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Study of Properties of Fly Ash Based Geo Synthetic Concrete Uses in Roads and High Way Embankment

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Abstract: *This experimental study is intended to identify the mix ratios for different grades of Geo polymer Concrete. Compressive strength of geo polymer concrete and parameters that affect it are analyzed and proved experimentally. Flexural strength and tensile strength tests were conducted on geopolymer concrete. In this study some durability properties are also studied like permeability and acid attack. From the test results it was clear that geo polymer concrete possesses good compressive strength and offers good durability characteristics. Geo polymer concrete can be used efficiently in concrete industry especially in precast members.*

Keywords: *Geo polymer Concrete, polymeric reaction, compressive strength, durability characteristics, concrete industry, precast member.*

1. Introduction

In the context of increased awareness regarding the ill-effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Concrete usage around the world is second only to water. Cement is conventionally used as the primary binder to produce concrete. The carbon dioxide released during the manufacture of cement due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of cement produced. In addition, the extent of energy required to produce cement is only next to steel and aluminum. The ever increasing unit cost of the usual ingredients of concrete has forced to think of ways and means of reducing the unit cost of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts of materials like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal problems.

2. Geo Polymer Concrete

In 1978, 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 and rice husk ash. In other words we can produce concrete by using fly ash and alkaline binders replacing the cement by 100%. As geo polymer concrete is new to the concrete industry lot of work is to be done to assess it as an alternative to cement concrete.

Ever since the introduction of geo polymer binders by Davidovits in 1978, it has generated a lot of interest among engineers as well as in the field of chemistry. In the past few decades, it has emerged as one of the possible alternative to cement binders.

3. Objectives of the Project

- To develop a mixture proportioning process to manufacture fly ash based geopolymer concrete.
- To identify and study the effect of salient parameters that affects the properties of fly ash-based geo polymer concrete.
- To study durability properties like permeability and resistance to acids of geo polymer concrete.

4. Materials Used

4.1. Fly Ash

Fly ash provides the necessary source constituents like aluminum and silicon needed for the formation of polymer backbone. Specific gravity of fly ash varies from 1.9 to 2.55. So specific gravity of fly ash used in the present study needed to be determined.

4.2. Alkaline Liquids

The chemical composition of the sodium silicate solution used is Na_2O=14.7%,SiO_2=29.4%, and water 55.9% by mass. The other characteristics of the sodium silicate solution are specific gravity=1.53 g/cc and viscosity at 20^0C=400 cp.

4.3. Aggregates

Aggregates used are:

- 10mm
- 16mm
- 20mm

5. METHODOLOGY

In order to determine the compressive strength, tensile strength and flexural strength of geopolymer concrete various cubes & cylinders are casted. Six cubes of size 150mm * 150mm *150 mm are casted to determine compressive strength. Three cylinders of are casted to determine the spilt tensile strength.

Volume of cylinder and volume of beam is approximately taken as $5.5*10^{-3}m^3$, so volume of 3 cylinders and 3 cubes comes out to be $33*10^{-3}m^3$. Total volume of casting comes out to be $54*10^{-3}m^3$. M20 grade concrete is to be casted with a ratio of 1:1.5:3 (Fly ash: Aggregates: sand)

5.1. Parameters Fixed for the Casting

- Alkaline liquid to fly ash ratio as 0.35.
- Sodium silicate to sodium hydroxide ratio as 2.5.
- Concentration of sodium hydroxide as 12M.
- 12M Sodium hydroxide is prepared by mixing 400g of sodium hydroxide pellets in one liter of water. After mixing sodium hydroxide in water it must be left for 24 hours because large amount of heat is liberated.
- Sodium silicate is also prepared by mixing sodium silicate pellets in water. Sodium silicate needs higher temperature for dissolution in water
- Sodium silicate and sodium hydroxide solutions are mixed together 24 hours before casting.
- Cubes of size 150 mm * 150 mm * 150 mm are casted to obtain the compressive strength of concrete.

Table 1 sows the total amount of materials required in kg's for the casting.

Table1. *Total amount of materials required*

Materials		Mass kg/m^3	Amount required. (kg)
Coarse aggregate	20mm	445.73	24.06
	16mm	297.15	16.04
	10mm	495.264	26.74
Fine sand		609.84	32.93
Fly ash		408	22.03
Sodium silicate solution		103	5.562
Sodium hydroxide solution		41	2.214

5.2. Proportioning of Mix

No specific codal guidelines are available for design of geoplymer concrete mixes. Some arbitrary guidelines are available for proportioning of mixes.

