

Effect of Alkaline Activator on Compressive Strength of Geopolymer Concrete with Ambient Curing

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ABSTRACT: Geopolymer binder is the invention in binding materials in the area of concrete technology and one step towards the sustainable development in construction materials. This will support to reduce the air pollution which is produced while manufacturing of cement. Also it will solve the disposal problem of fly ash from thermal power plants. Geopolymer concrete requires the temperature curing for gaining the sufficient strength. But practically in cast-in-situ condition it is not possible to provide the temperature curing to structural elements. In this experimental research work the Ordinary Portland cement (OPC) was used as a curing agent in geopolymer concrete. Experimental investigation has been carried out to optimize the percentage of OPC for various concentrations of sodium hydroxide to achieve the maximum compressive strength at room temperature (i.e. without external temperature curing). For this study the 0%, 5% and 10% OPC and 8, 10, 12, 14 and 16 molar sodium hydroxide, and solution to fly ash ratios 0.35 and 0.40 were used. The effect of concentration of sodium hydroxide, solution to fly ash ratio and percentage of OPC on workability and compressive strength of Geopolymer concrete is evaluated. The results show that, the compressive strength increases when increasing the percentage of OPC up to 10%. Geopolymer concrete achieves the maximum strength at 16 molar concentration of sodium hydroxide with 10 % OPC at room temperature. The workability of Geopolymer concrete increases when increasing the concentration of sodium hydroxide as well as increase the solution to fly ash ratio.

KEYWORDS: Fly Ash, sea sand, Geopolymer concrete, OPC, Sodium hydroxide, curing etc.

I. INTRODUCTION

The fly ash based Geopolymer is the most effective binding material which can replace the cement by 100% in concrete. In geopolymer mix the source materials react with highly alkaline solution (Sodium or potassium based hydroxide and silicates) and form inorganic aluminosilicates polymer, product known as Geopolymer. The reaction between source material like fly ash and alkaline activator solution is polymerization. For better bonding in polymer, the elevated temperature is required. In India most of the concrete structures are constructed on site instead of pre-cast constructions. Practically it is not possible to provide the temperature curing to structure. The effect of properties of geopolymer concrete with various concentrations of alkaline solution with temperature curing and ambient curing has been studied. Without temperature, curing the geopolymer concrete cannot set early and not gain the sufficient strength. In summer season, the geopolymer concrete can set at sunlight temperature but in winter season that cannot happen. Surrounding temperature is also affecting on the hardening of geopolymer concrete. Considering this challenges in view the present research work is carried out. Also from many decades the river sand is used as fine aggregate but dredging of sand from river beds is hazardous to environment. This has made the government to restrict the use of river sand in construction. On the other hand, the sea sand is available in abundant quantity but due to presence of salt and chloride it can not be used as fine aggregate in concrete. But after removal of salt and chlorides of the sea sand that can be use as fine aggregate in addition to river sand for achieving the required zone of sand.

The aim of the research work is to achieve the maximum strength of geopolymer at ambient temperature using some pozzolanic material so as to use the geopolymer concrete in cast in situ condition in any season. The objective and scope of this work is limited to study the effect of addition ordinary portland cement (OPC) with different solution to fly ash ratio and concentration of alkaline solution on compressive strength under ambient curing and elevated temperature curing.

II. MATERIALS AND METHODS

Experimental programme was design to optimize the solution to fly ash ratio and concentration of sodium hydroxide solution to achieve the maximum compressive strength of geopolymer concrete without temperature curing. To get harden and achieving the strength, 5% and 10% OPC were used in the each mix.

In this experimental works, two types of curing were used that is temperature cutting and ambient curing. For geopolymer concrete the unprocessed fly ash, 90 % particle smaller than 45 μ was use as a source material, which is a product from coal based Sofiya Thermal Power plant, Amravati, India. The chemical properties of fly ash are given in Table-1. Basalt aggregate passing from 20 mm sieve nominal size were use as a coarse aggregate. Locally available river sand and treated sea sand collected from "Gaymukh Retibazar Thane Greek" was used as a fine aggregate. To minimise the use of river sand the treated sea sand were used in addition to river sand. By adding the sea sand in river sand the zone II sand was obtained. The physical properties of fine and coarse aggregates are shown in Table-2. The sodium hydroxide (NaOH with 98% purity) flake form, and sodium silicate (Na₂SiO₃ with Na₂O = 14.3%, SiO₂ = 32.9%, H₂O = 52.8% and specific gravity 1.58) in liquid form were used as an alkaline activator. The solution to fly ash ratio was 0.35 and 0.40 for temperature curing and ambient curing. The concentration of sodium hydroxide was 8, 10,12, 14 & 16 molar. For all the mixes, the ratio of Na₂SiO₃-to- NaOH was kept 2. To achieve the strength at room temperature, the 5% and 10% OPC were use as a curing agent by replacement to fly ash. The surrounding environmental temperature was in the range of 16 °C to 37°C. The alkaline activator solution was prepared before one day prior to its application. The mix details are given in Table 3.

