International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-05, Aug 2019

Assessment of Compressive Strength of Geo-Polymer Concrete in Ambient Temperature [For DEHRADUN]

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Abstract - The geopolymer is a promising candidate as an alternative to ordinary Portland cement for developing various sustainable products in making building materials, concrete, fire resistant coatings, fibre reinforced composites and waste immobilization solutions for the chemical and nuclear industries. Large amount of industrial wastes are being released from various industries like power generation industry, iron making industry, steel making industry, mining industry, etc. These wastes like fly ash, bottom ash, blast furnace slag, metakaolin, etc poses various difficulties in their disposal. To overcome these waste management issues, the best solution is to utilize these waste products for some other applications. On the other hand cement industry have been found to be highly energy intensive industry acting as a major source for carbon dioxide emission leading to some serious environmental hazards like global warming, however, due to the need of high infrastructure the use of cement is unavoidable. Therefore, the approach can be to find the best alternative of the conventional Ordinary Portland Cement concrete which can provide better or comparable strength and durability properties and is economical and easy to prepare. The intense amount of work on geopolymeric binders derived from these industrial by-products have proved its utility having similar strength and durability properties that of conventional concrete. This alkali source provider, in the presence of alkaline medium forms geopolymerization products, that have comparable or even better characteristics than Calcium-Silicate-Hydrate products of conventional concrete.

Key words - Geopolymer, compressive strength, fly ash, alkaline activator, curing temperature.

I. Introduction

The demand of concrete is increasing day by day to complete the need of development of infrastructure facilities. It is well known fact that the production of OPC not only consumes significant amount of natural resources and energy but also releases huge quantity of carbon dioxide to the atmosphere. Therefore, it is necessary to find alternatives to make the concrete environment friendly with consideration of natural resources and atmospheric pollution.

It should be noted that, most of the geopolymer concrete tested so far was either heat cured or steam cured at higher temperature than ambient. While such concrete can be precast easily, it is not always practicable in cast-in-situ applications due to delayed setting and slow strength development in ambient condition. Hence it is necessary to investigate the properties of geopolymer concrete suitable for ambient curing condition. This study aimed to improve the mixtures of low calcium fly ash based geopolymer that can be cured in ambient condition without elevated heat.

II. Objective

Following are the objective of the study-

A. To obtain the compressive strength of the geopolymer concrete cured at ambient temperature (in March- April) in Dehradun.

B. Obtain the difference between oven cured and ambient cured geopolymer concrete compressive strength.

III. Materials Used in Geopolymers Concrete

A. Coal Fly Ash (Dry precipitator fly ash)

Coal fly ash mainly contains three types of particles i.e. spherical vitreous particles, Fe-oxide particles and irregular unburned coal particles . The composition of each particle type varies according to the quality of coal and boiler operation conditions. Unprocessed fly ash particle size can vary in the range 0.1 to 150 μm. The fly ash devided into two main groups i.e. class F and class C.

 DOI : 10.35291/2454-9150.2019.0385

[a] Class F fly ash (CFA)

Class F fly ash has been identified as the most suitable source material (anthracite & bituminous coal) for geopolymer binders because of its reactivity and availability.

The mass ratio of SiO_2 and Al_2O_3 in class F fly ash is in the range of 1.7 - 4.0 while the amorphous content is generally more than 50 %. Table illustrates typical chemical composition of the class F type fly ash. Shi et al. Class F fly ash has cleaner surface compared to class C fly ash due to the absence of alkalis and sulphates ions. As class F fly ash has low CaO level, the main reaction products generated by alkaline activation are amorphous geopolymer gel and sodium aluminium silicate hydrate (N-A-S-H).

[b] Class C fly ash (CCA)

Class C fly ash can be further segmented considering the percentage of calcium in it i.e. intermediate calcium fly ash has calcium 10-19.9% and high calcium fly ash has more than 20% calcium. High calcium fly ash has crystalline phases like free CaO, C_3A, C_2S ,$CaSO_4$, MgO and $4CaO.3Al_2O_3.SO_3$ which are not available in class F.

