Experimental Work on Alumino Silicate Mortar and Paste

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Abstract— This paper presents workability, compressive strength for geopolymer pastes and mortars made of Alkaline Activator solution, class C fly ash and GGBFS at mass ratios of liquid to binder from 0.5 to 0.55. The strengths of mortar were 35 MPa to 72 MPa when they were cured under Ambient Temperature geopolymer mortar. 8M mortar and paste were prepared and using polypropylene fibers.

Key words: Geopolymer Mortar and Paste, Molarity (M), Alkaline Activator Solution (AAS), Fly Ash, Slag Or GGBFS, Class C Flash, Polypropylene Fibers

I. INTRODUCTION

Geopolymer has emerged in the field of construction and building materials. Geopolymer is well known for its excellent properties such as good fire and acid resistance, high compressive strength, low shrinkage, and solidification of heavy metal wastes. This material is usually based on an alumino–silicate precursor activated in a concentrated alkali hydroxide solution, to which is often added alkali silicate to control the final chemical composition. The main distinction between class F fly ash and class C fly ash is that the latter contains a higher amount of calcium. class C fly ash has both pozzolanic and cementitious properties and calcium content has significant influence on the properties of the fresh mixture as well as the properties of the final hardened product and may lead to the formation of calcium silicate hydrate compounds in addition to the geopolymer gel products.

Geopolymer have been manufactured as paste, mortar and concrete. In previous studies, compressive strength and Young's modulus of fly ash-based geopolymer did not change significantly between paste and mortar .However, in mortar, compressive strength depends on the strength of the geopolymeric gel, the interfacial bonding between the geopolymeric gel and aggregate and the aggregate itself . Moreover, any partial reaction of the surfaces of siliceous aggregates with the alkali silicate solution may form additional reaction products surrounding the aggregate particles that may contribute to its strength. Thus, the properties of geopolymer paste and mortar differ to some extent.

II. MATERIALS

A. FLYASH:

The constituents of the fly ashes are SiO, Al O, Fe O, CaO, MgO, NaO, KO, SO, MnO, TiO and unburnt carbon. The major principal constituents of silica, alumina and ferric oxide .When the sum of these three principal constituents is more or equal to 70% and reactive calcium oxide is less than 10% - technically such fly ash is called as class F fly ash. Such type of fly ash is produced by burning of coal and possesses pozzolanic properties. The active constituents are calcium alumino-silicate glass, free lime (CaO), and rarely, calcium silicate etc. The calcium alumino-silicate reactive with the calcium and alkali hydroxides released from cement fly ash system and forms cementitious gel, which provide additional strength.

Content	Range
Appearance	glassy, hollow and spherical in shape
Size	1 micron to 1 mm
Specific Gravity	1.9 to 2.55.
Fineness(m^2/kg)	1134.1
SiO_3	61.12
Al_2O_3	31.23
Fe_2O_3	1.50
Na_2O_3	1.35
CaO	3.2
MgO	0.75
SO_3	0.53
Chloride	0.06

Table 1: Constituents of the Fly Ashes

B. GGBFS:

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. GGBS is a glassy, granular, non-metallic material consisting essentially of silicates and aluminates of calcium and other bases. Slag when ground to less than 45 micron from coarser, popcorn like friable structure, will have a specific surface of about 400 to 600 m2/kg (Blaine).

Content	Range
Appearance	glassy, non-crystalline material
Size	Various (depending on chemical compounding n method of production)
Specific Gravity	2.9
Fineness(m^2/kg)	416.0
SiO_3	37.21
Al_2O_3	13.24
Fe_2O_3	0.65
Na_2O_3	---
CaO	37.2
MgO	8.46
SO_3	2.23
Chloride	0.003

Table 2: Ground granulated blast furnace slag

C. Aggregates:

Locally available from river sand

Properties	Fine aggregates
Source	River sand (Zone II)
size	Less than 4.75
Specific gravity	2.63
Water absorption	1%
Fineness modulus	2.5
Bulk density (kg/m^3)	1541
Flakiness Index	NA
Elongation index	NA

Table 3: Aggregates

D. *Alkaline Liquid*

Properties of sodium hydroxide:

Molecular formula	NaOH
Molar mass	39.9971 g/mol
Appearance	White solid
Density	2.13 g/cm3
Melting point	318°C,591K, 604°F
Boiling point	1388°C,1661K,2350°F
Solubility in water	111 g/100ml
Solubility in ethanol	13.9 g/100ml
Solubility in methanol	23.8 g/100ml
Solubility in glycerol	Soluble
Acidity(pKa)	13
Basicity point (pK_b)	-2.43
Refractive Index	1.412
Flash point	Non-Flammable
Availability	Pellets, flakes, granules, 50% solution
Heat of solution	44.2 kJ/mole

