Properties of Geopolymer Concrete for Split Tensile Strength of Cylinder with Different Molarities of NaOH.

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ABSTRACT

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 split tensile strength of cylider 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 concrete split tensile strength of cylinder with different molarities of sodium hydroxide.

Keyword :- *Geopolymerconcrete, Sodiumhydroxide, Sodium silicate, flyash*

1. INTRODUCTION

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 experimental work is carried out in the framework 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 split tensile strength of cylinder tests. In this experimental 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 tensile strength of cylinder tests and the workability of geopolymer concrete are influenced by the proportions and properties of the constituent materials that make the geopolymer paste

2 OBJECTIVES OF STUDY

- To investigate the split tensile strength of cylinder tests of geopolymer concrete with varying molarities of NaOH.
- To study the effect on split tensile strength of geopolyemer concrete with ratio of Na2SiO3/ NaOH in the mix.
- To study split tensile strength of geopolymer concrete with various molarites of NaOH .

3 MATERIAL

3.1 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. 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. Sodium silicate solution with SiO2 to Na2O ratio 2.25 was used. The fine aggregates used was natural sand of specific gravity and fineness 2.47 and 3.15 respectively. The Course aggregates were crushed stone with maximum size 20mm(75%) and minimum size 10mm (25%) with specific gravity 2.90.

Table - 1 Physical properties of fly-ash.

Sr.No.	Physical property	Unit	Manufacture Specifications of fly ash	IS 3812-1987 specifications
1	Sample name	-	P63	-
2	Colour	-	Light grey	-
3	Residual retained	%	10	34
4	Fineness	Sq.m/kg	435	320
5	Specific gravity	-	2.25	-
6	Moisture content (max)	%	0.50	2

Table - 2 Chemical composition of fly-ash used.

Chemical composition of fly ash	Quantity present in the fly-ash used (% mass)
SiO_2+Al2O_3+Fe_2O_3	92.65
SiO_2	61.18
Cao	1.34
MgO	-
Total sulphur as SO_3	-
Available alkali as Na_2O	0.051
Loss-on-ingnition	1.63

3.2 Sodium hydroxide

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so 98% purity of sodium hydroxide flakes was procured form M/s. Abhay Chemicals Ahmednagar and was used in this project whose chemical properties are given in table -3 as below.

Table - 3 Chemical composition of sodium hydroxide.

Chemical Composition	**Percentage**
Sodium hydroxide	97
Carbonate (Na_2CO_3)	2
Chloride (Cl)	0.01
Sulphate (SO_2)	0.05
Potassium (K)	0.10
Silicate (SiO_3)	0.05

3.4 Sodium silicate (Na_2SiO_3)

The sodium silicate solution used contained Na_2O=15.06% , SiO_2=34.01% of water by mass which ratio is 2.25 and was procured from M/s. Shanti Chemicals Belgavi. The chemical composition of sodium silicate is given in table - 4 as below.

Table - 4 Chemical composition of sodium silicate

Chemical Composition	**Percentage**
Na2O, %	15.06
SiO2, %	34.01
Ratio of Na2O:SiO3	2.25
Total Solid %	49.07
Water content %	50.93

3.4 Water

The role of water in the geopolymer mix is to make workable concrete in plastic state. The demand of water increases with increase in fineness of source material for same degree of workability. So the minimum quantity of water required to achieve desired workability is selected on the basis of degree workability ,fineness of fly-ash and grading of fine aggregate. The PH value of water shall not be less than 6 and is suitable for drinking is satisfactory for use in geopolymer concrete.

3.5 Alkaline liquid preparation

Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When solution mixed together the both solution start to take polymerization, it liberate large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent.

3.6 Molarities calculation of Sodium hydroxide

Solids of sodium hydroxide flakes dissolved in water to make a solution with the required concentration. The mass of NaOH solids in a solution varies depending on concentration of the solution.
For NaOH solution with concentration of 12 Molarities consists of 12x40=480 grams of NaOH solids per liter of water, where 40 is the molecular weight of NaOH.

4.0 Method adopted for mix proportioning (For M30 grade of concrete)

4.1 Data required for mix design

- Charecteristic compressive strength of geopolymer concrete (fck)
- Fineness of flay-ash in terms of specific surface in m^2/kg
- Workability in terms of flow
  Oven curing (heating) 60 ^OC for 24 hours and tested after 3 days, 7 days and 28 days
- Fineness modulus of fine aggregate
- f. Water absorption and water content in fine and coarse aggregate

The following design steps are used to select the suitable mix proportion of fly-ash based geopolymer concrete.

