To Enhance the Properties of Gepolymer Concrete for Different Molarities of NaOH and Varying Ratio of Na2SiO3/ NaOH

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ABSTRACT

The development of fly ash based geopolymer concrete is in response for the need of a 'greener' concrete in order to reduce the carbon dioxide emission from the cement production. Portland cement is one of the most energy intensive construction materials. Each ton of Portland cement releases a ton of carbon dioxide into the atmosphere. On the other side fly ash is waste material available from thermal power plant. Fly ash is possible up to certain extent to reduce the cementing material due to pozzolanic activity of fly ash. It is necessary to activate the fly ash by using alkaline activators. At present study investigations sodium based activators are used. Sodium hydroxide solution having different molarity concentration is used and Sodium silicate solution with Na_2O *and* SiO_2 *were maintained constant throughout the experimentation. Further Geopolymer technology is new technology in which pozzolanic material which is rich in silica and alumina is used and it is activated by alkaline activators. Alkaline solutions may be sodium based or potassium based. Generally sodium based solution is used from economy and availability point of view.The experimental paper presents the cube test results of geopolymer concrete with different molarities of sodium hydroxide with various ratio of sodium silicate solution. This adopted mix design of M30 grade of geopolymer concrete procedure is relevant to previously adopted experimental study adopted by S.V.Patankar et.al(2013) carried the research of binder ratio in the production of fly ash based geopolymer concrete. This existing cement concrete Mix Design was applied to Geopolymer Concrete as experimental study to identify the higher compressive strength of concrete cubes with different molarities of sodium hydroxide.*

Keywords: *fly ash; geopolymer concrete ; sodium hydroxide; sodium silicate.*

I.INTRODUCTION

The greatest difficulties concern the developing countries which are in urgent need of implementations. A framework capable of providing necessary building houses, goods, & entire fundamental needs of their population. Potential for concrete & need for cement manufacture in developing countries are tremendous .Concrete is the most commonly used construction material in the world. Due to exponential use of concrete, cement production has increased at much higher speed. It is estimated that one MT of cement production approximately results into the production of one MT of carbon dioxide gas. This is the main cause of global warming. Thus the researchers are searching for alternative to cement. Davidovits (1988; 1994) Proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term 'Geopolymer' to represent these binders. The main constituents of geopolymer concretre are source material which is rich in silica & alumina

, alkaline liquids .The alkaline liquids are prepared from soluble alkali metals which are mainly sodium or potassium based. Sodium based solutions are easily available & are economical as compared to potassium based solutions

In geopolymer technology 100 % replacement of cement is possible by using the source materials and alkaline liquids. The most commonly used source materials are fly ash, GGBS, Metakeolin. In India more than 100 million tons of fly ash is produced annually, out of which 17 – 20 % fly ash is utilized either in concrete as a part replacement of cement or workability improving admixture or in stabilization of soil [6-7].Molarities of NaoH is also important to enhance the properties of Geopolymer concrete. Generally sodium hydroxide is available in solid state in the form of flakes or pellets. Cost of sodium hydroxide depends upon purity of substance. Sodium silicate is a combination of Na_2O and SiO_2.Ratio of Na_2O/SiO_2 also plays important role in Geopolymer concrete.This study aims to synthesize geopolymer concrete for varying ratio of Na_2SiO_3/NaOH.

A new technology material like geopolymers that offer waste utilization and emissions reduction, in which fly ash is used as a base material instead of OPC in geopolymer concrete.

The present work is carried out in the framework of a project aims to produce the geopolymer concrete with different molarities of sodium hydroxide (NaOH) with the variation in ratio of sodium hydroxide to sodium silicate (Na2SiO3) solution to find out the higher compressive strength. In this project work, geopolymer is used as the binder instead of cement paste to produce the concrete. The geopolymer paste binds the loose course aggregates ,fine aggregates together to form the geopolymer concrete. Geopolymer concrete do not require any water for matrix bonding instead the alkaline solution react with silicon and aluminium present in the fly ash. The polymerization process involves a substantially fast chemical reaction under alkaline condition. As in the case of OPC concrete, the course and fine aggregates occupy about 75 to 80% of the mass of geopolymer concrete. These components of geopolymer concrete mixtures can be designed using the tools currently available for OPC concrete. The compressive strength and the workability of geopolymer concrete are influenced by the proportions and properties of the constituent materials that make the geopolymer paste

