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Compressive Strength Study on Geopolymer Mortar using GGBFS and Fly Ash

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Abstract—*Geopolymer Concrete has gained attention to the development of pavement repairs, Airport highways and other civil engineering structures. In this paper a comprehensive study was carried out for compressive strength of Geopolymer mortar incorporating mineral admixtures namely Ground Granulated Blast Furnace Slag (GGBFS) and Fly Ash. The compressive strength of M40 grade Geopolymer mortar prepared by replacing 100% cement with GGBFS and Fly Ash was checked. Alkali activators such as sodium hydroxide and sodium silicate were used as binders. Compressive strength were checked at 7 days, 14 days and 28 days by performing compression test and it was observed that from the result of optimum molarity dosage of 12M ,the compressive strength of Geopolymer mortar made using 100% replacement of cement with GGBFS and Fly Ash came more at all ages.*

1. INTRODUCTION

The principle of geopolymer was portrayed in French by the applicant sir J. Davidovits in 1979. The American patent, US 4,349,386 was conceded on September 14, with the title Mineral polymers and methods for making them. Geopolymer are made from the waste products such as Fly Ash, ground Granulated Blast Furnace Slag, Metakoline and other type of waste products which are rich in silica and calcium oxide. Every 1 ton of cement releases about 1 tons of carbon dioxide in the air [1]. It is very important to reduce the rate of carbon dioxide emission and to substitute Ordinary Portland Cement with the by-products such as fly ash, ground granulated blast furnace slag, metakoline etc.

Fig. 1 shows the bond formation in geopolymer cement. When the mortar is oven heated they go under a process known as geopolymerization in which hydroxile ion is released and gel is formed [5].

Goepolymerization process is divided mainly into three phase; namely dissolution of Si and Al species found in mineral products through the effect of hydroxile ion followed by condensation of precursor ions into monomer and finally polymerization of polymer into three polymer structure [3].

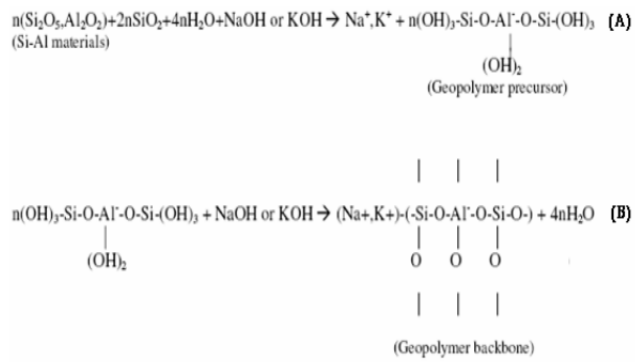

Fig. 1 Systematic Diagram of Geopolymer Cement

2. RESEARCH AIM

This project was carried out to study on processing of geopolymer by using sodium hydroxide and sodium silicate along with all the by- products such as GGBFS and fly ash. Sodium hydroxide and sodium silicate solution were used as alkali activators. This study comprises of geopolymers formed by using GGBFS and fly ash by 100% replacement of cement. The tests were carried out on 7^{th} day, 14^{th} day and 28^{th} day to find out the compressive strength of the geopolymer mortars as per IS 516 (1959) .

3. MATERIALS USED

There are various types of waste that can be used in making of geopolymer mortar. Ground Granulated Blast Furnace Slag (GGBFS) and Fly Ash are used in this study for making geopolymer mortar.

4. GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)

Conventional iron manufactures leaves slag as a crystalline stone that is dispersed as waste product or used as road-railway-track base material in replacement of crushed basalt or granite. Such crystalline structure does not provide geopolymeric reactivity. Only that slag's that are glassy and have been prevented from crystallization can be used in geopolymer concrete. The blast furnace slag is a molten material that is formed from the smelting of the siliceous matter found in iron core, the residue of coke combustion, the limestone and other added ingredients. Its temperature is in the range between 1400ºC and 1600ºC and is close to that of the molten iron. The slag becomes suitable for geopolymeric reaction when quenched from the melt. It is called granulated slag or ground granulated blast furnace slag (GGBFS). GGBFS is nowadays used along with cement for various applications. Table 1 shows the chemical properties and the composition of GGBFS powder.