4.2 Target mean strength (Fck) for mix design

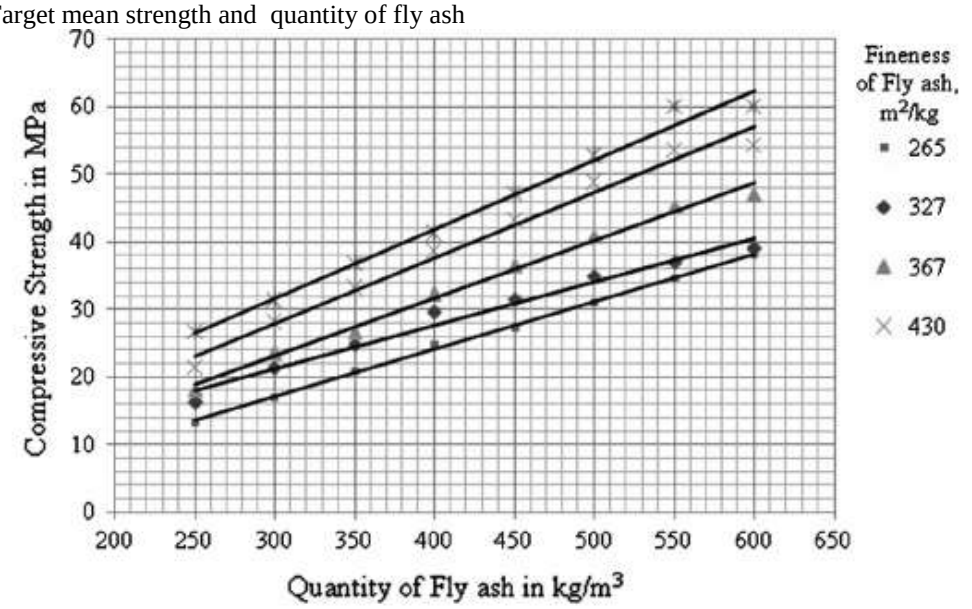
Fck=fck+1.65 x S

The standard deviation S for each grade of geopolymer concrete may calculated, separately on the basis of minimum 30 test samples. A pre IS 456-2000, the value of S is assumed as per Table

4.3 Fly-ash quantity calculations (F)

This quantity is based on target mean strength and fineness of fly-ash at solution-to-flay-ash ratio of 0.35 from chart -1

Chart - 1 Target mean strength and quantity of fly ash



4.4 Calculation of the quantity of alkaline activators

Based on the quantity of fly-ash (F) determined in the previous step, the amount of total solution is obtained using solution-to-fly-ash ratio of 0.35 by mass. Then the quantity of sodium silicate and sodium hydroxide is decided using sodium silicate-to-sodium hydroxide ratio of 1 by mass.

4.5 Total solid content in alkaline solution

Solid content in sodium silicate and sodium hydroxide solution ca ne calculated on the basis of percentage solid present in each solution.

4.6 Calculation of quantity of water

Workability of geopolymer concrete is depending on total quantity of water including water present in both alkaline solutions and the degree of workability. Total quantity of water shall be selected to achieve desired workability based on fineness of fly-ash as per Table - 5

Table - 5 Water content per cubic meter of concrete

Degree of workability	Flow in percentage	Quantity of water required in kg/m^3			
		Fineness of fly-ash in m$^{2/}_{kg}$			
		<300	300-400	400-500	>500
Low	0-25	80	85	100	110
Medium	25-50	90	95	110	120
High	50-100	100	110	120	135

Very high	100-150	120	130	140	160

4.7 Water content corrections

The volume occupied by fine and coarse aggregate is about 70-85% of total volume. As per previous study fine particles have large surface area as compared to coarse one. Hence more water required to produce workable mix. IS: 10262, suggested some correction in water content for mix proportioning of cement concrete on the basis of grading of fine aggregate.In geopolymere concrete ,the role of water is to make workable concrete. So that it is recommended to apply same correction to geopolymer concrete in the proposed mix design on the basis of grading zones of fine aggregate. Table - 6 shows the correction in water content per cubic meter of concrete on the basis of grading zones of the fine aggregate.

Table - 6 Correction in water content per cubic meter of concrete

Grading zone of fine aggregate as per IS 383	Correction in water content (%)
Zone-I	-1.5
Zone-II	-
Zone-III	+1.5
Zone-IV	+3

4.8 Calculation of additional quantity of water

The certain quantity of water is available in the alkaline solutions. It is necessary to meet workability requirements, additional water may be added in the mix externally which can be calculated as under. Additional quantity of water ,if required = [Total quantity of water] – [Water present in alkaline solutions]