Table 4: Sodium Hydroxide

E. *Properties of Sodium Sillicate*

Also called water glass or Soluble Glass. Mixture of sodium silicates varying ratios of SiO2 to Na2O, solids contents, and viscosity. These compounds are colorless, transparent, glasslike substance available commercially as a powder or as a transparent, viscous solution in water. They can be dissolved in water to form a syrupy liquid. Some forms are slightly soluble, and some are almost insoluble; they are best dissolved by heating with water under pressure. Sodium Silicate is a major component of the geopolymer concrete mix. The microstructure and performance of metakaolin- and fly ash-based derived geopolymers are both known to be dependent on the amount of soluble silicon in the activating solution.

The properties of sodium silicate are listed in table below:

pH value	Neutral
Na2O	7.5percent - 8.5percent
SiO2	25percent - 28percent

F. *Super Plasticiser*

This is not activator directly for chemical reactions and is expected to affect only fresh concrete properties. In order to improve the workability of fresh GPC and CC, naphthalene based super plasticiser can be used, though they are not as effective in GPCs as they are in CCs. CAE based super plasticisers are found to be ineffective in GPCs. CONPLAST SP 430. as per IS 9103-1999.

Chemical base	Sulphonated Naphthalene Formaldehyde Condensate (SNFC)
Density	1206 kg/m^3
Colour	Brownish
Nature	Free flowing liquid
Recommended dosage	0.1-1.5 kg/100 kg cement
Type of surface	Anionic
pH	8.027

Table 5: Properties of Super plasticisers

Effective diameter	0.2mm
Length	6 mm.
Specific gravity	more than 1.0.
Suggested dosage	0.6-2.0 kg/cumec (0.15% volume of concrete).
Water absorption	less than 0.45 percent.
The aspect ratio	200 to 2000.
Yield strength	550Mpa
Youngs modulus(E)	3500 Mpa

Table 6: Properties of Polypropylene fibers:

Fig. 1: Polypropylene Fibres

III. EXPERIMENTAL PROCEDURE

A. *Preparation of Alkaline Solution*

320 g (molarity x molecular weight) of sodium hydroxide flakes dissolved in one litre of water to prepare sodium hydroxide solution of 8M. The mass of NaOH solids in a solution vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 248 g per kg of NaOH solution of 8 M concentration. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the geopolymer concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds as early as possible as the setting times are very low.

B. *Dry Mixing*

Dry mixing is carried out manually. All the dry ingredients like fine aggregate with cementious material such as flyash and slag are mixed. In case for polypropylene based GPC fibres are added to the mortar mix after wet mixing.

C. *Wet mixing*

Alkaline liquids are prepared 24 hours prior to mixing, as NaOH liberates large amount of heat. Amount of super plasticizer (if required) is mixed with the alkaline solution and added to the dry mix, wet mixing time should be about 10 to 15 minutes or greater. The mixing of total mass will be continued till the mixture become homogenous, uniform in colour and have easy workability.

D. *Specimen casting*

The moulds were cleaned with water and then it should be oiled properly and set of three moulds should be ready before 5-10 minutes of mixing. Size of specimen 7.01x7.01x7.01 cm

E. *Curing*

The mortar and paste specimens were cured under ambient temperature .The temperature varied between 30-40^0C

IV. EXPERIMENTAL RESULTS

A. *Geopolymer Mortar*

8M L/B=0.5 SP=2% EW=2.5%

Proportion (Flyash:Slag)	size	Mix	Days		Strength (Mpa)	
50:50	7.01x	1:2	3	7	36.7	40.5
40:60	7cm	1:2	3	7	44.8	50.3

Table 7: Geopolymer Mortar

B. *Geopolymer Mortar with Polypropylene Fibres*

8M L/B=0.5 SP=2% E.W 2.5%

Proportion (Flyash: Slag)	size	Mix	curing	Polypropylene fibres	Days	Strength (Mpa)
60:40	7x	1:2		0.025%	7	34.7
50:50	7c	1:2	Air	0.025%	7	37.9
40:60	m	1:2		0.025%	7	46.4

Table 8: Geopolymer Mortar with Polypropylene Fibres

8M L/B=0.55 SP=2% EW=5%

Proportion (Flyash: Slag)	size	Mix	Polypropylene fibres	Days		Strength (Mpa)	
30:70	7x7	1:2	0.025%	3	7	44	50
70:30	cm	1:2	0.025%	3	7	36	40.1

Table 9: 8M L/B=0.55 SP=2% EW=5%

1) *8M L/B=0.55 SP=2% EW=5%*

Proportion (Flyash: Slag)	Size (cm)	Mix	curing	Days	Strength (Mpa)
100:0	7x7	1:3	Air	7	-
90:10		1:3		7	12.4
80:20		1:3		7	14.74
70:30		1:3		7	19.45
60:40		1:3		7	23.3
50:50		1:3		7	29.4
40:60		1:3		7	35.6
30:70		1:3		7	43.7
20:80		1:3		7	54.7
10:90		1:3		7	56.9
0:100		1:3		7	54.1

Table 10: 8M L/B=0.55 SP=2% EW=5%

Remarks: As the slag content increases the strength also increases. The best combination is (10FA:90SL).