II.OBJECTIVES OF STUDY

A. To investigate the compressive strength of geopolymer concrete with varing molarities of NaOH).

B. To study the effect on strength of geopolyemer concrete with ratio of Na2SiO3/ NaOH in the mix.

C. To study flexural and tensile strength of geopolymer concrete.

III MATERIAL

Fly ash P63, produced from Dirk India Pvt.Ltd Nashik , confirms to IS 3812(Part I) [16] of Specific gravity 2.25 and fineness 435 Sqm/kg. was used as a binder as listed in table I. The aluminosilicate binders (fly ash) were activated by a mixture of sodium hydroxide and sodium silicate solutions. Sodium hydroxide solution with desired concentration was prepared by mixing 97-98% pure pellets with tap water as listed in table II. Sodium silicate solution with SiO2 to Na2O ratio 2.25 was used as listed in table III. The fine aggregates used was natural sand of specific gravity and fineness 2.47 and 3.15 respectively as listed in table IV & V. Course aggregates were crushed stone with maximum size 20mm(75%) and minimum size 10mm (25%) with specific gravity 2.90 as listed in table IV.

TABLE I

Physical properties of fly ash.

Sr. No.	Physical property	Unit	Manufacture Specifications of fly ash	IS 3812-1981 specific ations
1	Sample name	-	P63	-
2	Colour	-	Light grey	-
3	Residual retained	%	10	34

4	Fineness	Cum/ kg	435	320
5	Specific gravity	-	2.25	-
6	Moisture content (max)	%	0.50	2

TABLE II : Chemical composition of sodium hydroxide.

Chemical Composition	**Percentage**
Sodium hydroxide (Minimum assay)	98
Carbonate	2
Chloride	0.01
Sulphate	0.05
Potassium	0.10
Silicate	0.05

TABLE III

Chemical composition of sodium silicate

Chemical Composition	**Percentage**
Na_2O, %	15.06
SiO_2, %	34.01
Ratio of Na_2O:SiO_3	2.25
Total Solid %	49.07
Water content %	50.93

TABLE IV

Properties of fine and course aggregates

Phisical properties	Coarse aggregates		Fine aggregates (Sand)
	CA-I	CA-II	
Type	Crushed ,angular shape	Crushed ,angular shape	River natural sand
Max.Size	20 mm	10 mm	4.75 mm
Specific gravity	2.90	2.90	2.47
Water absorption	0.90 %	0.90%	0.50%
Moisture Content	Nil	Nil	Nil
Fineness modulus	-	-	3.15

IV. EXPERIMENTAL WORK

A. Material-The experimental work is assigned to meet the objectives mentioned above. The mixes with various molarities of NaOH of M8, M10, M12, M13 and M14 with fly ash (P63) quantity at 410kg/cum and ratio of Na2O/SiO2 is 2.25 is kept constant for every mix of specimens. The variation in ratios of solution of Na2SiO3/ NaOH will be 1:1, 1:1.5 and 1:2 . The ratio of geopolymer activator is taken as (Na2SiO3+NaOH)/Fly ash=0.35 in which fly ash (P63) quantity at 410kg/cum is considered. The total mass of wet concrete mix is considered as 2535kg/cum. The density of water is taken as 108.35 kg.

B. Mix design-The example of mix design of geopolymer concrete is explained below for M12 molarities with ratios of solution of Na2SiO3/ NaOH is 1:1. (Na2SiO3+NaOH)/Fly ash=0.35 , Na2SiO3+NaOH=0.35x410=143.50 kg/cum

Therefore NaOH=71.75 kg/cum , Na2SiO3=71.75 kg/cum and fly ash=410.00 kg/cum. NaOH molarities calculation, Molecular weight of NaOH=40 i.e for 12 molarities 12x40=480 grams of NaOH solids per liter of water, therefore weight of water with NaOH of one liter=1447 gms. (480/1447)x100=33.17=A

i) (A/100)x71.75=(33.17/100)x71.75=23.80=B

ii) (49.07/100)x71.75=35.21=C

iii) D=B+C=23.80+35.21=59.01

iv) E=143.50-D=143.50-59.01=84.49

v) Extra water=108.35-E=108.35-84.49=23.86

vi) Total aggregates (TA)=2535.00-(71.75+71.75+410.00+23.86)=1957.64 kg/cum

vii) Fine aggregates (FA)=(34.50/100)xTotal aggregates(TA)=(34.50/100)x1957.64 =675.39 kg/cum

viii) Course aggregates (CA)=TA-FA=1957.64-675.39=1282.25 kg/cum.

