of water, by mass. The activator solution was prepared at least 2 hour prior to its use. Same procedure was done for 8M And 12M.

Fig. 2. Alkaline solution

C) Fine Aggregates

Natural river sand conforming to Zone II as per IS 383 (1987) [2], with a fineness modulus of 3.45 and a specific gravity of 2.6, was used.

D) Coarse Aggregates

Crushed granite coarse aggregate conforming to IS: 383 (1987) [2] was used. Coarse aggregate of size 20 mm and below with a specific gravity of 2.87, and fineness modulus of 8.14 was used. The aggregates were tested as per IS 2386 (1963) .

E) Super plasticizer

Master Glenium Sky 8784 made by BASF super plasticizer made by BASF was added to the mixture to improve the workability of fresh concrete.

F) Water

Extra water is added to increase the workability of the concrete.

III. MIX PROPORTIONS

Since no code provisions are available for the mix design of geo-polymer concrete, the density of geo-polymer concrete was assumed to be 2400 kg/m^3, and other calculations were made based on the density of concrete as per the design proposed by Lloyd and Rangan (2010) [14]. The combined total volume occupied by the coarse and fine aggregates was assumed to be77 %. The alkaline liquid to binder ratio was taken to be 0.35. The target strength of 30 MPa was fixed as for a regular strength concrete. The mix proportions are given in table 4.
In table 4 shows that the replacement of 100% GGBFS. Master glenium sky 8784 has been used to improve the workability of the mix. present study. An admixture dosage of 1.5% by mass of GGBFS, has been found suitable in the present study.

Table 2. Mix Proportion of Geo-polymer concrete

Mix	Temperature	GGBFS (kg/m^3)	Coarse aggregate (kg/m^3)		Fine aggregate (kg/m^3)	Sodium silicate (kg/m^3)	Sodium Hydroxide (kg/m^3)	S_p (%)	Water (%)
			20mm	10mm					
GP1 8M	Ambient	408.89	776.16	517.44	554.4	102.22	40.89	1.5%	17%
	60°C	306.66	776.16	517.44	554.4	102.22	40.89	1.5%	17%
	70°C	204.45	776.16	517.44	554.4	102.22	40.89	1.5%	17%
GP2 10M	Ambient	408.89	776.16	517.44	554.4	102.22	40.89	1.5%	17%
	60°C	306.66	776.16	517.44	554.4	102.22	40.89	1.5%	17%
	70°C	204.45	776.16	517.44	554.4	102.22	40.89	1.5%	17%
GP3 12M	Ambient	408.89	776.16	517.44	554.4	102.22	40.89	1.5%	17%
	60°C	306.66	776.16	517.44	554.4	102.22	40.89	1.5%	17%
	70°C	204.45	776.16	517.44	554.4	102.22	40.89	1.5%	17%

IV. PREPARATION OF TEST SPECIMENS

The materials for the mixes were weighed and first mixed in dry condition for 4-5 minutes. Then the alkaline solution, which is a combination of sodium hydroxide and sodium silicate, and the super-plasticizer, were added to the dry mix.

Extra water in the quantity of about 17% by weight of GGBFS was added to improve the workability. The mixing was continued for about 7-9 minutes. After casting, the moulds were placed in the oven where they were dried at Ambient Temperature 60°C and 70°C for 24 hours and ambient room temperature. Then the specimens were taken out and removed from their moulds. Then the specimens were taken out and allowed to cure at room temperature until the day of testing.

V. TESTS CONDUCTED

A) Compressive strength (MPa) test

The compressive strength of the geopolymer concrete was tested as per IS 516:1959 [8]. Cube specimens 150 mm in size were cast for each proportion and tested for their compressive strength at the ages of 3, 7 and 28 days. All the specimens weretested using the Compression Testing Machine (CTM) 2000 kN in capacity under a uniform rate of loading of 140 kg/cm2/min until failure, and the ultimate load at failure was registered to enable calculation of compressive strength.

B) Split tensile strength (MPa) test

The split tensile strength test was carried out as per IS 5816:1999 [12]. Cylindrical concrete specimens 150 mm in Diameter and 300 mm in height were cast. The specimens were then tested to determine the splitting tensile strength using a Universal Testing Machine (UTM) at the ages of 3, 7 and 28 days.

VI. RESULTS AND DISCUSSION

A) Compressive strength (MPa)

The compressive strength test results obtained for geo-polymer concrete at 3, 7 and 28 days.

