Geopolymer Using Lime With Ambient Curing

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Abstract- *Manufacturing of Portland cement releases large amount of the green house gas (CO2) into the atmosphere. Production of one ton of Portland cement requires about 2.8 tons of raw materials, including fuel and other materials. As a result of de-carbonation of lime, manufacturing of one ton of cement generates about one ton green house gas[6].At present, efforts have been made to promote the use of pozzolans to replace Portland cement by 100%. Recently, another class of cementitious materials, produced from an alumino-silicate activated in a high alkali solution, has been developed. This cementitious material is termed as geoploymer. Geopolymer concrete is very advantageous due to its durability, economy and environmental credit point of view. The Geopolymer requires the temperature curing for obtaining the sufficient strength. Practically it can be possible to produce the temperature curing to structure at site. Geopolymer concrete can gain the required strength at 30-36oC with some percent replacement of lime. Some effort is made for achieving the sufficient strength of geopolymer cure with ambient temperature. Various percentages of Lime were replaced in fly ash for obtaining the strength at room temperature. The effect of lime on initial setting time, compressive, flexural and tensile strength were studied. From this experimental work it is observed that increase in the percentage of lime, the initial setting time reduces as the compressive strength increases.*

Keywords- Geopolymer, Lime, activator solution, Ambient Curing.

I. INTRODUCTION

Consumption of electricity is increasing day by day. While producing the electricity by thermal power plants the fly ash is produced in huge quantity. For protecting environment it is very essential to dispose or utilize this fly ash. Construction industries have been using the fly ash as supplementary binding material or mineral admixtures in various types of concrete. Use of concrete is only the second after the water. The world wide consumption of concrete is estimated to be about 11.5 billion tons per year and year 2050 expects demand of 18 billion tons of concrete per year[15]. It is well known that there are environmental benefits of reducing the use of Portl and cement in concrete and using a cementitious material such as fly ash or ground granulated blast furnace slag or rice husk ash instead. Davidov its proposed the 100 %replacement of cement by cementitious materials which are rich in silica and alumina by activating alkaline solution[4].Fly ash, one of the source materials for geopolymer binders, is available abundantly worldwide, but to date its utilization is limited. In India the production of the fly ash will be about 1373 million tons annually (ICC 2012).Due to more percentage of silicon and aluminum, Fly ash has great potential as a cement replacement material in concrete. Yet near about 40% fly ash were used as cement replacement in high volume fly ash concrete. But to replace the Portland cement totally, fly ash need to be activated by using alkalinesodium or potassium based solution. Then polymerization chemical reactions were formed. The strength of geopolymer depends on the nature of source material, chemical composition, types of activator solution, solution to fly ash ratio, rest period, types of curing and curing temperature. But in practice it is not possible to produce the temperature curing to structure. Without temperature cutting the geopolymer concrete cannot set early and gain strength. But it is possible by using lime in some percentage with fly ash. This paper presents information on fly ash based geopolymer mortar with ambient curing. In this experimental works the paper covers the materials and chemical proportions, curing temperature and type and the effect of addition of lime in geopolymer concrete. In experimental work unprocessed fly ash were used as a source material which was collected form Dirk India, Nasik plant, Maharashtra, India. In addition to that the hydrated lime was used as acuring agent.

II. METHODOLOGY

Fly ash: Class F fly ash used in the present research work was collected from Dirk India, Nasik plant, Maharashtra, India. It had chemical composition as given in Table-1.About 75% of particles were finer than 45 micron and Blaine's specific surface was 320m2/kg.

Hydrated Lime: The locally available hydrated lime which is generally used as a construction material was used for early setting at room temperature. It allows buildings to "breathe" and does not trap moisture in the walls. Lime was added 5%, 10%, 15% and 20%. The Lime is a solid composite; it has an average particle size less than 70μ.