Class C fly ash gives different geopolymer structure compared to class F fly ash due to the availability of significant level of calcium. Class C fly ash has self-cementing properties which enable alkali activated class C fly ash to harden at room temperature. Class C fly ash formed from younger lignite or sub bituminous coal.

B. Alkaline solution

[a] Sodium Hydroxide

NaOH is also commonly used as an alkaline activator in geopolymer production. While it does not maintain the level of activation as a K^+ ion, sodium cations are smaller than potassium cations and can migrate throughout the paste network with much less effort promoting better zeolitization. Furthermore, it bears a high charge density which promotes additional zeolitic formation energy.

The concentration and molarity of this activating solution determines the resulting paste properties. While high NaOH additions accelerate chemical dissolution, it depresses ettringite and CH (carbon-hydrogen) formation during binder formation.

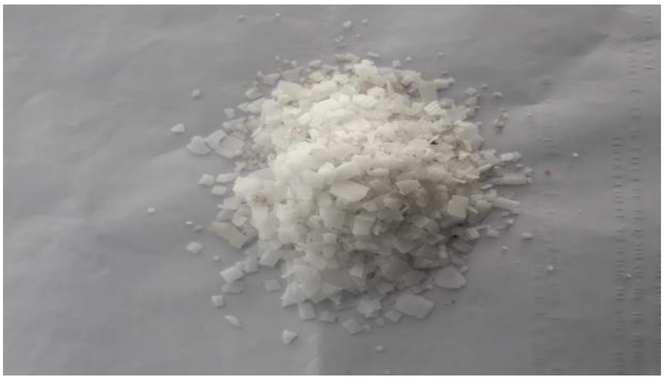

Fig 1 Sodium Hydroxide pallets

[b] Sodium Silicate

Sodium (or potassium) silicates are manufactured by fusing sand (SiO_2) with sodium or potassium carbonate (Na_2CO_3 or K_2CO_3) at temperatures in excess of 1100 °C and dissolving the product with high pressure steam into a semi-viscous liquid referred to as waterglass.

Waterglass is rarely used as an independent activating unit, because it does not possess enough activation potential to initiate pozzolanic reaction alone.

C.Fine aggregate

Sand taken from river beds and pits, is normally used as fine aggregate, after it is cleaned and rendered free from silt, clay and other impurities. Fine aggregate can be natural or crushed depending upon the local availability of it.

D. Coarse aggregate

Different types of naturally available aggregate i.e. quartzite gravel, flint gravel, lime stone, river gravel, crushed granite etc. were used in past to make geopolymer concrete. The size of coarse aggregate used in kept fairly uniform to minimize surface roughness and for better aesthetic. The use of geopolymer concrete is decide the size of aggregate used, and size can vary from 10mm to 20mm to optimize the strength. Coarse aggregates are produced by disintegration of rocks and by crushing rocks. There are available in many different sizes. Coarse aggregates are usually those particles which are retained on an IS 4.75mm sieve.

Fig 2 Coarse aggregate

E.Superplasticizer

We use the super plasticizer which name is SIKA VISCOCRETE 5101 NS. It has the aqueous solution of modified poly carboxylate, which has the light brown colour with ph value >6.

 DOI : 10.35291/2454-9150.2019.0385

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IV. MATERIAL PROPERTIES

4.1.Properties of fly ash:-

(a) Physical properties:

S.NO.	CHARCTERSTICS	OBSERVED VALUE	ASTM C-618 CLASS-C	AS PER IS-3812
1	Specific Gravity	2.20	2.5	2.10 – 2.52
2	Fineness (m2/kg)	400	200 - 600	200 – 600
3	Lime reactivity (N/mm2)	4.1	4	3.0 – 8.0
4	Loss on Ignition (% by mass)	0.65	1	0.3 – 8.8
5	Soundness by autoclave method	0.11	0.3	1.0 – 12

(b) chemical properties:

S.NO.	CHARACTERSTICS	OBSERVED VALUE%	(% RANGE) AS PER ASTM C-618	AS PER IS-3812
1	SiO2	63	41	37 – 66
2	Al2O3	24	20	20 – 31
3	Fe2O3	4	5	2 – 12
4	SO3	0.36	2	0.3 – 2.9
5	CaO	6	17	1.3 – 5.0
6	MgO	0.40	3	0.3 – 2.9

4.2. Fine aggregate:

S.NO.	PHYSICAL PROPERTIES	OBSERVED VALUE	RANGE ACCORDING TO IS -383 (1970)
1	Grading zone	2	As per IS-383(1970)permissible % passing
2	Fineness modulus	3.15	2.9 – 3.2
3	Specific gravity	2.60	2.6 – 2.67
4	Silt factor	2.76%	-
5	Water absorption	1.02	-

4.3. Coarse aggregate:

S.NO.	PHYSICAL PROPERTIES	OBSERVED VLUE
1	Fineness modulus (20mm)	6.9
2	Fineness modulus (10mm)	6.52
3	Specific gravity	2.70
4	Water absorption	0.45

V. METHODOLOGY

5.1. Trial mix-

MIX NO.	ALKALINE SOL./FLY ASH RATIO	FLY ASH (kg/m3)	FINE AGGREGATE (kg/m3)	COARSE AGGREGATE (kg/m3)	NaOH (kg/m3)	Na2SiO3	SUPER PLASTICIZER (kg/m3)	MOLARITY (M)
1.	0.35	380	800	1050	40	110	6	12 14 16 18
2.	0.40	380	800	1050	40	110	6	12 14 16 18
3.	0.45	380	800	1050	40	110	6	12 14 16 18

VI. EXPERIMENTAL RESULT

Four different alkaline solution to fly ash ratio as 0.35, 0.40, 0.45 with three different molarities as 12M, 14M & 16M with mixing of fly ash, coarse aggregate (20mm & 10mm) and fine aggregate properly and all the curing done at 90 degree centigrade because of previous literature study.

All the result associated with the effect of different curing conditions on the geopolymer concrete. Compressive testing of GPC trial mix known as M-1, M-2 & M-3 which has different properties and all the oven curing done for trial mix at the 90°C because of the literature shows that the strength developed in GPC is better at 90°C in comperision of 80-100°C curing -

 DOI : 10.35291/2454-9150.2019.0385

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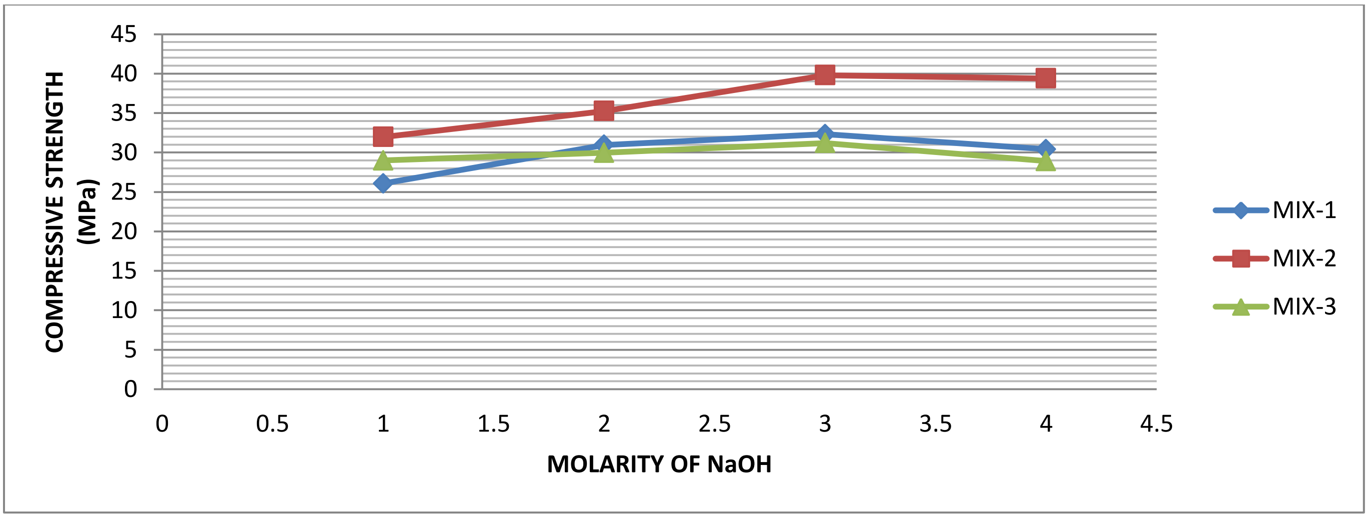
6.1 Compressive strength test result for the trial mix:

MIX	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
Alkaline solution to Fly ash ratio 0.35 @7 DAYS CURED AT 90°C **M 1**	**12**	**25.00**	**25.53**
		25.60	
		26.00	
	14	**29.00**	**28.77**
		31.10	
		26.20	
	16	**32.00**	**31.87**
		31.90	
		31.7	
	18	**30.00**	**29.99**
		29.2	
		30.77	

MIX	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
Alkaline solution to Fly ash ratio 0.40 @7 DAYS CURED AT 90°C **M-2**	**12**	**33.8**	**31.6**
		33.10	
		27.90	
	14	**36.00**	**35.17**
		34.90	
		34.6	
	16	**41.1**	**39.86**
		39.2	
		39.3	
	18	**40.0**	**39.43**
		39.20	
		39.1	

MIX	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
Alkaline solution to Fly ash ratio 0.45 @7 DAYS CURED AT 90°C **M-3**	**12**	**27.90**	**28.63**
		28.00	
		30.00	
	14	**29.70**	**29.9**
		30.10	
		29.90	
	16	**31.5**	**31.2**
		30.9	
		31.2	
	18	**29.10**	**28.87**
		27.80	
		29.70	

6.2 COMPARISION OF M-1, M-2 & M-3 (FOR OVEN CURING @90°C)



DOI : 10.35291/2454-9150.2019.0385

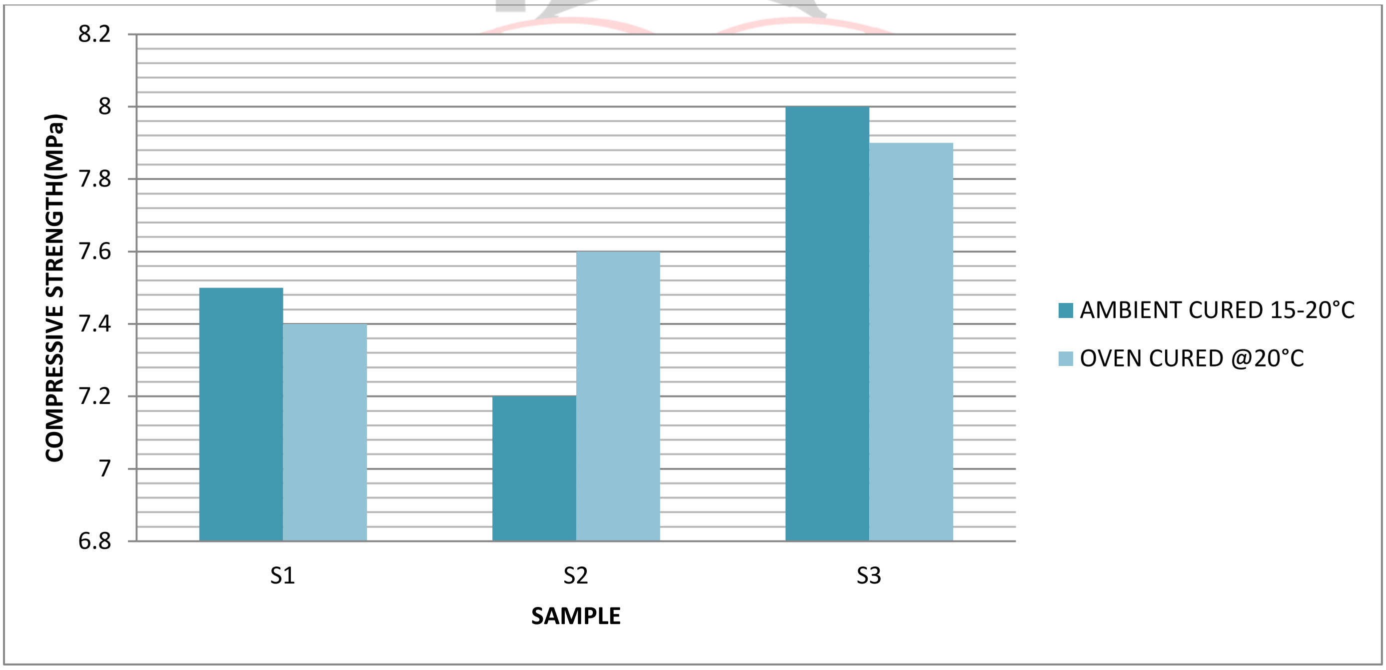
From the above graph we can easily compare all the alkaline solution to fly ash ratio and all the molarities of NaOH solution. And all the result shows that the target mean strength for M25 grade of geopolymer concrete fulfill at the molarity of 16M and when we found the alkaline solution to fly ash ratio is 0.35. From the above experimental study of Geo-polymer concrete we find a result as, there is a maximum value for M25 grade of Geo-polymer concrete when the alkaline solution to fly ash ratio is 0.35 and the molarity of the sodium hydroxide is 16M. So can choose this proportion for the experiment for the ambient curing of Geo-polymer concrete. And for this we prepare Mix X for the ambient curing in the month of March-April at Dehradun and we make sure the curing temperature satisfactory we do all the MIX X sample oven cured at the 20°C also. All the compressive strength test is done at the period of 7, 14 and 28 days.