Table 3. Compressive strength at ambient Temperature

GGBFS	Molarity	Compressive strength		
		3 days	7 days	28 days
100%	8M	23.7614	31.2606	34.1940
100%	10M	27.8920	32.9394	39.7012
100%	12M	32.5645	35.7153	44.6643

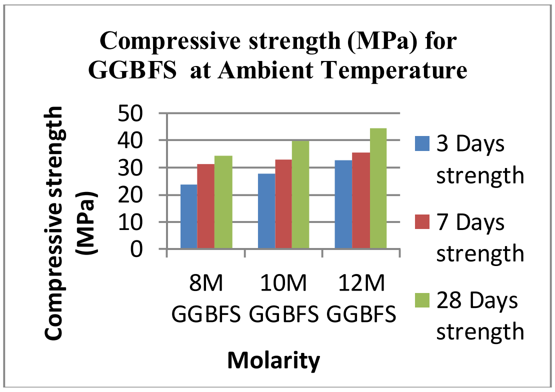

Fig. 3. 6- Compressive strength at ambient temperature

As shown in figure 3 that 100% of GGBFS at ambient temperature. It is observed that when increase in molarity. The compressive strength of Geopolyymer concrete increase

Table 4. Compressive strength at 60°C

GGBFS	Molarity	Compressive strength		
		3 days	7 days	28 days
100%	8M	31.7832	37.0207	41.0192
100%	10M	36.7652	39.2414	43.9125
100%	12M	39.8963	43.9629	50.6633

As shown in figure 4 that 100% of GGBFS at ambient temperature. It is observed that when increase in molarity. The compressive strength of Geopolyymer concrete increase

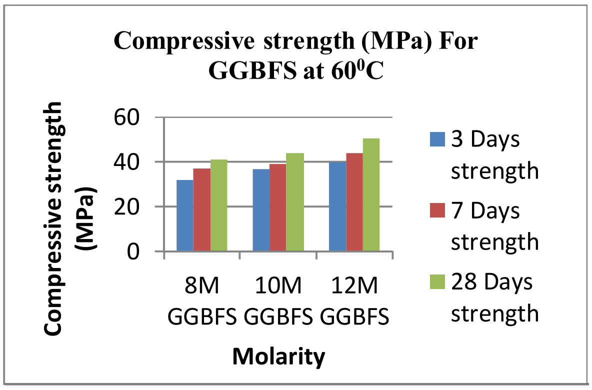

Fig. 4. Compressive strength at 60°C

Table 5. Compressive strength at 70°C

GGBFS	Molarity	Compressive strength		
		3 days	7 days	28 days
100%	8M	33.2158	40.7538	43.7524
100%	10M	36.5375	42.5326	45.9265
100%	12M	41.1749	45.9639	53.3302

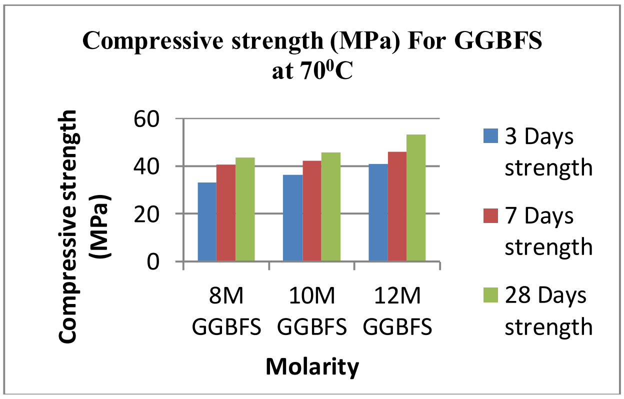

Fig. 5. Compressive strength at 70°C

As shown in figure 5 that 100% of GGBFS at ambient temperature. It is observed that when increase in molarity. The compressive strength of Geopolyymer concrete increase.

B) Split Tensile strength(MPa)

The split tensile strength test was carried out as per IS 5816:1999 [12]. Cylindrical concrete specimens 150 mm in diameter and 300 mm in height were cast. The specimens were then tested to determine the splitting tensile strength using a Universal Testing Machine (UTM) at the ages of 3, 7 and 28 days.