Proportioning of mixes with different concentrations of NaOH -NM

To study the effect of concentration of sodium hydroxide different mixes with different concentration of sodium hydroxide are prepared. Molar weight of sodium hydroxide is 40gm. Four different mixes are prepared which vary only in sodium hydroxide concentration, rest parameters are kept same.

Proportioning of mixes with different sodium silicate to sodium hydroxide ratio-SSM

In order to assess the effect the ratio of sodium silicate to sodium hydroxide different mixes are prepared with different concentrations of sodium silicate and sodium hydroxide.

Proportioning of materials for mixes with different alkaline liquid to fly ash ratio- AFM

Different mixes are prepared with alkaline liquid to fly ash ratio as 0.30, 0.35, 0.40, and 0.45.

Table 2, 3 & 4 sows the proportioning of mixes.

Table2. *Mixes used with different NM ratio*

Nomenclature	Ratio	Propotion
NaOH mix1 (N M_1)	8M	320grams NaoH+one litre of water
NaOH mix2 (NM_2)	10M	400grams NaoH+one litre of water
NaOH mix3(NM_3)	12M	480grams NaoH+one litre of water
NaOH mix4 (N M_4)	16	640grams NaoH+one litre of water

Table3. *Mixes used with different AF ratio*

Nomenclature	AFM_1	AFM_2	AFM_3	AFM_4
Ratio	0.3	0.35	0.40	0.45
Fly ash used kg/m^3	424.6	408	394.28	380.68
Alkaline liquid used kg/m^3	127.38	144	157.71	171.31
Sodium silicate used kg/m^3	36.39	103	112.65	122.36
Sodium hydroxide used kg/m^3	90.98	41	45.06	48.94

Table4. *Mixes used with different SS ratio*

Nomenclature	Ratio
(SSM_1)	0.4
(SSM_2)	1
(SSM_3)	2.5
(SSM_4)	3.5

6. EXPERIMENTAL INVESTIGATIONS

In order to get assessed with laboratory work associated with GPC different cubes and cylinders are casted to determine compressive and tensile strength of GPC.

1) Mixes used for Compressive strength

Sodium hydroxide can be used in different concentrations like 8M, 10M, 12M, and 16M. To study the effect of concentration of sodium hydroxide different mixes with different concentration of sodium hydroxide are prepared. Molar weight of sodium hydroxide is 40gm.

In order to assess the effect of alkaline liquid to fly ash ratio on the strength of concrete different cubes are prepared with different alkaline liquid to fly ash ratio. Different mixes are prepared with alkaline liquid to fly ash ratio as 0.30, 0.35, 0.40, and 0.45.

Table 5 shows the proportioning of mixes with different ratio's of materials for casting of cubes

Table5. *Proportioning of mixes with different Ratio's for casting of cubes*

Materials	NM kg	AFM_1 kg	AFM_2 kg	AFM_3 kg	AFM_4 kg	SSM_1 kg	SSM_2 kg	SSM_3 kg	SSM_4 kg
Flyash	4.28	4.45	4.28	4.1	3.9	4.2	4.2	4.2	4.2
NaS solution	1.08	0.95	1.08	1.1	1.2	0.4	0.7	1.1	1.1
NaOH solution	0.435	0.38	0.435	0.48	0.52	1.08	0.75	0.48	0.35

7. TEST RESULTS AND DISCUSSIONS

7.1. Tests on Materials

The various types of tests were conducted on cement, fine aggregate, fly ash and coarse aggregate and the results are tabulated in table 6. The table 6 below shows the different types of tests carried out on various materials.

Table6. *Test on Cement*

Test	Results
Fineness modulus for crushed aggregate of 20 mm size	5.817
Fineness modulus for crushed aggregate of 10 mm size	4.446
Fineness modulus for sand modulus	2.9
Grade of sand specific gravity of fly ash	Zone II 2.31

7.2. Testing of Cubes for Compressive Strength

- *Effect of concentration of sodium hydroxide*

Cubes casted are heat cured for 24 hours in an oven. After 24 hours cubes are removed from moulds and taken out from oven. After taking out from oven cubes are kept in open air for 6 days. After 7 days cubes are tested on CTM and seven day strength is obtained. The table 7&8 below shows the compressive strength obtained after testing specimens on CTM.