Alkaline solution to Flyash ratio 0.35 @7 DAYS AMBIENT CURED (15-20°C)

MIX X	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
S1	16M	7.50	**7.56**
S2		7.20	
S3		8	

Alkaline solution to Flyash ratio 0.35 @7 DAYS OVEN CURED at 20°C

MIX X	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
S1	16M	7.40	**7.63**
S2		7.60	
S3		7.90	



Graph-2

From above graph we can easily found that, when alkaline solution to fly ash ratio is 0.35 and we cured at ambient temperature 15-20°C and cured at 20°c in oven for @7days then we found all the strength respectively 7.58MPa & 7.66MPa

Alkaline solution to Fly ash ratio 0.35 @14 DAYS AMBIENT CURED (15-20°C)

MIX X	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
S1	16M	10.90	**11.4**
S2		11.60	
S3		11.70	

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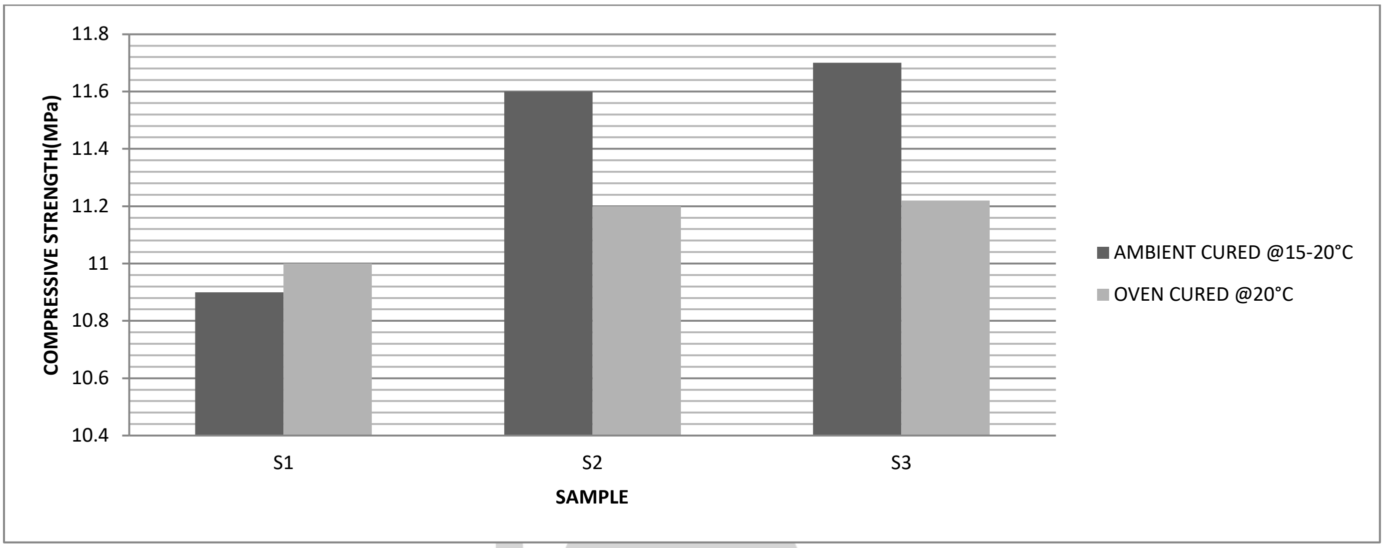
Alkaline solution to Fly ash ratio 0.35 @14 DAYS OVEN CURED 20°C