Table 1. COMPOSITION OF FLY ASH (MASS %)

Chemical Analysis

Test	Unit	IS Specification	Result
Loss On Ignition (Max.)	%	5	1.00
$SiO_2 + Al_2O_3 + Fe_2O_3$	%	70 min. by mass	93.15
SiO_2	%	35 min. by mass	60.42
MgO	%	5 max. by mass	1.82
SO_3	%	3 max. by mass	0.83
Na_2O	%	1.5 max. by mass	0.47
Total Chlorides	%	0.05 max. by mass	0.031

Alkaline activator: Sodium based hydroxide and silicates were used as an alkaline activator. Laboratory grade sodium hydroxide in flake form (98 percent purity) and sodium silicate solution (Na_2O= 15.12%, SiO_2 =34.08% and 50.8% water)was supplied by Gandhi Ahmednagar and Shanti chemicals Ltd, India. Sodium Hydroxide of 13 morality, Na_2SiO_3/NaOH ratio of 2 was used and prepared one day before casting. Both the chemicals were well mixed together one hour before adding to mixer and then added to dry mix.

Water to Fly ash ratio was of 0.45 for 5% and 10%replacement of lime also 0.55for 15% and 20% replacement of lime. For compressive strength the cubes of size 150mmwere used. After casting the cubes moulds were kept for ambient curing at room temperature. Then cubes were left in ambient temperature up to testing. The surrounding temperature was 30 to 36oC. For comparison temperature curing was done with 50oc for same composition of lime.

The following parameters were optimized step by step. Before starting this work some trials were done for finalizing all parameters (solution to fly ash ratio, sodium silicates to sodium hydroxide ratio, curing temperature etc.) After several trials following all the parameters were finalized from results and are given as under:

A) For 5% and 10% lime replacement

1) Solution to fly ash ratio = 0.45
2) Ratio of Na_2SiO_3 to NaOH = 2
3) Rest period = 1 day
4) Curing Temperature = 32-38oC
5) Curing Duration = Till date of testing

B) For 15% and 20% lime replacement

1) Solution to fly ash ratio = 0.55
2) Ratio of Na_2SiO_3 to NaOH = 2
3) Rest period = 1 day
4) Curing Temperature = 32-38oC
5) Curing Duration = Till date of testing

For this study the total 18 trial mixes of mortar were studied. The Mix 1 is design for Plain geopolymer mortar and serves as a control mix. The strength of this mix was used for comparison with strength of all other mixes. The cubes of mix 1 we recured at an elevated temperature of 60o C for 24 hrs, with 1day rest period. Lime was added 5%, 10%, 15% and 20%.

Mixing and Curing of Geopolymer Mortar:

The mixing of geopolymer mixtures can be done in two

major steps: preparation of the alkaline activator solution and final mixing of all ingredients. The alkaline activator solution was prepared at the time of final mixing with the other ingredients.

Figure 1. Dry mixture of Geopolymer concrete

The sodium hydroxide and sodium silicate solution of desired quantity were mixed together and stirred well. Fine aggregates and the binders (fly ash and lime) were dry-mixed thoroughly in the mixing pan for two minutes. Premixed alkaline activator solution was then added gradually and mixing was continued for another 3–4 min. All the mixes of geopolymer mortars were mixed manually in a laboratory pan to obtain a uniform mixture. As lime is a replacement of fly ash concrete needed extra water i.e. more than design requirement to form a consistent mixture. Fresh mortar mixture was cast in cube moulds (150 mm x 150 mm x 150 mm). The moulds were filled in two layers and each layer was compacted on a vibrating table.

Figure 2. Geopolymer Cubes, Beams & Cylinders for curing

They were then stored at a room temperature of 32–38oC (Ambient curing). Samples were removed from the mould after 24 h of casting and left again at room temperature.

Table 2. MIX PROPORTION DETAILS OF THREE CUBES QUANTITY.

Mix	Fly Ash (kg)	Lime (kg)	SH (kg)	SS (kg)	Extra Water (ml)
TC	5.14	0	0.77	1.54	0
AC 1 5%	4.88	0.26	0.77	1.54	200
AC 2 10%	4.63	0.51	0.77	1.54	300
AC 3 15%	4.37	0.77	0.94	1.88	200
AC 4 20%	4.12	1.03	0.94	1.88	250

TC: Mixture for temperature curing.
AC: Mixture for ambient curing.