The quantities of materials required for geopolymer concrete per cum for M12 of NaOH and ratio of Na2SiO3/ NaOH =1:1, 1:1.5, 1:2 is as listed in table VI.

TABLE V :Fine aggregate grading

Sr. No	Sieve size mm	Wt.retained gms.	Cumulative % wt.retained	
1	10.00	028.00	04.90	Fineness modulus =3.15
2	04.75	232.00	16.50	
3	02.36	233.00	28.15	
4	01.18	460.00	51.15	
5	00.60	218.00	62.05	
6	00.30	280.00	76.05	
7	00.15	003.00	76.20	
		Total	315.00	

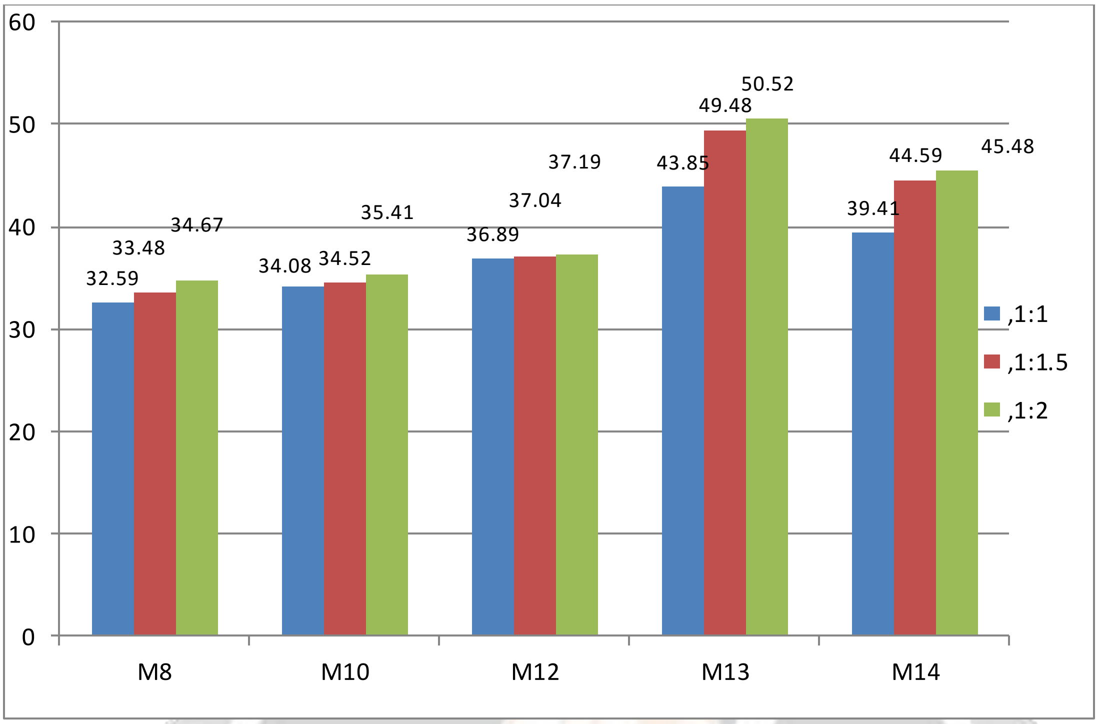
TABLE VI: Material required for M12 molarities of NaOH and Na2SiO3/NaOH ratios according to above mix desgin.