4.9 PREPARATION OF GEOPOLYMER CONCRETE MIXES

Preparation of geopolymer concrete is similar to that of cement concrete. Two types of coarse aggregates, sand and fly ash were mixed in dry state. Then add prepared mixture solution of sodium hydroxide and sodium silicate along with extra water based on water-to-geopolymer binder ratio and mix thoroughly for 3–4 min so as to give homogeneous mix. It was found that the fresh fly ash based geopolymer concrete was viscous, cohesive and dark in color. Concrete cubes of side 150 mm are casted in three layers. Each layer is well compacted by tamping rod of diameter 16 mm. All cubes were place on table vibrator and vibrated for 2 min for proper compaction of concrete. After compaction of concrete, the top surface was leveled by using trowel. After 24 h of casting, all cubes were de molded and then placed in an oven for thermal curing (heating). To avoid the sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature in an oven. Three cubes were cast and tested for compressive strength for each curing period.

5. EXPERIMENTAL WORK

5.1 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.

5.2 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

- (A/100)x71.75=(33.17/100)x71.75=23.80=B
- (49.07/100)x71.75=35.21=C
- D=B+C=23.80+35.21=59.01
- E=143.50-D=143.50-59.01=84.49
- Extra water=108.35-E=108.35-84.49=23.86
- Total aggregates (TA)=2535.00-(71.75+71.75+410.00+23.86)=1957.64 kg/cum
- Fine aggregates (FA)=(34.50/100)xTotal aggregates(TA)=(34.50/100)x1957.64 =675.39 kg/cum

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

Table -7 Details of calculations for value of "A" for various molarities as stated in above mix design

Sr.No.	Molarities of NaOH	Wt.of NaOH according to molecular wt.(40) (col.2x40) in gms.	Wt. of NaOH Solids per liter of water in gms.	Value of "A" [(col.3/col.4)/100]
1	2	3	4	5
1	M8	320	1157	27.66
2	M10	400	1182	33.84
3	M12	480	1207	39.77
4	M13	520	1284	40.50
5	M14	560	1360	41.18
6	M16	640	1374	46.58
7	M24	960	1600	60.00

Table -8 Material required for various molarities of NaOH and Na2SiO3/NaOH ratios according to above mix design.

Sr.No.	Molarities	Na2SiO3/ NaOH	Fly ash (kg/cum)	Fine aggregates (sand) (kg/cum)	Course aggregates (stone metal) (kg/cum)	NaOH solution (kg/cum)	Na2SiO3 solution (kg/cum)	Extra water (kg/cum)	Total in kg
1	M8	1.00	410.00	676.75	1284.84	71.75	71.75	20.41	2535.00
2		1.50	410.00	675.69	1282.83	57.40	86.10	22.98	2535.00
3		2.00	410.00	674.98	1281.49	47.20	96.30	25.03	2535.00
1	M10	1.00	410.00	675.22	1281.94	71.75	71.75	24.34	2535.00
2		1.50	410.00	675.06	1281.63	57.40	86.10	24.81	2535.00
3		2.00	410.00	674.62	1280.79	47.20	96.30	26.09	2535.00
1	M12	1.00	410.00	673.75	1279.16	71.75	71.75	28.59	2535.00
2		1.50	410.00	673.29	1278.28	57.40	86.10	29.93	2535.00
3		2.00	410.00	672.98	1277.70	47.20	96.30	30.82	2535.00
1	M13	1.00	410.00	673.57	1278.81	71.75	71.75	29.12	2535.00
2		1.50	410.00	673.74	1279.12	57.40	86.10	28.64	2535.00
3		2.00	410.00	672.86	1277.47	47.20	96.30	31.17	2535.00
1	M14	1.00	410.00	673.40	1278.49	71.75	71.75	29.61	2535.00
2		1.50	410.00	673.01	1277.75	57.40	86.10	30.74	2535.00
3		2.00	410.00	672.75	1277.25	47.20	96.30	31.50	2535.00
1	M16	1.00	410.00	672.07	1275.94	71.75	71.75	33.49	2535.00

2		1.50	410.00	671.95	1275.59	57.40	86.10	33.96	2535.00
3		2.00	410.00	671.86	1275.56	47.20	96.30	34.08	2535.00
1		1.00	410.00	668.74	1269.65	71.75	71.75	43.11	2535.00
2	M24	1.50	410.00	669.29	1270.67	57.40	86.10	41.54	2535.00
3		2.00	410.00	669.54	1271.16	47.20	96.30	40.80	2535.00

5.3 Split tensile strength

According tom IS 5816-1999 for determining split tensile strength cylinder specimens of size 150mm in diameter and 300mm in length (according to IS: 10086-1982) are horizontally placed between the two plates of universal testing machine. Split tensile strength of cylinder specimen is determined by placing the between two plates of universal testing machine, ply strips of 3mm. thick, 25mm wide and 300mm long were placed between the plates and the surface of the concrete specimen. The split tensile strength of cylinder is calculated by the following formula.Fcys=2Psp/3.14DL Where , Fcys=Split tensile strength. Mpa, Psp=Load at failure N, L=Length of cylinder, mm D=Dia. Of cylinder,mm.

