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Effect of different molarities of Sodium Hydroxide solution on the Strength of Geopolymer concrete

Shivaji S. Bidwe[1], Ajay A. Hamane[2]
[1]*Civil Engineering department, S.R.T.Marathwada University, Nanded, India.*
[2]*Civil Engineering department, S.R.T.Marathwada University, Nanded, India.*

ABSTRACT : *This paper contains the experimental study of strength of geopolymer concrete for different molarities of sodium hydroxide solution. This paper also contains results of the laboratory tests conducted to find out the effect of sodium hydroxide concentration on the strength of the geopolymer concrete. In these days the world is facing a major problem i.e. the environmental pollution. We can use fly ash instead of cement in the construction in order to reduce environmental pollution. The Concrete made by using Fly ash and alkaline liquid mixture as a binder is known as geopolymer concrete. In this study for the polymerization process alkaline liquids used are Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3). Different molarities of sodium hydroxide solution i.e. 8M, 10M and 12M are taken to prepare different mixes and the compressive strength is calculated for each of the mix. The size of the cube specimens taken are 150mm X 150mm X 150mm. Curing of these cubes is done in an oven for 3 days and 28 days. The Compressive strength of these geopolymer concrete specimens is tested at 3 days and 28 days. The results show that there is increase in comp. strength of geopolymer concrete with increase in molarity of Sodium Hydroxide Solution. Ordinary Concrete Specimens are also manufactured with cement as binder. It is found that the Compressive strength of Geopolymer Concrete specimens is higher than the Compressive strength of Ordinary Concrete Specimens.*

KEYWORDS - *Alkaline Binder, Fly ash, Geopolymer, Green Concrete, Inorganic Polymer, molarity.*

I. INTRODUCTION

The biggest problem to the human beings on this planet is environmental pollution. Environmental pollution means adding impurities to the atmosphere. Ecosystem is badly affected by this kind of pollution. This Pollution is caused by so many reasons. In the construction field, Cement is the main ingredient for the production of concrete. But the production of cement requires large amount of raw material. During the production of cement burning of lime stone take place which results in emission of carbon dioxide (CO_2) gas into the atmosphere. There are two different sources of CO_2 emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of burning limestone. Concrete is used globally second only to water. Due to increase in demand of concrete there is increase in production of cement which results in increase in environmental pollution and global warming. In 1995 the production of cement was 1.5 billion tons which goes on increasing up to 2.2 billion tons in 2010. 1 ton of production of cement causes 1 ton of emission of CO_2 into the atmosphere. Among all the greenhouse gases, CO_2 alone causes 65% of total global warming. Geopolymer is a light weight, inorganic polymer. Joseph Davidovits in 1979 proposed a theory that an alkaline liquid could be used to react with byproduct material such as fly ash and rice husk ash to produce binders [1].

Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and the development of alternative binders to Portland cement. Almost all the states in India have thermal power plants and abundant availability of fly ash. The ingredients of the alkaline solution viz. sodium hydroxide and sodium silicates are cheap and easily locally available [2]. In this respect, the geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of global warming, the geopolymer technology could significantly reduce the CO_2 emission to the atmosphere caused by the cement industries. Studies on the fly ash based geopolymer concrete dates back to three decades only. Most of the studies are done under heat cured regime. At 60^{o}C to 90^{o}C temperature the polymerization process is fast [3]. Most parts of India come under tropical region where the normal temperature during summer is above 30^{o}C [4]. Geopolymer which is naturally cured at ambient outdoor temperature can be considered as a curing free concrete [5].