Table7. *Slump test*

Slump test	
NM_1	67mm
NM_2	83mm
NM_3	115mm
NM_4	145 mm

Table8. *Compressive strength obtained after testing specimens on CTM.*

Avg Compressive Strength	
NM_1	19.55 MPa
NM_2	22.14 MPa
NM_3	24.36 MPa
NM_4	25.1 MPa

Effect of concentration on strength of concrete is represented on the graph with concentration of sodium hydroxide along x axis and strength along y axis is shown below in figure 1.

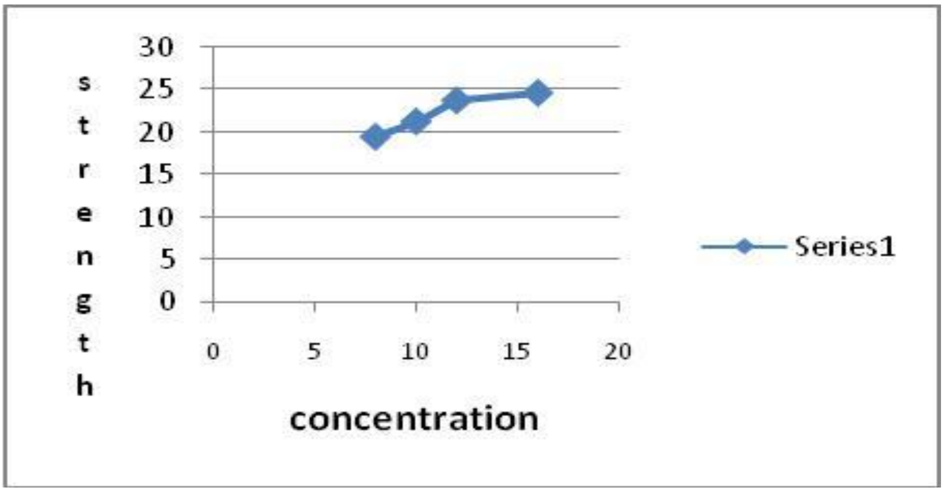

Fig1. *Variation of strength with concentration of NaOH*

It is clear from the above results that with increase in concentration of sodium hydroxide, strength increases. So, higher concentration sodium hydroxide is used for producing high strength cubes. Concentrated sodium hydroxide can be prepared easily because sodium hydroxide is highly soluble in water.

- *Effect of alkaline liquid to fly ash ratio*

Cubes are cured for 24 hours in oven. After 24 hours cubes are removed from moulds and taken out from oven and kept at room temperature in open air for 6 days. Cubes are then tested on CTM to determine their compressive strength. The table 9 & 10 below shows the compressive strength obtained after testing specimens on CTM.

Table9. *Slump test*

Slump test	
AF_1	87mm
AF_2	84mm
AF_3	83mm
AF_4	92 mm

Table10. *Compressive strength obtained after testing specimens on CTM.*

Avg Compressive Strength	
AF_1	25.1MPa
AF_2	23.84MPa
AF_3	21.10 MPa
AF_4	18.73MPa

Effect of concentration on strength of concrete is represented on the graph with concentration of alkaline liquid to fly ash ratio along x axis and strength along y axis is shown below in figure 2.

