Experimental study of effects of super plasticizer on the strength of Geo-polymer concrete

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***Abstract*— Geo-polymer concrete utilizes an alternate material including fly ash as binding material in place of cement. This fly ash reacts with alkaline solution (e.g., NaOH) and Sodium Silicate (Na_2SiO_3) to form a gel which binds the fine and coarse aggregates. Since Geo-polymer concrete is the emerging field, the guidelines from the Bureau of Indian Standards are yet to be formulated. An attempt has been made to find out an optimum mix for the Geo-polymer concrete. Concrete cubes of size 150 x 150 x 150 mm were prepared and cured in oven for 24 hours. The compressive strength was found out at 7 days and 28 days. The results are compared. The optimum mix is Fly ash: Fine aggregate: Coarse aggregate (1:1.5:3.3) with a solution (NaOH & Na_2SiO_3 combined together) to fly ash ratio of 0.35. This mix is further prepared with adding PAC 2% by mass of fly ash and the effects on the compressive strength, flexural strength and split tensile strength, Stress-Strain were checked. High and early strength was obtained in the Geo -polymer concrete mix while strength started reducing in the presence of PAC.**

Keywords: Geo-polymer concrete, optimum mix ratio, PAC

I. INTRODUCTION (*HEADING 1*)

General

Concrete, a usual mixture of cement with sand, crushed rocks and water is currently a most sought-after choice for the construction material. In United States only, 63 billion tons of Portland cement was transformed into 500 billion tons of mortar, five times the consumption by weight of steel. In several countries the ratios of mortar consumption to steel consumption go beyond ten to one. The total world consumption of mortar is expected to be 11 billion metric tons each year. Water is the only thing that human being utilizes in such a huge volume. Even though, the worldwide concrete production is of key importance the cement production affects the environment with major impact being global warming due to CO_2 emission during production of cement. The cement production is accountable for about 3% of the global greenhouse gas emission and for 5% of the global CO_2 emission. Given that 50% of the CO_2 emitted during cement production is related with the decomposition of limestone during burning, the incorporation of clinker with auxiliary materials is therefore thought to be very efficient way to reduce CO_2 emission. Usually the cement production utilizes the industrial wastes as a blending material. Since the recycling of industrial wastes has technical, economical and environmental benefits along with the reduction of CO_2 emission from cement production. While the use of waste and by-products in mortar production improve the performance of mortar and expected to be economical too. Generally fly ash, blast furnace slag and silica fume uses industrial wastes in cement and mortar production because of their pozzolanic activity. In addition to pozzolanic materials, other inert by-products and waste materials are also used in mortar and cement production as inert filler material. Among these, Fly ash based Geopolymer Cement is recommended by various researchers for its application in mortar production as cement alternatives. A good number of the researches confirm their positive effects and benefits.

II. MATERIALS USED

Cement as binder material ,replacement by fly ash ,its obtained by satpura power plant sarni, betul, M.P.

Sodium hydrooxide is available in th locla market in pellet form its 10 molar solution used.since moleculer weight of sodium hydrooxide is 40 , and I order to prepare 10 molar solution 10×40= 400 gms of sodium hydrooxide dissolved in 1000 ml of water.

Sodium silicate is also commercially available in market . Its reactivity with sodium hydroxide depends upon the Na_2O/SiO_2 ratio which was maintained as 2.2. The mass of soluble silicate (SiO_2) and sodium oxide (Na_2O) present in sodium silicate liquid is 33% and 15% respectively, and rest 52% is water

Poly aluminum chloride In this test liquid poly aluminum chloride is to be used. Poly aluminium chloride (PAC) is manufactured in both liquid and powder form. The product is used in deodorants and antiperspirants, as a flocculants in water purification, in treatment of drinking / potable water, wastewater treatment and paper sizing

III. Trial mix Design

Taking previous studies on Geopolymer concrete (Van Chanh Bui et al., 2008; Wallah & Rangan, 2006) as reference we used a mix proportion of fly ash: Fine Aggregate: Coarse Aggregate are 1:1.35:3.17 with a solution (NaOH& Na_2SiO_3 combined together) to fly ash ratio of 0.35. Four trail mixes were prepared by slightly modifying the quantities of fine and coarse aggregates. The proposed mix ratios are: Trial Mix I - : 1:1.3 : 3.10; Trial Mix II - : 1:1.4 : 3.20; Trial Mix III- : 1:1.5 : 3.30; Trial Mix IV- : 1:1.6: 3.40. For all the four trial mixes, the solution to fly ash ratio was kept same as 0.35. The exact quantities for 1m^3 are presented in Table below.