II. MATERIALS USED

2.1 Fly ash: - It is obtained from Thermal Power Plant, Parli, Beed, Maharashtra. The properties of fly ash are given in table 1,

Table 1: Properties of Fly Ash

Parameters	Experimental Value in %	Requirements as per IS 3812-2003 in %
Silica	64.11	> 35
Aluminium Oxide	18.58	> 70
Iron Oxide	4.32	> 70
Calcium Oxide	1.21	-
Sodium Oxide	0.21	< 1.5
Potassium Oxide	1.02	< 1.5
Magnesium Oxide	0.24	< 05
Loss of Ignition	0.64	< 12

2.2 Aggregates: - Locally available coarse aggregate is used. Maximum size of coarse aggregate used is 20 mm and specific gravity is 2.66. The coarse aggregate was used in saturated surface dry (SSD) condition.
Manjra river sand is used as fine aggregate. Specific gravity of fine aggregate used is 2.61 and fineness modulus was 2.76. Fine aggregate was sieved for the size less than 5 mm and used in dry condition.
The properties of aggregates are given in table 2,

Table 2: Properties of Aggregates

Property	Coarse Aggregate (20mm)	Fine Aggregate(Sand)
Fineness Modulus	8.14	2.76
Specific Gravity	2.66	2.61
Bulk Density	1533.33Kg/m^3	1254.24Kg/m^3
% Voids	45.24%	51.76%

2.3 Alkaline Solution: - Alkaline Solution plays an important role in geopolymerisation process. In this case the mixture of Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) is used as alkaline Solution. Sodium hydroxide in pellets form with 99% purity and Sodium silicate solution (Grade A53 with SiO_2 = 29.43%, Na_2O = 14.26% and water = 56.31%) were used as the alkaline activators. In order to make sodium hydroxide solution, sodium hydroxide pellets were dissolved in potable water. Both the liquid solutions were then mixed together and alkaline solution was prepared.

2.4 Water: - The potable drinking water which is available in the concrete technology lab is used for this purpose of making concrete.

III. MIX PROPORTIONS

In this experimental work, three different grades of geopolymer concrete cubes for three different molarities of sodium hydroxide solution were prepared. M20, M25, M30 were the three grades of concrete and 8M, 10M, 12M of sodium hydroxide solution. To activate the aluminosilicate based materials with alkalis generally requires heat curing for the formation of alkali-activated binders. The concrete cube specimens were kept in oven for heat curing. These specimens were cured in an oven at 90^{0}c temperature for the period of 24 hours.

3.1 Preparation of Alkaline Solution:

Photo 1: Alkaline Solution

In this paper, the comp. strength of geopolymer concrete is examined for the mixes of different molarities of Sodium Hydroxide (NaOH) such as 8M, 10M and 12M. The Molecular Weight of Sodium Hydroxide is 40gm (Addition of Atomic Mass of Na=23, O=16, H=1). i.e. 8M Sodium Hydroxide Solution requires 320 gms. Of NaOH, 10M Sodium Hydroxide Solution requires 400 gms. Of NaOH and 12M Sodium Hydroxide Solution requires 480 gms. Of NaOH. The Sodium Silicate (Na_2Sio_3) to Sodium Hydroxide (NaOH) ratio used in this experiment is 1.5.

To prepare 8M Sodium Hydroxide Solution, 320 gms. Of NaOH pellets are weighed and they can be dissolved in distilled water to form 1 liter solution. Firstly, take the volumetric flask of 1 liter capacity, sodium hydroxide pellets are added slowly to distilled water to prepare 1 liter solution. The weights to be added to get required molarity are given in table 3,

Table 3: Weights of NaOH Pellets

Required Molarity	Weight of Sodium Hydroxide in gms.
8M	320
10M	400
12M	480

3.2 Mixing, Casting and Curing:

The density of geo-polymer concrete is assumed as 2440 Kg/m^3 because there are no code provisions for the mix design of geopolymer concrete. The other calculations are done by considering the density of concrete. The total volume occupied by the aggregates (Coarse and fine aggregates) is assumed to be 65%. The alkaline liquid to fly ash ratio is taken as 0.30. The quantities of all ingredients are kept constant as given in table below except the molarity of NaOH is changed in the each mix. The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete. First, the fine aggregate, coarse aggregate and fly ash are mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the cubes are casted by giving proper compaction. The sizes of the cubes used are of size 150mm X 150mm X150mm. The cubes are demoulded after 1 day of casting and placed in an oven. The curing of geopolymer concrete cubes is done by placing the cubes in hot air oven. For oven curing, the cubes are placed in an oven at 90^0 c for 3 days and 28 days. Mixing Proportions of geopolymer concrete is given in table 4,