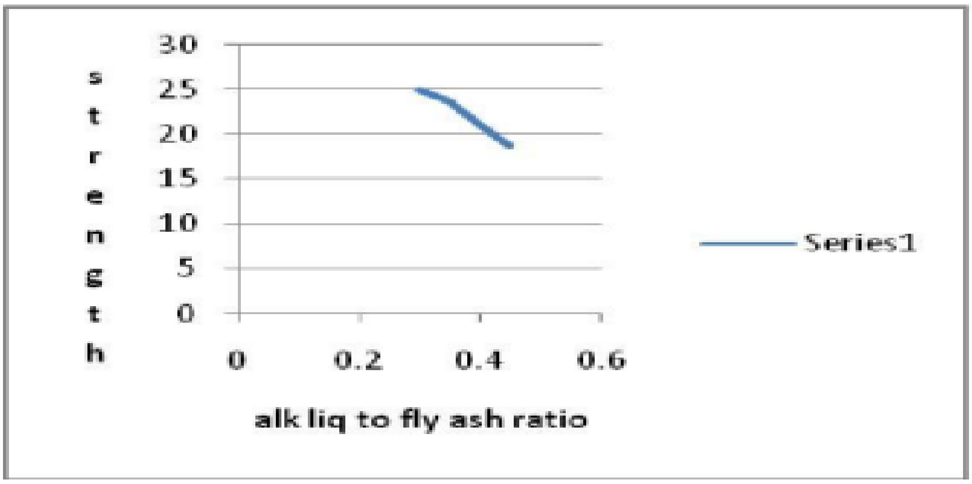

Fig2. *Variation of strength with concentration of AF ratio*

As seen from the above results, that with increase in alkaline liquid to fly ash ratio, strength decreases. By decreasing alkaline liquid to fly ash ratio, strength increases. But decreasing alkaline liquid to fly ash ratio beyond 0.3 makes concrete stiff which is no more workable.

- *Effect of sodium silicate to sodium hydroxide ratio*

Cubes prepared are heat cured for 24 hours in an oven. After 24 hours moulds are removed and cubes are taken out from oven and kept in open air at room temperature for six days. After 7 days cubes are tested on CTM.. The table 11 & 12 below shows the compressive strength obtained after testing specimens on CTM.

Table11. *Slump test*

Slump test	
SS_1	74mm
SS_2	80mm
SS_3	85mm
SS_4	85 mm

Table12. *Compressive strength obtained after testing specimens on CTM*

Avg Compressive Strength	
SS_1	19.03MPa
SS_2	20.36MPa
SS_3	23.48MPa
SS_4	20.14MPa

Effect of concentration on strength of concrete is represented on the graph with concentration of alkaline liquid to fly ash ratio along x axis and strength along y axis is shown below in figure 3.

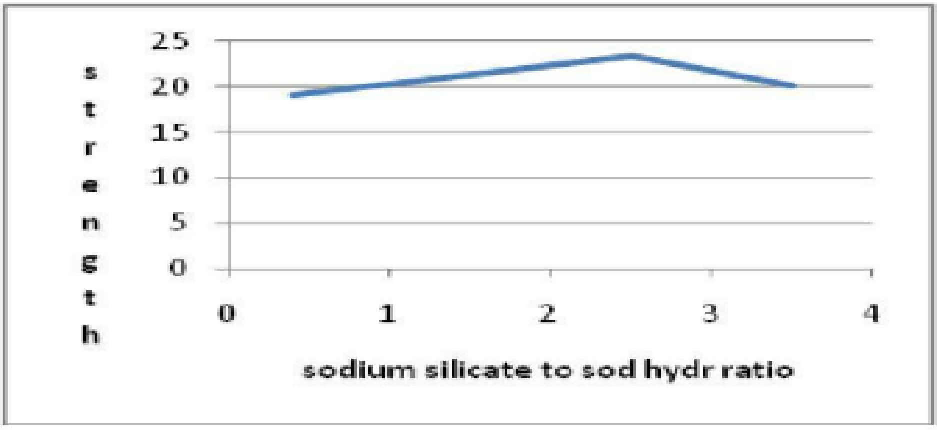

Fig3. *Variation of strength with concentration of SS ratio*

From the above results it is clear that strength increases with increase in sodium silicate to sodium hydroxide ratio. This increase is till the ratio reaches 2.5 beyond which strength decreases with increase in sodium silicate to sodium hydroxide ratio. So optimum ratio to obtain maximum strength is 2.5

- *Gain of strength with time*

Cubes are heat cured for 24 hours. After heat curing moulds are removed and cubes are taken out from oven. One day strength is determined for 3 cubes on CTM. Rest cubes are kept at room temperature in open air. After 3 days 3 more cubes are tested and 3 day strength is determined. After 7 days 3 more cubes are tested to determine 7 day strength test. Remaining 3 cubes are kept at room temperature for 28 days and are tested after 28 days to determine 28 days strength. The table 13 below shows the Gain of compressive strength with time

Table13. *Gain of compressive strength with time*

one	**$_3$rd**	**$_7$th**	**28th**
day	**day**	**day**	**day**
Avg	**Avg**	**Avg**	**Avg**
Stren	**Stren**	**Stren**	**Stren**
gth	**gth**	**gth**	**gth**
9.67	14.67	23.67	24.83

Results obtained can be graphically represented with strength along y axis and number of days along x axis.