MIX X	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
S1	16M	11	**11.1**
S2		11.20	
S3		11.10	



Graph-3

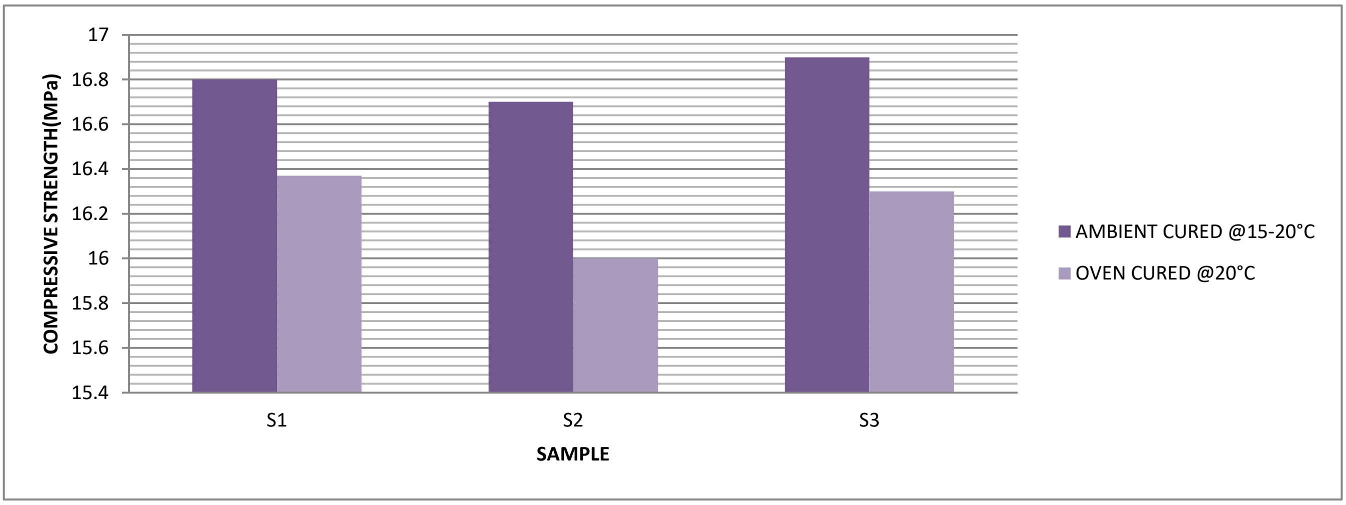
From above graph we can easily found that, when alkaline solution to fly ash ratio is 0.35 and we cured at ambient temperature 15-20°C and cured at 20°c in oven for @14days then we found all the strength respectively 11.34MPa & 11.11MPa

Alkaline solution to Fly ash ratio 0.35 @28 DAYS AMBIENT CURED AT 15-20°C

MIX	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
S1	16M	16.80	**16.80**
S2		16.70	
S3		16.90	