Table 4: Mixing Proportions of Geopolymer Concrete

Ingredients (Kg/m^3)	Different Mixes		
	M20	M25	M30
Fly Ash	383	463.50	530
Fine Aggregate	546	530.70	514
Coarse Aggregate (20 mm)	1188	1154.06	1117
Sodium Silicate Solution	120	120	1200
Sodium Hydroxide Solution	80	80	80

IV. RESULTS

The test is done on geopolymer concrete cubes in compressive testing machine to determine its compressive strength after the age of 3 days and 28 days. The compressive strength results obtained are given in table 5,

Grade of Concrete	Molarity	3 Days Comp. Strength (Mpa)	28 Days Comp. Strength (Mpa)
M20	8M	13.48	29.62
M20	10M	15.26	31.39
M20	12M	17.03	33.17
M25	8M	16.80	32.43
M25	10M	18.57	34.21
M25	12M	20.35	35.98
M30	8M	20.41	42.80
M30	10M	22.19	45.02
M30	12M	23.97	47.24

Table 5: Experimental Results of Geopolymer Concrete

In order to compare the Comp. Strength of Geopolymer Concrete with the Comp. Strength of Normal Concrete, normal concrete cubes were also casted and its strength is measured at the age of 3 days and 28 days. The compressive strength results obtained are given in table 6,

Table 6: Experimental Results of Normal Concrete

Grade of Concrete	3 Days Comp. Strength (Mpa)	28 Days Comp. Strength (Mpa)
M20	10.22	20
M25	12.64	24.32
M30	15.98	29.62

From experimental Results of normal Concrete and geopolymer Concrete obtained, we can conclude that, the rate of gain of strength of geopolymer Concrete is more than the normal Concrete. Also the maximum Comp. Strength of geopolymer Concrete is higher than the maximum comp. strength of normal Concrete at the age of 3 days and 28 days. This property of rapid strength gain permits geopolymer concrete to be applied in areas where a fast and reliable fix is required such as on highways. The faster a highway can be repaired, the sooner it can be reopened to restore the traffic flow.

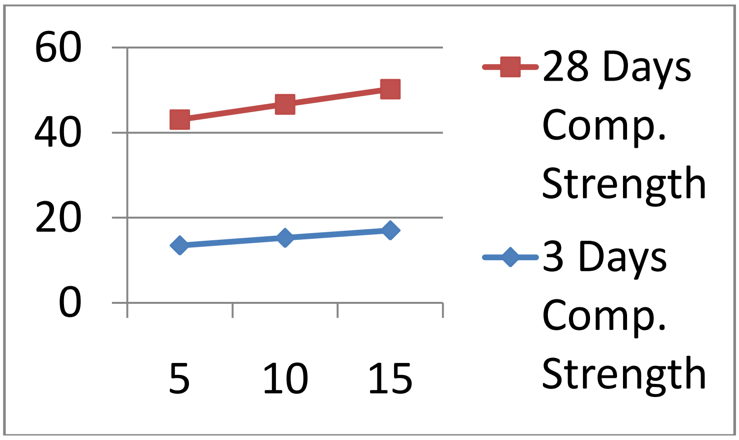

Fig. 1: Comp. Strength of M20 Grade GPC at the age of 3 days and 28 days for different molarities of NaOH Solution