Table - 9 Split tensile strength of cylinders (150mm dia. & 300mm length) for different molarities in N/sq.mm (MPa)

Sr. No.	Molarities	Na2SiO3 /NaOH	28 days	Molarities	Na2SiO3 /NaOH	28 days	Molarities	Na2SiO3 /NaOH	28 days
1		1.00	1.97		1.00	1.76		1.00	2.62
2	M8	1.50	2.18	M10	1.50	2.56	M12	1.50	2.66
3		2.00	2.61		2.00	2.99		2.00	3.46
1		1.00	3.05		1.00	1.43		1.00	1.54
2	M13	1.50	3.47	M14	1.50	2.97	M16	1.50	1.93
3		2.00	4.00		2.00	3.18		2.00	2.62
1		1.00	1.50						
2	M24	1.50	1.85						
3		2.00	2.50						

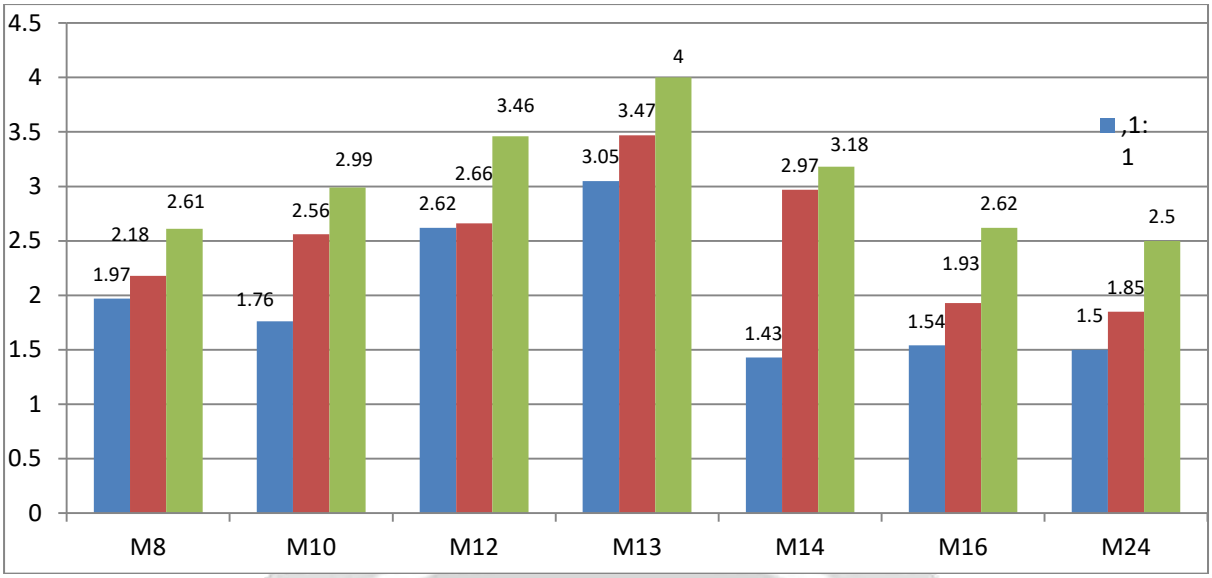


Chart - 2 Split tensile strength of cylinder (150mm.dia and 300mm.ht.) for 28days shown in column in N/sq.mm and different molarities of NaOH in rows and ratio of Na2OH/NaOH in legends

6.0 Test results

The split tensile strength of cylinder test was carried on geopolymer concrete cylinder specimen as per IS:516-1959 in universal testing machine. A minimum of three samples were tested to evaluate the split tensile strength. The samples were tested for 3, 7 and 28 days. The results of split tensile strength are shown in Chart- 2 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 - 9 It is seen from the present results that the split tensile strength of cylinder are increased gradually with increase of molarities of NaOH solution from M8 to M13 and then for M14,M16 and M24 the strength of split tensile strength of cylinder are decreased. So that M13 has the more strength with comparison with other molarities as shown in Chart- 2

7.0 CONCLUSION

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

- The split tensile strength of cylinder is increased gradually with increase of molarities from M8 to M13 and decreased at M14 to M24 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.
- The split tensile strength of cylinder of geopolymer concrete increases due to the more availability of Na2SiO3 ratio in the mix .i.e strength of 1:2 is more than 1:1.(/Na2SiO3/ NaOH).
- The split tensile strength of cylinder reached for the age of 3days specimen is not significantly increased for 7 and 28 days when tested.

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