Table 1: Chemical Composition of GGBFS

Sr. No.	Characteristic	Requirement As Per BS:6699	Test Result
1	Fineness(M2/KG)	275(min)	420.00
2	Residue on Wet sieve on 45µ (%)		2.00
3	Initial setting time(Min)	Not less than IST of OPC	195
4	Insoluble Residue (%)	1.5 (Max)	0.28
5	Magnesia Content (%)	14.0 (Max)	8.06
6	Sulphide Sulphur (%)	2.00 (Max)	0.53
7	Sulfate Content(%) as SO3	2.50 (Max)	0.24
8	Loss on Ignition	3.00 (Max)	0.29
9	Manganese content (%)	2.00 (Max)	0.23
10	Chloride Content (%)	0.1 (Max)	0.001
11	Moisture Content (%)	1.0 (Max)	0.03
12	Glass content (%)	67 (Min)	94.00
13	Compressive strength(N/mm2) After 7 days After 28 days	12.0 (Min) 32.5 (Min)	24.74 UT
14	Chemical Moduli		
	a.) CaO+MgO+SiO2	66.66 (Min)	82.00
	b.) CaO+MgO/SiO2	>1.0	1.30
	c.) CaO/SiO2	<1.4	1.06

5. FLY ASH

According to ACI 116 R, definition of fly ash is, "The finely divided residue that results from the combustion of ground or powdered coal and that is transported by fuel gases from the combustion zone to the particle removal system".

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. Table 2 shows the chemical composition of fly ash and the various constituents that are present in the fly ash.

Table 2: Chemical Composition of Fly Ash

Compound	Content, % weight
SiO2	57.00
Al2O3	23.00
Fe2O3	3.80
CaO	6.60
MgO	1.50
SO3	1.10
K2O	0.80
LOI	4.62

6. ALKALI LIQUID SOLUTION

Sodium hydroxide is obtained in the form of pellets (98% purity). These pellets are mixed in the distilled water in proper proportion so as to obtain the molarity. Distilled water is used so that no extra chemical reaction takes place in the alkali liquid. After adding sodium hydroxide to water stir it properly until all the pellets are dissolved in it. Take proper care of the skin as the pellets dissolves the temperature of water goes on increasing. The temperature of the water reaches the boiling temperature of water. The solution is then left to cool down properly. It takes 3 to 4 hours for the solution to cool down. Once the solution is cooled to room temperature then after sodium silicate is added to solution. Sodium silicate is dark brown color intense liquid used in the process of geopolymerization. The alkali solution can be made on the same day of casting but at least 6 hrs before the casting is to be done. Here we have considered four different types of molarity i.e. 8M, 10M, 12M and 14M. Table 3 shows the density and molecular weight of different molar solution and Table 4 gives the amount of sodium hydroxide to be mixed into water for producing 1000 grams of NaOH solution.

Table 3: Density and Molecular Weight for Different Molar Solution

Molarity	Density (Kg/m3)	Molecular Weight of NaOH (grams)
8M	1.2	40
10M	1.24	40
12M	1.28	40
14M	1.32	40

Table 4 Quantities of NaOH solids and Water to Produce NaOH Solution

Molarity	Weight of NaOH in solution (grams)	Weight of Water (grams)	Total NaOH solution	Amount for 1000 ml of NaOH solution	
				NaOH	Water
8M	266.66	833.33	1100	242.42	757.42
10M	375	806.45	1129.03	285.71	714.71
12M	322.58	781.25	1156.25	324.32	675.32
14M	424.24	757.58	1181.82	358.97	641.97

7. PARAMETERS CONSIDERED

The basic difference between ordinary cement mortar and geopolymer mortar is the binder. The silicon and aluminum oxide present in Fly ash and GGBFS reacts with alkali liquid to form a geopolymer paste which on heating goes through a geopolymerization process.