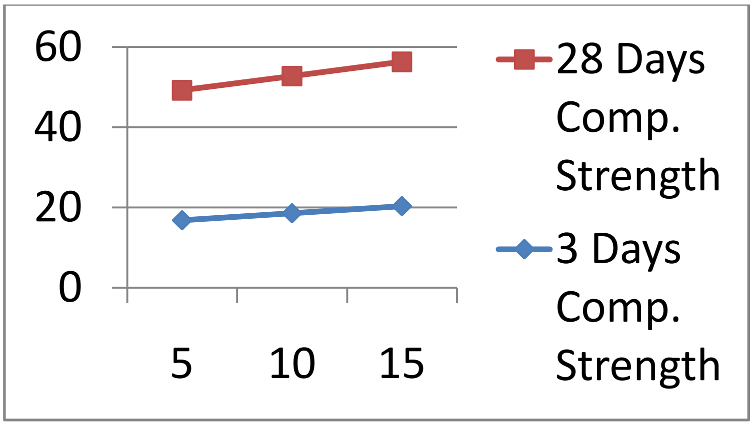

Fig. 2: Comp. Strength of M25 Grade GPC at the age of 3 days and 28 days for different molarities of NaOH Solution

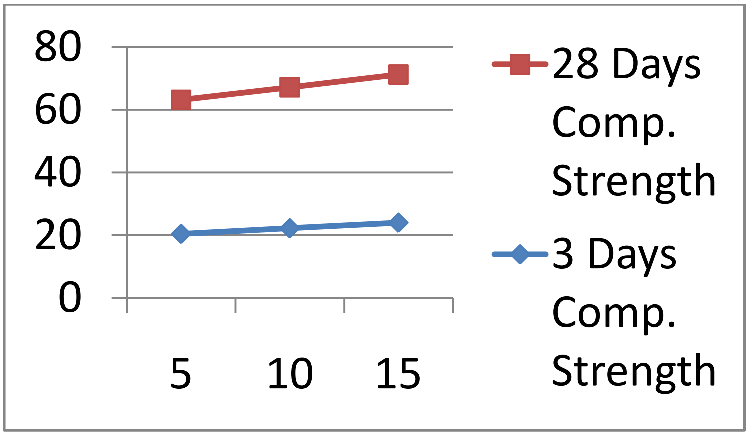

Fig. 3: Comp. Strength of M30 Grade GPC at the age of 3 days and 28 days for different molarities of NaOH Solution

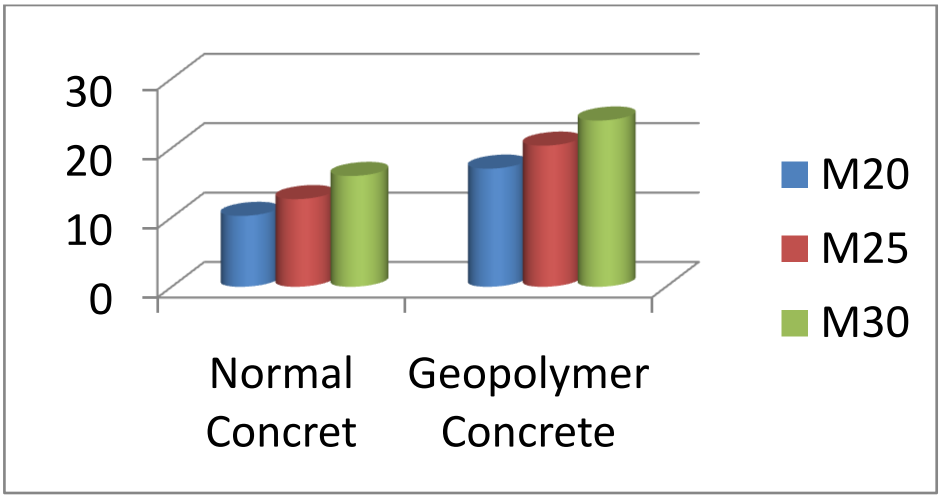

Fig. 4: Variation of Comp. Strength of Concrete at the age of 3 days for different grades