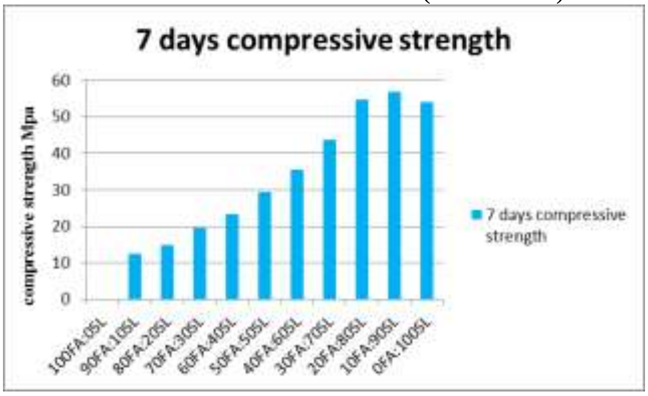

Fig. 2: Compressive Strength

C. *Geopolymer Paste:*

1) *8M L/B=0.5 SP=2% E.W=5%*

Proportion Flyash: slag 60:40	Size (cm)	Days	Strength (Mpa)	Remarks
Paste kept in water	7x7	7	36	No cracks on the surface
Paste kept in ambient condition	7x7	7	30	Large shrinkage cracks developed
After cracking paste kept in water(I.e. 2 days after casting)	7x7	7	32	All the cracks sealed
Paste added with polypropylene fibers (0.025%)	7x7	7	38.8	Still cracks appeared on the surface

Table 11: Geopolymer Paste

Conclusion: Paste requires 100% humidity to prevent cracking.

2) *8M L/B=0.5 SP=2% E.W=5%*

Proportion (Flyash:Slag)	Size (cm)	curing	Days	Strength(Mpa)
75:25	7x7	Air	7	24
50:50			7	34.5
25:75			7	38.9
0:100			7	51

Table 12: 8 M L/B=0.5 SP=2% E.W=5%

3) *8M L/B=0.48 S.P=2.5% E.W=6%*

Proportion Flyash: Slag	Days	Strength(Mpa)
60:40	1	25
	2	29
	3	37
	7	48
	10	52

	14	59
	21	66
	28	69.7
	42	70
	56	72

Table 13: 8M L/B=0.48 S.P=2.5% E.W=6%

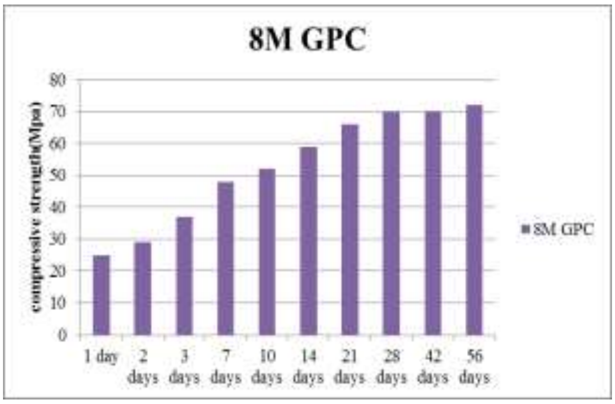

Fig. 3: 8M GPC

Remarks: AS number of days increases compressive strength also increases.

V. Conclusions

– Higher the molarity that is higher concentration of sodium hydroxide, more is the cohesiveness of mix and stiffer the mix, and hence higher the fluid demand.
– 8M solution will be usable up to 30-36 hours .
– polypropylene fibers do not contribute to any strength enhancement but increases toughness and ductility observed through failure.
– As the percentage of slag increase, the compressive strength increases significantly in paste, mortar and concrete.
– Mortar do not crack in ambient temperature but paste cracks in unacceptable limits. Unless it is kept in water.
– Interestingly the cracks seal when the paste is kept in water within 2 days.
– It was found that the fresh geopolymer mortar was cohesive and homogenous. The amount of water in the mixture played an important role on the behavior of fresh mortar. When the mixing time was long, mixtures
– with high water content bleed and segregation of aggregates and the paste occurred. It was found that the occurrence of bleeding and segregation ceased. The effects of water content in the mixture and the mixing time were identified as test parameters in the detailed study.

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