Alkaline solution to Fly ash ratio 0.35 @28 DAYS OVEN CURED AT 20°C

MIX X	MOLARITY	COMPRESSIVE STRENGTH (MPa)	AVG. COMPRESSIVE STRENGTH (MPa)
S1	16M	16.40	**16.23**
S2		16	
S3		16.30	



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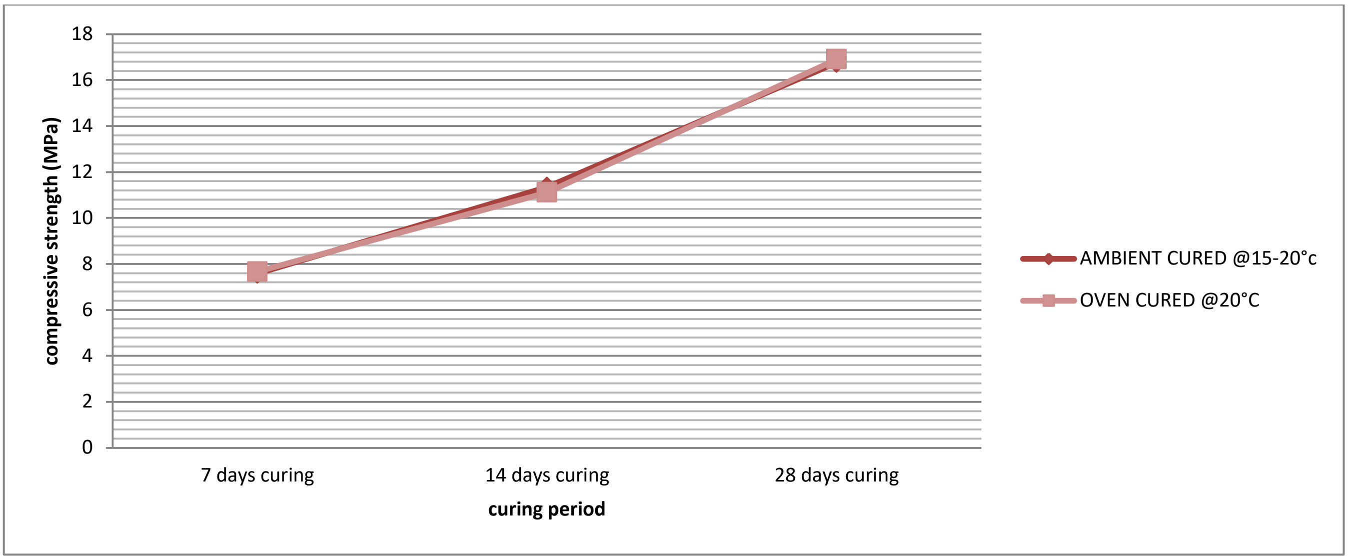
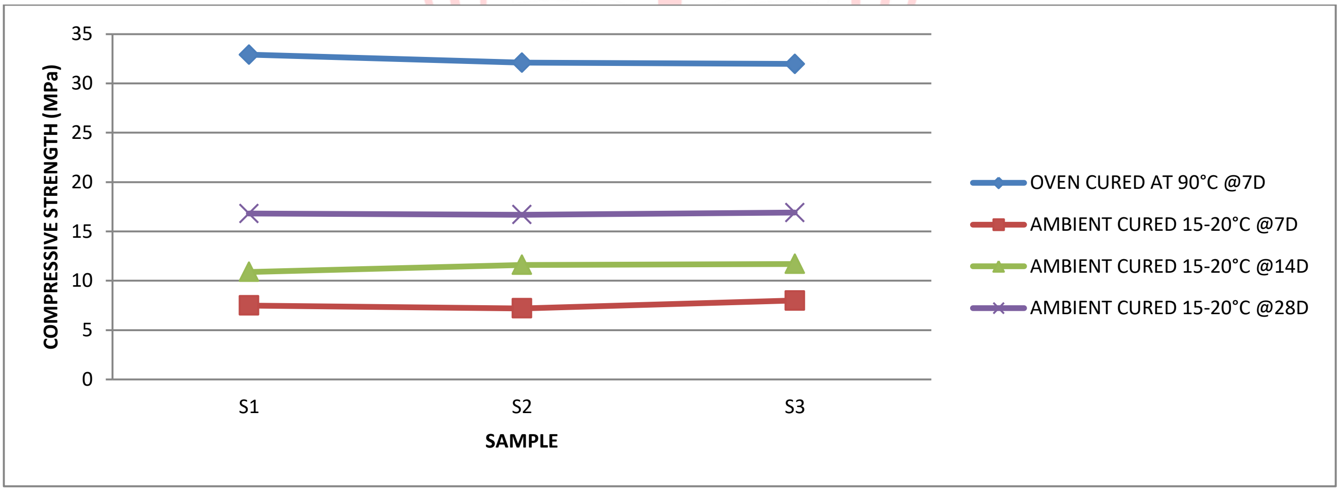
From above graph we can easily found that, when alkaline solution to fly ash ratio is 0.35 and we cured at ambient temperature 15-20°C and cured at 20°c in oven for @28days then we found all the strength respectively 16.75MPa & 16.19MPa