Table 1 Proportions of trial mix prepared

Materials	Mix I(Kg/m^3)	Mix II(Kg/m^3)	Mix III(Kg/m^3)	Mix IV(Kg/m^3)
Flyash	408	408	408	408
Sand	530.40	571.20	612.00	652.80
Coarse Aggregate	1264.80	1305.60	1346.40	1387.20
Sodium meta silicate solution	103	103	103	103
Sodium Hydroxide Solution (10M)	41	41	41	41

IV. Mixing of Geo-polymer concrete

The fly ash, fine aggregates and coarse aggregates were mixed manually in a container and then the alkaline solution was added to prepare the geo-polymer concrete. The geo-polymer

Concrete was placed in 150 mm cube moulds in three layers and each layer was compacted by giving 25 blows with a 25mm tamping rod.

Volume of cube = $.15\times.15\times.15$ m^3

$= 3.375\times10^{-5}$ m^3

Volume of 3 cubes = $3\times3.375\times10^{-5}$ m^3

$= 0.010125$m^3

Table 2 Quantity of materials consumed in preparation of specimens of each group.

Materials	Mix I (Kg)	Mix II (Kg)	Mix III (Kg)	Mix IV(Kg)
Fly ash	4.131	4.131	4.131	4.131
Sand	5.37	5.78	6.19	6.60
Coarse Aggregate	12.80	13.21	13.63	14.04
Sodium meta silicate solution	1.04	1.04	1.04	1.04
Sodium Hydroxide Solution (10M)	0.41	0.41	0.41	0.41

V. Compressive strength test

To observe the performance of concrete prepared by each mix this test was performed.

For compressive strength cubes of dimensions 150mm×150mm×150mm were prepared. To check the repeatability of results three cubes of each mix were prepared and then tested for 7days and 28 days strength in compression testing machine.

Table 3 Compressive strength achieved by each trial mix

Mix	Samples code	Compressive strength in N/mm^2		Average strength in 28 days in N/mm^2
		7 days	*28 days*	
I	S1	32.0	37.33	39.70
	S2	36.5	39.11	
	S3	38.0	42.66	
II	S1	43.5	47.11	47.55
	S2	42.5	48.0	
	S3	41.0	47.55	
III	S1	47.0	51.55	52.44
	S2	48.5	53.33	
	S3	48.0	52.44	
IV	S1	42.0	48.88	48.73
	S2	41.5	43.33	
	S3	39.8	48.00	

From above test it was observed that the increase in percentage of fine aggregates and coarse aggregates increased the compressive strength up to the optimum level. This may be due to the high bonding between the aggregates and alkaline solution. The compressive strength was found reduced beyond the optimum mix.

This may be due to the increase in volume of voids between the aggregates. The optimum mix is- Fly ash: Fine aggregate: Coarse aggregate are 1:1.5:3.3 with a solution (NaoH& Na_2SiO_3 combined together) to fly ash ratio of 0.35 i.e. **MIX III.** Now this mix will be prepared with different proportions of super-plasticizer and will be tested

VI Final Mix Design

In this design super-plasticizer is added to the **Mix III** at the rate of 2% of quantity of fly-ash, further this 2% is mixed in the proportion of 20%, 40%, 60%, 80%, & 100%.

Total quantity of materials to be consumed is calculated as follows.

Volume of cube = $.15 \times .15 \times .15\ m^3$

$= 3.375 \times 10^{-5}\ m^3$

Volume of 3 cubes = $3 \times 3.375 \times 10^{-5}\ m^3$

$= 0.010125 m^3$

Volume of cylinder = $5.29875 \times 10^{-3}\ m^3$

Volume of 3 cylinders = $3 \times 5.29875 \times 10^{-3}$

$= 0.01589625\ m^3$

Volume of beam = $0.15 \times 0.15 \times 0.70 m^3$

$= 0.01575 m^3$

Volume of 3 beams = $3 \times 0.01575 m^3$

$= 0.04725 m^3$

Therefore, total volume of concrete = 0.010125+ 0.01589625 + 0.04725= $0.07327125 m^3$