III. RESULTS:

First of all the consistency of fly ash was found out by using Vicats apparatus, and it was found to be 29% water required for making a standard paste of fly ash. Setting time of geopolymer were studied the variation of setting time due to variation of lime. The setting time tests were carried out in a temperature of 32-360C. In this condition, fly ash based geopolymer generally takes a long time to set due to slow rate of chemical reaction at low temperature. In this study, mortar GC1 required more than 24 hours before showing any sign of setting. Setting time of geopolymer pastes improved significantly when lime was incorporated in the mix as a binder. Initial setting time decreased with the increase of lime content. Mix GC2 having 10% slag of total binder achieved initial setting time of 45 minutes, which decreased to 25 minutes and 15 minutes for inclusion of 15% and 20% lime in mix GC3 and GC4 respectively.

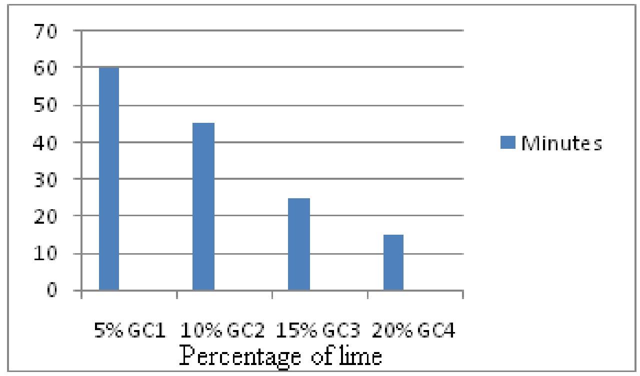

Figure 3. Graph representing variation of setting time of geopolymer mortar.

It also indicates that the higher the lime content in the paste the quicker is the rate of setting. The results establish that lime as a part of fly ash binder is effective to accelerate setting time of geopolymer concrete in ambient condition. The quantity of water calculated for geopolymer mortar in the same way as cement mortar. After making the homogeneous mix, workability of fresh geopolymer concrete was measured by flow table apparatus as per IS 5512-1983 and IS 1727-1967. It was observed that the result of work ability in terms of flow is 40.10%which is in between 25 and 50% which was considered for the design mix. For mix of 5% and 10% lime of 0.45 fly ash to solution ratio has medium workability whereas for 15% and 20% it was very harsh concrete, in trial mix it needed more extra water than mix design procedure, hence fly ash to solution ratio for 15% and 20% was kept 0.55 which gave satisfactory workability.

Compressive strength:

Three cubes of size 150 mm x150 mm x150 mm were casted to work out the 3rd, 7th and 28th day's compressive strength of all the proportions. There was slow increment in compressive strength with time beyond 28 days for the samples without Lime the strength trends were likely to change over time. Compressive strength obtained for the specimens are presented in figure 4, 5 and 6. Addition of Lime caused increase in compressive strength of specimens. Significant increases of strength occurred for AC1 specimen (30 MPa) which contained 5% Lime. Similarly, the compressive strength further increased with additional of 10%. The results clearly indicate successive increment in compressive strength of the specimens both for ambient and temperature curing.

Table 3. TEST RESULTS OF COMPRESSIVE STRENGTH.