From the above graph we can obtain properly the strength comparision in ambient cured @15-20°C and oven cured @20°C because the ambient temperature varied time to time from day to night, so it is necessary to maintain temperature by the oven for the comperision of compressive strength at 7,14 and 28 days.

VII. CONCLUSION AND DISCUSSION

7.1 Difference between oven cured at 90°C and ambient cured at 15-20°C



Form the above graph result we can see that the compressive strength is increasing with increase in temperature as well as curing periods in days. The strength of geo-polymer concrete is observed to increase linearly at high curing temperature as 90°C.

It is observed that when curing temperature is increases, it requires less duration of curing to gain higher compressive strength. Following are the some conclusion which are made from above result-

1. Compressive strength of geo-polymer concrete is increases with increases in alkaline solution to fly ash ratio but when alkaline solution to flyash ratio found 0.45 then we found the compressive strength as decreasing order.

2. When temperature is found as ambient temperature in Dehradun in the month of March-April for curing the geo-polymer concrete the strength gain is 25% of the geo-polymer concrete cured at oven temperature in 7 days and for 28 days ambient curing the compressive strength gain is found 50% of the strength gain in 7 days for oven cured at 90°C.

3. We found the temperature increases the compressive strength gradually with the rising temperature at high temperature we found high chemical polymer reaction which is responsible for the strength developing.

4. The curing condition is very important parameter for GPC.

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5. When molarty of NaOH increases then the compressive strength increases upto 12M-16M but when this molarity increase upto 18M the compressive strength of the GPC decreases in proper way.

REFERENCES

[1] D. Hardjito and B.V. Rangan “development and properties of low calcium fly ash based geopolymer concrete” research report GC 1, faculty of curtin university of technology Perth, Australia2005.

[2]Olivia et.al. (2008)“investigationon the water penetrability of low calcium fly ash geopolymer concrete”.

[3] PrinyaChindaprasit et al. (2014) “setting tim, strength, and bond of High calcium fly ash geopolymer concrete” American Society of civil engineers, 10.1061/(ASCE)MT .

[4]P.Chindaprasirt et al (2011)”high strength geopolymer using fine high calcium fly ash” American society of civil engineers.

[5] Herbert Sindujaet. Al (2011) “ review on Geopolymer concrete with different additives” international journal of engineering research(IJOER).

[6]Raijiwala et al. (2011) “ Geopolymer concrete: a concrete of next decade” JERS/vol2/issue1/January-march2011.

[7] Prakash R. Vora et.al (2012) “effect of various parameters onGeopolymer concrete.”

[8]Shankar H.Sanni R.B.(2012) “ performance of alkaline solutions on grades of geopolymer concrete” International journal of research in Engineering & Technology eISSN:2319-1163|pISSN2321-7308.

[9] AmmarMotrwalaet. Al.(2013) “an experimental study of fly ash based geopolymerconcrete”ISSN:2277-9655.

[10] Rajamane et.al.(2013) “Studies on development of ambient temperature cured GGBS based geopolymerconcrete” .

 DOI : 10.35291/2454-9150.2019.0385