Table 6. Split tensile strength at ambient temperature

GGBFS	Molarity	Split tensile strength		
		3 days	7 days	28 days
100%	8M	1.37	2.12	3.03
100%	10M	1.58	2.23	3.42
100%	12M	1.95	2.90	3.59

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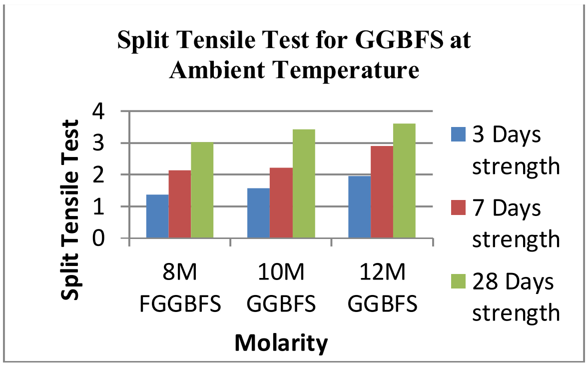

Fig. 6. Split tensile strength at ambient temperature

As shown in figure 6 that 100% of GGBFS at ambient temperature. It is observed that when increase in molarity. The split tensile strength of Geopolyymer concrete increase.

Table 7. Split tensile strength at 60°C

GGBFS	Molarity	Split tensile strength		
		3 days	7 days	28 days
100%	8M	2.01	3.17	4.74
100%	10M	2.35	3.69	5.36
100%	12M	2.64	4.05	6.11

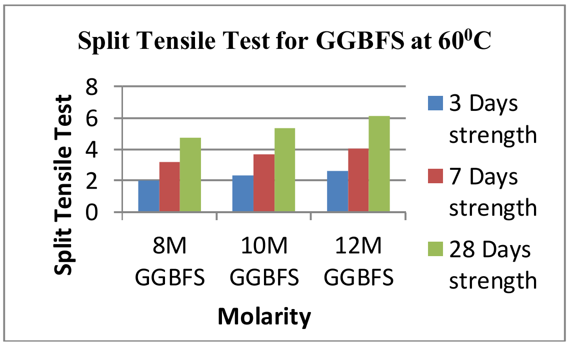

Fig. 7. Split tensile strength at 60°C

Table 8. Split tensile strength at 70°C

GGBFS	Molarity	Split tensile strength		
		3 days	7 days	28 days
100%	8M	2.45	3.65	5.15
100%	10M	2.98	4.02	5.76
100%	12M	3.21	4.25	6.52

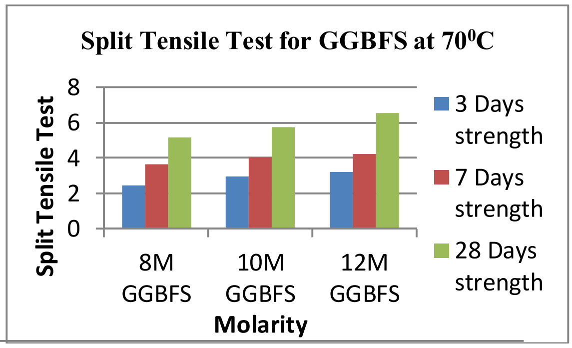

Fig. 8. Split tensile strength at 70°C

As shown in figure 8 that 100% of GGBFS at ambient temperature. It is observed that when increase in molarity. The split tensile strength of Geopolyymer concrete increase.

Table 9. Molarity and Temperature comparison

Molarity	Temperature	Compressive strength			Split Tensile strength		
		3days	7 days	28 days	3days	7 days	28 days
8M	Ambient	23.7614	31.2606	34.1940	1.37	2.12	3.03
	60°C	31.7832	37.0207	41.0192	2.01	3.17	4.74
	70°C	33.2158	40.7538	43.7524	2.45	3.65	5.15
10M	Ambient	27.8920	32.9394	39.7012	1.58	2.23	3.42
	60°C	36.7652	39.2414	43.9125	2.35	3.69	5.36
	70°C	36.5375	42.5326	45.9265	2.98	4.02	5.76
12M	Ambient	32.5645	35.7153	44.6643	1.95	2.90	3.59
	60°C	39.8963	43.9629	50.6633	2.64	4.05	6.11
	70°C	41.1749	45.9639	53.3302	3.21	4.25	6.52

VII. CONCLUSION

The experimental results show that it is possible to produce geo-polymer concrete of substantial strength using GGBFS The following conclusions can also be derived from the present study:

- In comparison to the ordinary Portland concrete the setting time of the geo-polymer concrete is very less.
- Compressive Strength as the Molarity of NaoH increase, there is increase in the strength for 3, 7 and 28 days of concrete.
- Split Tensile Strength as the Molarity of NaoH increase, there is increase in the strength for 3, 7 and 28 days of concrete.
- There is very less different in strength between 60°C and 70°C.
- It is possible to achieve comparable strength (60°C and 70°C) of Geo-polymer concrete at ambient temperature using GGBFS
- It is also conclude that the compressive and tensile strength is increasing with Increasing the temperature.

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