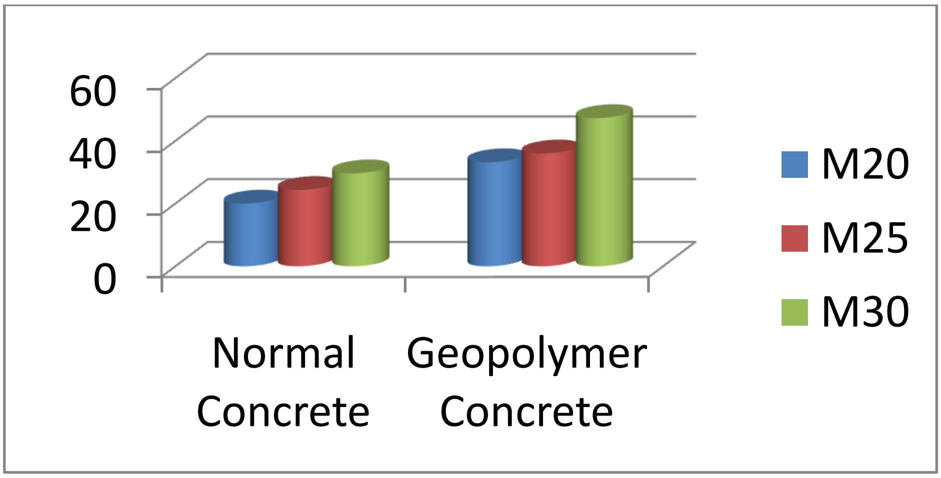

Fig. 5: Variation of Comp. Strength of Concrete at the age of 28 days for different grades

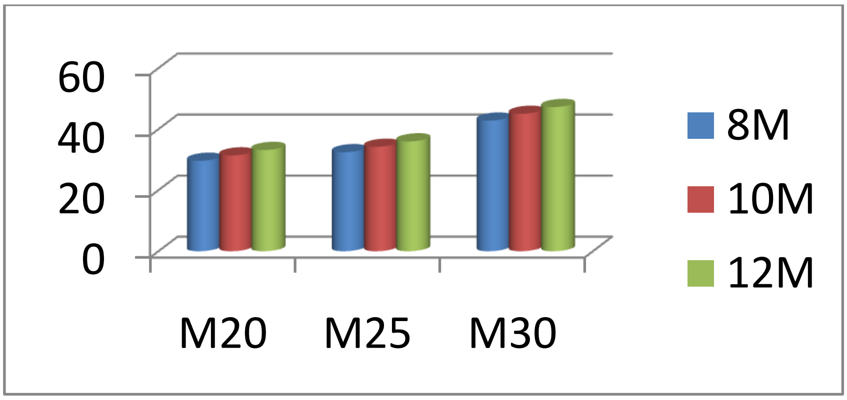

Fig. 6: Variation of Comp. Strength of GPC at the age of 28 days for different grades at different molarities of NaOH solution

V. CONCLUSION

1) It is observed that, the rate of gain of Comp. strength of geopolymer concrete is more than the conventional concrete made up of ordinary Portland cement.
2) It is also observed that, the maximum Comp. strength of geopolymer concrete is more than that of conventional concrete made up of ordinary Portland cement.
3) Comp. strength of geopolymer concrete increases with increase in molarity of sodium hydroxide (NaOH) solution.
4) If not handled properly, Sodium hydroxide can be very harmful to health if mishandled. It has been rated with a classification of 3 in terms of danger to health (0 being the least hazardous, and 4 being the most).
5) Sodium hydroxide is also very corrosive to areas such as the eyes, skin, and nose.
6) One application of geopolymer concrete is in the construction and repair of highways, roads, and airport runways.
7) Another possible application of geopolymer concrete is in maritime settings. Due to its high resistance to salt water, geopolymer concrete may be used for concrete structures that will be under constant attack from salt water.
8) Because of its high resistance to acids and toxic waste, geopolymer concrete can be applied in various highly acidic and toxic environments.

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