Trial	% of lime	Mean compressive strength N/mm^2		
	Days	3	7	28
1.	CC	15.15	23.56	39.23
2.	GPC (TC)	19.85	29.18	40.12
3.	05% (AC1)	17.4	26.83	30.31
4.	10% (AC2)	18.75	27.28	32.86
5.	15% (AC3)	14.96	21.71	28.08
6.	20% (AC4)	13.85	18.85	26.08

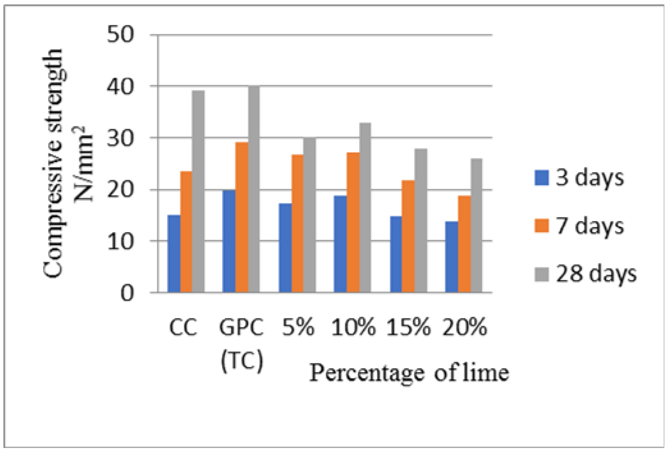

Figure 4. Results of Compressive Strength (N/mm2) % of Lime

CC: conventional concrete
GPC: Geopolymer concrete.
AC: Mixture for ambient curing.

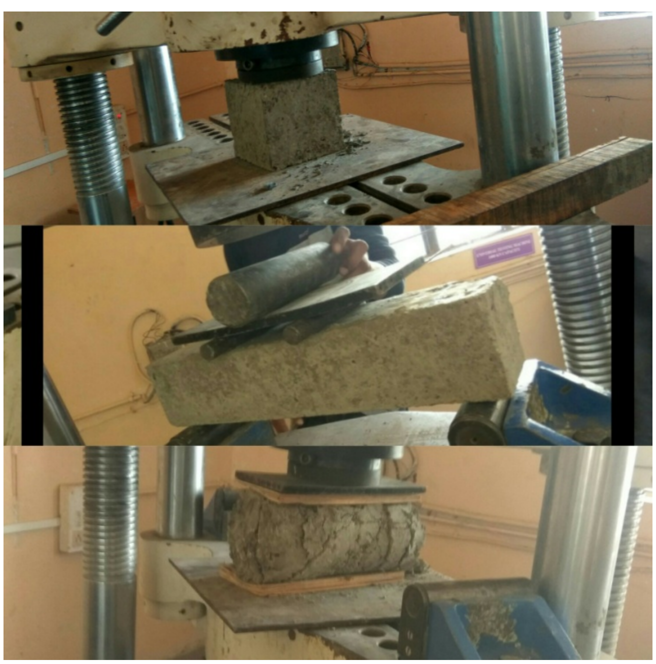

Figure 5. Compressive, flexural, split tensile testing setup.

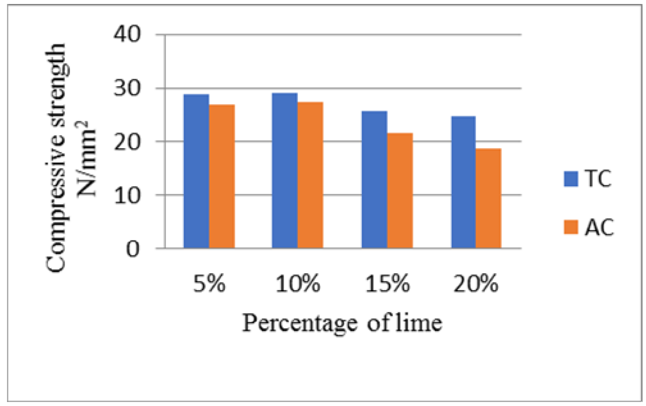

Figure 6. Variation of Compressive Strength (N/mm2) of 7 days, temperature curing (TC) and ambient curing(AC).

Flexural strength

Three beam section of size 100 mm x 100 mm x 500 mm were casted and cured for 28 days. The flexural strength is determined by the
Formula:far = Pf L / bd2 or 3Pf a / bd2

Where, far = Flexural strength, N/mm2
Pf = Central load through two point loading system, N
L = Span of beam, mm
b = Width of beam, mm
d = Depth of beam, mm
a = distance between line of fracture to the nearest support, mm.