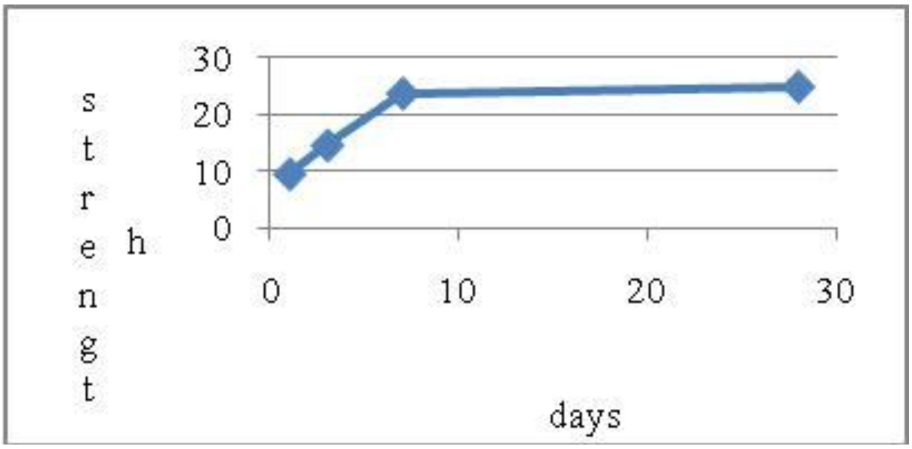

Fig4. *Gain of strength with time.*

From the above results it is clear that increase in strength is very rapid within 3 days. Cubes reach their maximum strength in 7 days. After 7 days increase in strength is very less. So we can say that geopolymer concrete reaches its maximum strength within 7 days whereas plain cement concrete reaches its maximum strength in 28 days. Gain in strength in geopolymer concrete is 4 times rapid as compared to plain cement concrete.

- *Other Tests*

The specimens are tested on high pressure permeability apparatus under pressure of 10kg/cm^2 and left for 24 hours. After 24 hours drop in water level is measured which gives discharge.

After seven days of curing and 30 days exposure to 10 % concentrated sulphuric acid cubes are removed from acid and kept in open air for drying. The table 14 below shows results of other tests done on the casted specimen.

Table14. *Other tests done on casted specimen*

Testing of cylinders	**Average strength= 2.56**			
	AFM$_1$	**AFM$_2$**	**AFM$_3$**	**AFM$_4$**
Permeability test (Avg. K)	2.96*1	4.84*	7.8*1	1.26*
	$_0$-11	$_{10}$-11	$_0$-11	$_{10}$-10
Effect on strength after acid attack	AFM$_1$	AFM$_2$	AFM$_3$	AFM$_4$
Acid attack Compressive strength (N/mm^2)	20.2	18.66	15.74	12.96
Average tensile strength of geopolymer concrete	2.56 Mpa			

8. CONCLUSIONS

- M20 grade GPC can be formed by adopting nominal mix of 1:1.5:3 (fly ash: fine aggregates: coarse aggregates) and fixing alkaline liquid to fly ash ratio as 0.35.
- With increase in concentration of sodium hydroxide strength increases.
- With increasing alkaline liquid to fly ash ratio strength decreases.
- GPC gains its final strength in 7 days which is 4 times faster than ordinary plain cement concrete. In 3 days there is more than 50% gain in strength.
- Optimum ratio between sodium silicate and sodium hydroxide to get maximum strength is 2.5. Ratio below or above 2.5 strength gets decreased.
- High temperature (about 60^{0}C) curing is necessary for the development of strength.
- There is decrease in strength in GPC when immersed in acid solution. Cubes with lower alkaline liquid to fly ash ratio showed large decrease in strength as compared to cubes with higher alkaline liquid to fly ash ratio.
- Permeability of GPC is very low. Permeability increases with increase in alkaline liquid to fly ash ratio.
- With increase in alkaline liquid to fly ash ratio workability increases. Mix with alkaline liquid to fly ash ratio less than 0.3 is very stiff.

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