1. In the study work, low calcium, class F dry fly ash and GGBFS obtained from Guru Corporation is used as base material to make the geopolymers.
2. Sodium silicate (Na_2SiO_3) mixed with sodium hydroxide (NaOH) as an alkaline activator has been used in this study, NaOH in pellet form with 98% purity & Na_2SiO_3 consist of Na_2O=9.4%, SiO_2=30.1% & H_2O=60.5%.
3. The ratio of Na_2SiO_3 & NaOH is kept as 2.5.
4. Oven dry curing temperature i.e., 60ºC for time in 24 hours is kept constant.
5. The ratio of alkali to cementacious material is considered as 1.2.
6. The ratio of water to alkali liquid binder is taken as 0.25.

8. HAND MIXING AND CASTING OF MORTAR

Geopolymer mortar is made by using the technique of ordinary Portland cement. The method for both geopolymer mortar and ordinary Portland cement mortar is same [4].

The main components considered in making of mortar are fly ash, GGBFS, sand, binder and super plasticizer. We had used master glenium as a plasticizer to increase the workability of the mortar.

The sand is passed through 4.75mm sieve and cleaned as per IS 2116-1980. Cementacious to sand ratio is taken as 1:3. Sand and cementacious material is properly mixed by hand mixing and very slowly alkali liquid is added to it. Master Glenium is added and mixed for 2 minutes.

When sodium hydroxide is added to water it undergoes exothermic reaction and the heat is liberated from it. The heat is so high that water goes up to its boiling temperature. Once the solution is cooled down it can be used. Table 5 shows the various specimens considered with types of molarity for the study purpose.

Table 5: Mixes Formulated in Study

Specimen ID	Molarity	Ratio of Fly ash or GGBFS / Sand
G1	8M	1:3
G2	10M	1:3
G3	12M	1:3
G4	14M	1:3
F1	8M	1:3
F2	10M	1:3
F3	12M	1:3
F4	14M	1:3
OPC	----	1:3

G= GGBFS and F=Fly Ash

The alkali liquid binder and cementacious material is properly mixed together. After mixing mixture is filled into the cube size of 70mm×70mm×70mm as per IS 2250(1981) . Compressive strength test is performed on 7 day, 14 day and 28 days. Geopolymer mortar blocks are kept in open air for curing. Mortar blocks are wrapped in plastic to retain its moisture condition.

9. RESULTS AND DISCUSSIONS

A compression testing machine of 2000 kN load capacity is used to measure the compressive strength of OPC and geopolymer mortar. The compressive strength is measured with a compressive load if 1.3 kN/s on the geopolymer mortar cubes at the end of 7 days, 14 days and 28 days.

Effect of Molarity in GGBFS based Geopolymer Mortar

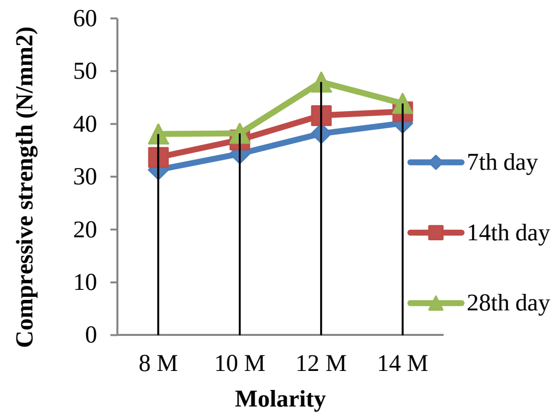

Fig. 2: Compressive Strength for GGBFS mortar

From Fig. 2 it can be stated that the strength of GGBFS mortar increases as the days passes. There is a drastic effect of alkali solution on the GGBFS material. There is a uniform bond formed between alkali liquid and GGBFS particles, due to presence of more silica content in GGBS. That is the reason that the strength increases for GGBFS material. Due to the change in molarity of alkali liquid there is a change in compressive strength for GGBFS material. As the molarity goes on increasing, the strength also increases. There is a vast change in strength between 12M and 14M solution. The compressive strength of 12M solution at the age of 28th day is comparatively more than 28th day of 14M solution.