It is clear from table 4 Flexural strength obtained for concrete with 10 % lime replacement showed a higher value compared to Geopolymer concrete for 28 days.

Table 4. TEST RESULTS OF FLEXURAL STRENGTHFOR 28 DAYS.

Trial	% of lime	Mean flexural strength (N/mm^2)
1.	CC	7.28
2.	GPC (TC)	7.87
3.	05% (AC1)	5.71
4.	10% (AC2)	5.9
5.	15% (AC3)	5.5
6.	20% (AC4)	4.85

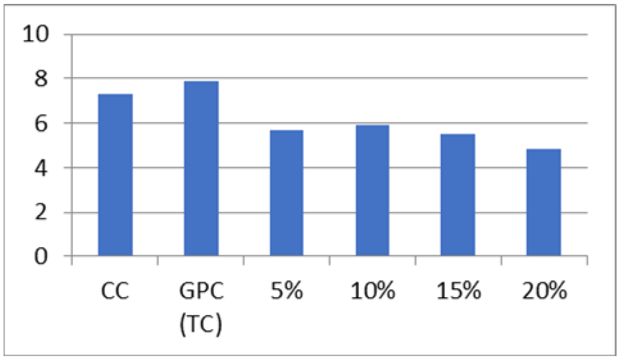

Figure 7. Results of Flexural Strength (N/mm2) of 28 days.

Spilt tensile strength

Three cylindrical sections of diameter 150 mm and length 300 mm were casted and cured for 28 days. The split tensile strength of cylinder is calculated by the following formula:

$fcys = 2Psp / \pi D L$

Where, fcys = split Tensile strength, N/mm2
Psp = Load at failure, N
L = Length of cylinder, mm
D = Dia. Of cylinder, mm

Table 5. TEST RESULTS OF TENSILE STRENGTHFOR 28 DAYS.

Trial	% of lime	Mean tensile strength N/mm^2
1.	CC	3.89
2.	GPC (TC)	5.30
3.	05% (AC1)	3.97
4.	10% (AC2)	4.23
5.	15% (AC3)	3.50
6.	20% (AC4)	3.29

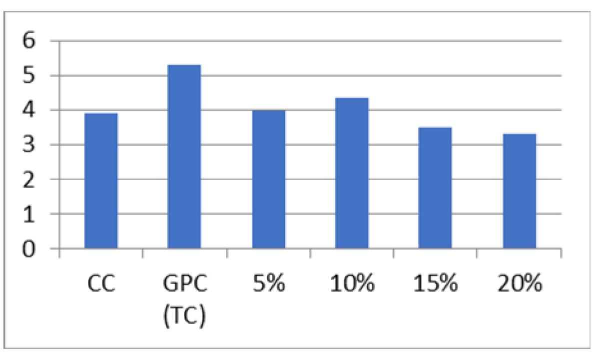

Figure 8. Variation of split tensile strength (N/mm$^{2)}$ of 28 days

IV. CONCLUSION:

1. As the percentage of lime increases in themixtures the workability decreases.
2. The initial setting time of Geopolymer mortar with lime decreases when the percentage of lime increases. Initial setting time of Geopolymer mortar with lime up to 10% was nearly 45 minutes.
3. Geopolymer mortar with 10% lime increases the compressive strength, flexural and tensile strength as compared to geopolymer concrete.
4. Mixture with 10% lime with temperature curing and ambient curing achieves more strength than mixture of other percentage variation of lime.

V. ACKNOWLEDGMENT:

Project work was carried out using the facilities in Civil Engineering Department laboratory of DR.V.V.P.COE, Ahmednagar. I express my heartiest gratitude and sincere thanks to, Prof. U. R. Kawade, H.O.D., my project guide and Prof. P. B. Autade, ME Co-ordinator, Department of Civil Engineering for their valuable guidance, authorities and expert comments. Finally I am thankful to the supporting staff and all those who directly or indirectly contributed to this project work.

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