Table 4 Actual quantity of materials consumed per mix on adding PAC

Materials	Mix I (Kg)	Mix II (Kg)	Mix III (Kg)	Mix IV(Kg)	Mix V (Kg)	Mix VI (Kg)
Flyash	29.89	29.89	29.89	29.89	29.89	29.89
Sand	44.84	44.84	44.84	44.84	44.84	44.84
Coarse Aggregate	98.65	98.65	98.65	98.65	98.65	98.65
Sodium meta silicate solution	7.54	7.54	7.54	7.54	7.54	7.54
Sodium Hydroxide Solution (10M)	3.00	3.00	3.00	3.00	3.00	3.00
Poly Aluminium chloride	-	0.59	0.47	0.35	0.23	0.11

4Tests performed on hardened concrete

4.1 Compressive, Flexural and Split tensile strength test

To observe the performance of Geo-polymer concrete prepared by addition of PAC these tests were performed. For compressive strength cubes of dimensions 150mm×150mm×150mm were prepared. To check the repeatability of results three cubes of each mix were prepared and then tested for 7days and 28 days strength in compression testing machine.

For flexural strength beams of dimensions 150mm×150mm×700mm were prepared. To check the repeatability of results three beams of each mix were prepared and then tested for 28 days strength in universal testing machine. For split tensile strength cylinders of diameter 150mm and height 300mm were prepared. To check the repeatability of results three cylinders of each mix were prepared and then tested for 28 days strength in compression testing machine. The results obtained from above test are discussed in Result Analysis section. however the values obtained from the above test in all the cases are depicted below.

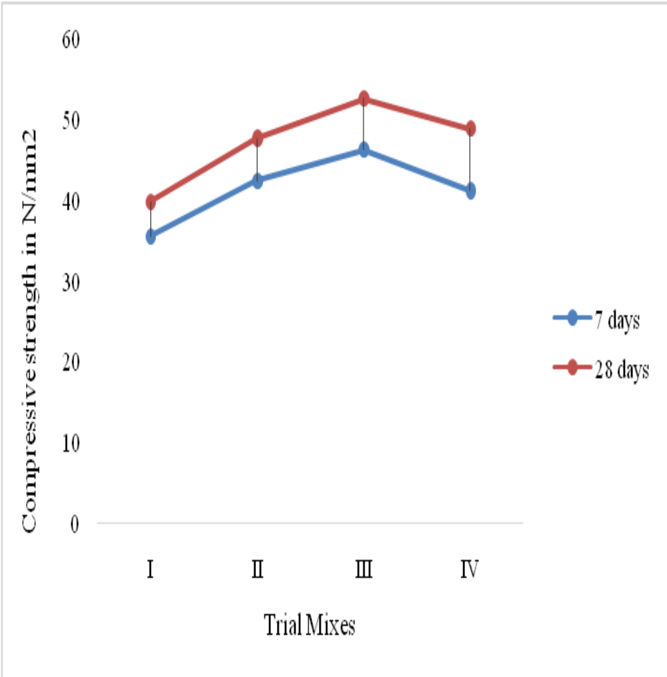
Table 5: Indicates the values of strengths achieved when PAC is added to each mix.

Strengths achieved on adding PAC with standard mix.						
Mix	% of addition of PAC	Samples code	Compressive strength in N/mm2		Flexural strength in N/mm2	Split tensile strength in N/mm2
			7 days	*28 days*		
Mix I	**0%**	S1	47	51.55	5.02	5.67
		S2	48.5	53.33	5.11	5.86
		S3	48	52.44	5.06	5.76
Mix II	**20**	S1	40.2	44.66	4.67	4.91
		S2	41.1	45.6	4.72	5.01
		S3	39.8	44.22	4.79	4.86
Mix III	40%	S1	41.3	45.88	4.74	5.04
		S2	41.9	46.55	4.77	5.12
		S3	42.3	47	4.79	5.17
Mix IV	60%	S1	42.9	47.66	4.83	5.24
		S2	43.2	48	4.84	5.28
		S3	43.6	48.44	4.87	5.32
Mix V	80%	S1	44.8	49.77	4.93	5.47
		S2	43.9	48.77	4.88	5.36
		S3	44.2	49.11	4.90	5.40
Mix VI	100 %	S1	45.7	50.77	4.98	5.58
		S2	45	50	4.94	5.50
		S3	46.1	51.22	5.00	5.63

The complete analysis of results is as follows:

Table 7 average compressive strength achieved by trial mix.