Effect of Molarity in GGBFS based Geopolymer Mortar

From Fig. 3 it can be seen that the compressive strength for different molarity of solution is different. It is not a linear graph. The maximum strength is attained at 12M of the solution, then after for 14M solution the strength goes on decreasing. This is due the density of the solution. As the molarity increases the thickness of the solution also goes on increasing. Thus uniform bond is not formed between the fly ash particles and the alkali solution.

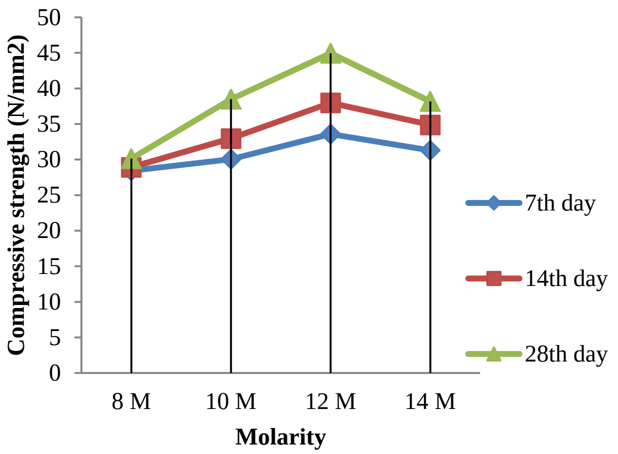

Fig. 3: Compressive Strength for Fly Ash Mortar

10. CONCLUSION

1. The test outcome demonstrates that compressive strength quality of geopolymer mortar for GGBFS and Fly Ash increments as sodium hydroxide fixation in the fluid stage increments from 8M to 12M; however, it diminishes with the further increment in sodium hydroxide solution. It is acknowledged that increment in alkali base fixation enhances geopolymerization process. It is seen that when the molarity increments from 12M to 14M, there is colossal expansion in hydroxide particle which causes aluminosilicate gel precipitation at right on time. This study demonstrates that when the activator fixation increments around 12M, a lower rate of polymer development was created bringing about the lessening of mechanical quality.
2. It can be also concluded that the optimum dose for making geopolymer mortar is considered to be as 12M.

REFERENCES

[1] Joseph Davidovits, "Geopolymer Green Chemistry and Sustainable Solution".

[2] Anuar. K.A (Institute of Infrastructure Engineering and Sustainable Management), “Strength characteristics of geopolymer concrete containing recycled concrete aggregate”, International *Journal of Civil & Environmental Engineering IJCEE-IJENS* Vol: 11 No: 01.

[3] Hardjito.D, Wallah. S.E, Sumajouw. D.M.J, Rangan. B.V, “Fly ash based geopolymer concrete”, *Aust. J. Struct. Eng* 6(1), 2005, pp. 1-9.

[4] Hardjito.D (Petra Christian University),”On the development of fly ash-based geopolymer concrete”, *ACI Materials Journal*, November-December 2004.

[5] Ravikumar.D, Peethamparan.S, Neithalath.N, “Structure and strength of NaOH activated concretes containing fly ash or GGBFS as the sole binder”, *Cement & Concrete Composites 32, 2010, pp. 399–410.*

[6] Lloyd.N.A (Curtin University of Technology), Australia, B V Rangan, (Curtin University of Technology Australia), “Geopolymer concrete : a review of development and opportunities”, *35th Conference on OUR WORLD IN CONCRETE & STRUCTURES:* 25 – 27 August 2010, Singapore.

[7] Venugopal K, Radhakrishna, J. Raju, M. A. Dar, " Properties and Application of Geopolymer Masonry Units", *SSRG International Journal of Civil Engineering (SSRG-IJCE) – EFES* April 2015.

[8] Prof.Bhosale.M.A, Prof Shinde.N.N, " Geopolymer Concrete by Using Fly Ash in Construction", *IOSR Journal of Mechanical and Civil Engineering*, ISSN : 2278-1684 Volume 1, Issue 3 (July-August 2012).