Sr. No.	Molarities	Na2SiO3/ NaOH	Fly ash (kg/cum)	Fine aggregates (sand) (kg/cum)	Course aggregates (stone metal) (kg/cum)	NaOH solution(kg /cum)	Na2SiO 3 solution (kg/cum)	Extra water (kg/cum)	Total in kg
1	12	1.00	410.00	675.39	1282.25	71.75	71.75	23.86	2535.00
2		1.50	410.00	674.46	1280.48	57.40	86.10	26.56	2535.00
3		2.00	410.00	673.91	1279.43	47.20	96.30	28.16	2535.00

TABLE VII Compressive strength of cubes (150x150x150mm) for different molarities in N/sq.mm (MPa)

Sr. No.	Molarities	Na2SiO3/ NaOH	3 days	7 days	28 days	Molarities	Na2SiO 3/NaOH	3 days	7 days	28 days
1	8	1.00	23.04	24.00	32.59	10	1.00	33.19	33.48	34.08
2		1.50	23.70	24.89	33.48		1.50	33.63	34.22	34.52
3		2.00	24.89	25.19	34.67		2.00	33.78	34.37	35.41
1	12	1.00	35.70	36.44	36.89	13	1.00	42.37	42.97	43.85
2		1.50	35.85	36.59	37.04		1.50	46.08	48.44	49.48
3		2.00	36.30	36.74	37.19		2.00	48.30	49.48	50.52
1	14	1.00	37.93	38.52	39.41					
2		1.50	41.34	43.41	44.59					
3		2.00	43.41	44.59	45.48					

GRAPH-I Compressive strength of cubes shown in column in N/sq.mm and different molarities of NaOH in rows and ratio of Na2OH/NaOH in legends



V. METHODOLOGY

A.Preparation of Alkaline Solutions

In this project the compressive strength of geopolymer concrete is examined for the mixes of various molarities of sodium hydroxide (NaOH) viz. M8, M10, M12, M13 and M14. The molecular weight of sodium hydroxide is 40. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For example NaOH solution with concentration of 13 molar consists of 13x40=520 grams of NaOH solids per liter of water. It was recommended that the sodium hydroxide solution must be prepared 24 hours prior to use.

B. Alkaline Liquid

Alkaline liquids were prepared by mixing of the sodium hydroxide solution and sodium silicate solution at the room temperature. When the solution mixed together the both solution start to react i.e polymerization take place. It produce large amount of heat, so it is left for 20 minutes to take place of as binding agent.

C. Mixing and Casting

The mix proportions were as given in table-VI, as there are no code provisions for the mix design of geopolymer concrete , the density concrete was taken as 2535 kg/cum. The other calculations are done by considering the density of concrete. The quantities of all ingredients were variable except flay ash of 410kg/cum has kept constant as given in table-VI and molarities of NaOH is changed in the each mix.

First of all ,the fine aggregates ,course aggregates and fly ash were mixed together in dry condition for 4-5 minutes and then alkaline solution of which was previously prepared with combination of sodium hydroxide and sodium silicate solutions was added to the dry mix. The mixing has done about 6-8 minutes for proper binding of all materials. After mixing the cubes of size 150x150x150 mm were casted by giving proper compaction with using table vibrating machine for 1-2 minutes.

D. Curing

After 24 hours of rest period, the cubes were demoulded and kept in an oven at 60 C for 24 hours for heat curing. At the end of curing period the cubes were removed from the oven and allowed to cool down to room temperature in open area till the day of testing.

E. Test results

The compressive strength test was carried on geopolymer concrete cubes specimen as per IS:516-1959 in universal testing machine. A minimum of three samples were tested to evaluate the compressive strength. The samples were tested for 3, 7 and 28 days. The results of compressive strength are shown in graph-I are the average of the results of three specimens. The various parameters of mixes such as the molarities of NaOH solution are presented in table-VI. It is seen from the present results that the strength of cubes are increased gradually with increase of molarities of NaOH solution from M8 to M13 and then for M14 the strength of cubes are decreased. So that M13 has the more strength with comparison with other molarities as shown in graph-I..

VI CONCLUSION

The results of experimental project work are as presented and discussed above. The following conclusions can be drawn as under.

A. The compressive strength is increased gradually with increase of molarities from M8 to M13 and decreased at M14 due to ratio of solutions of sodium hydroxide and sodium silicate to certain mix proportion because the higher concentration of NaOH up to M13 will make the good bonding between aggregate and the paste of concrete.

B. The compressive strength of geopolymer concrete increases due to the more availability of Na_2SiO_3 ratio in the mix .i.e strength of 1:2 is more than 1:1.(/Na_2SiO_3/ NaOH).

C. Compressive strength reached for the age of 3days specimen is not significantly increased for 7 and 28 days when tested.

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