Mix	Average compressive strength in N/mm2	
	7 days	*28 days*
I	35.5	39.70
II	42.33	47.55
III	46.16	52.44
IV	41.1	48.73

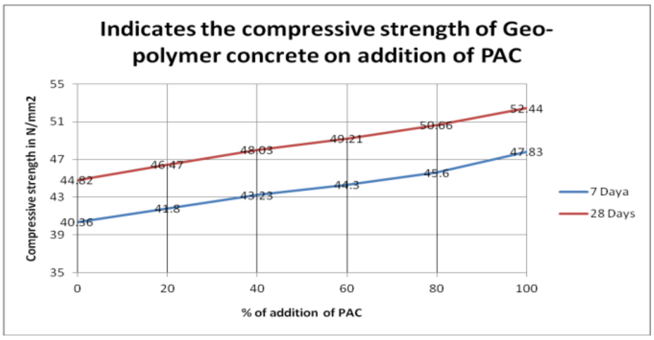


Graph 1 Showing average compressive strength of trial mixes.

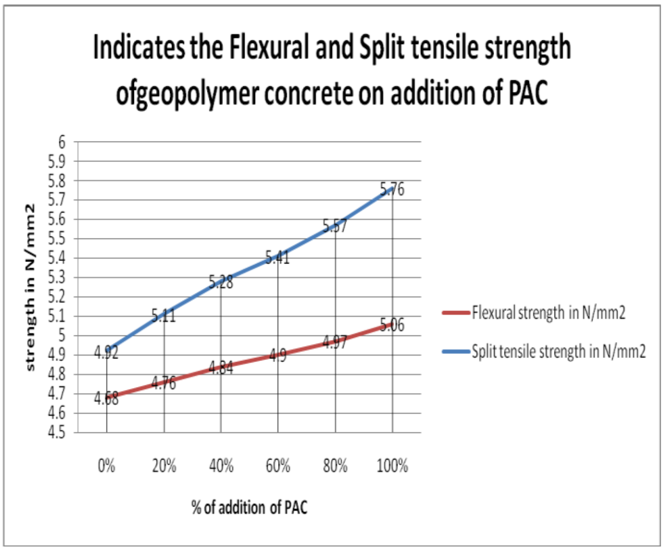
Trial mix III was found to be the optimum mix which is further prepared with PAC and all tests were performed on it.

Table 8: Indicates the average values of strengths achieved on adding PAC with the mix.

Mix	% of addition of PAC	Compressive strength in N/mm2		Flexural strength in N/mm2	Split tensile strength in N/mm2
		7 days	28 days		
Mix I	0	40.36	44.82	4.68	4.92
Mix II	20	41.8	46.47	4.76	5.11
Mix III	40	43.23	48.03	4.84	5.28
Mix IV	60	44.3	49.21	4.90	5.41
Mix V	80	45.6	50.66	4.97	5.57
Mix VI	100	47.83	52.44	5.06	5.76



Graph 2: Indicates the compressive strength of Geopolymer concrete on addition of PAC



Graph 3: Indicates the Flexural and Split tensile strength of geo-polymer concrete on addition of PAC

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RESULT ANALYSIS & DISCUSSION

From the whole experimental program it was observed that The Geo-polymer concrete showed high performance with respect to the strength. The Geo-polymer concrete was a good workable mix. High early strength was obtained in the Geo-polymer concrete mix. The increase in percentage of fine aggregates and coarse aggregates increased the compressive strength up to the optimum level. This may be due to the high bonding between the aggregates and alkaline solution. The compressive strength was found reduced beyond the optimum mix. This may be due to the increase in volume of voids between the aggregates. The optimum mix is- Fly ash: Fine aggregate: Coarse aggregate are 1:1.5:3.3 with a solution (Na OH & Na_2SiO_3 combined together) to fly ash ratio of 0.35.he initial and final setting time of Geo-polymer cement are much more than normal concrete. Increase in the strength was observed on addition of PAC to the mix

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