Table 1: Composition of Fly Ash (Mass %)

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O	K ₂ O	TiO ₂	MgO	P ₂ O ₅	SO ₃	LOI*
61.85	27.36	5.18	1.47	0.08	0.63	1.84	1.0	0.54	0.05	1.0

*Loss of Ignition

Table 2: Properties of Fine and Coarse Aggregate

Sr. No	Properties	Results	
		Fine Agg.	Coarse Agg.
01.	Particle Shape, Size	Rounded, 4.75mm	Angular, 20 mm
02.	Fineness Modulus	2.6	6.0
03.	Specific Gravity	2.63	2.71
04.	Silt /Dust Content	3.3 %	Nil
05.	Surface Moisture	Nil	Nil
06.	Water absorption	1.43 %	2.835 %



Fig. 1: Geopolymer concrete



Fig. 2: Casting of Cubes

Table 3: Materials for 1kg/m³ concrete

Mix	Solution to Fly ash Ratio	Fly Ash (kg)	Na ₂ SiO ₃ (kg)	NaOH (kg)	Fing Agg. (kg)	Coarse Agg. (kg)	Water (kg)
Mix A	0.35	400	93.33	46.66	660	1232	66.45
Mix B	0.40	400	106.67	53.33	657	1226	56.03

By using the quantity of materials mentioned in the Table 3, the 100 mm size cube were casted. Under the Mix A and mix B, the total 5 different mixes were casted for various concentration of NaOH. (ie. 8M, 10M, 12M, 14M, 16M). For each concentration of NaOH the 4 mixes were casted for various curing conditions and percentage of OPC. Out of four mixes, the first mix was prepared for temperature curing. Second mix was prepared for curing at room temperature. Third and fourth mix were prepared for 5% and 10% OPC with curing at room temperature respectively (ie. Ambient curing). The cubes of mix first were kept in hot air oven for temperature curing for 24 hours at 80°C. The cubes of mix second, third and fourth were kept in room for ambient curing. Similarly, the same mixes were prepared under mix 2. Under mix A and mix B, total 40 mixes were used for this study. In each mix for each parameter, three cubes were casted to determine the compressive strength. The casting and testing have done as per the respective Indian standard codes.



Fig. 3: Temperature Curing



Fig. 4: Tecting of cubes

III. RESULT AND DISCUSSION

Table 4 shows the results of compressive strength of geopolymer concrete conducted as per the IS 516-1975. Compressive strength was evaluated at the age of 28 days after casting. For each parameter, three cubes are tested for

compressive strength and average of these three cubes has been considered as strength of concrete for that respective parameters. The compression test was conducted on Compression testing machine of capacity 3000 kN. In Table 4, the column 4,5,6,7 and 8 represents the compressive strength of geopolymer concrete for solution to fly ash ratio 0.35 and 0.40 for 8M,10M,12M, 14M and 16 M of NaOH respectively. Results show that, the compressive strength of geopolymer concrete found more when the solution to fly ash ratio 0.40 as compared to 0.35. Compressive strength of geopolymer concrete increases when increasing the concentration of NaOH solution. In case of geopolymer concrete with OPC, the results show that, compressive strength increase when increasing the percentage of OPC in the mix. Geopolymer concrete with 10 percent of OPC produce similar strength as to geopolymer concrete with temperature curing.

Table 4: Test Results of Compression Test

Sr. No.	Mix Details	Sol/FA Ratio	Compressive Strength (N/mm ²)				
			Molarity of NaOH Solution				
			8M	10M	12M	14M	16M
01	02	03	04	05	06	07	08
01	A	0.35	10.90	11.20	12.54	16.37	21.00
02			11.97	14.56	16.82	19.73	24.93
03			13.48	17.78	23.24	26.76	29.9
04			15.50	20.13	24.20	26.73	30.86
05	B	0.40	13.87	14.67	16.67	19.93	23.07
06			17.56	19.04	22.33	23.26	25.46
07			20.33	23.22	29.04	31.53	36.33
08			21.32	24.86	28.4	30.67	35.53

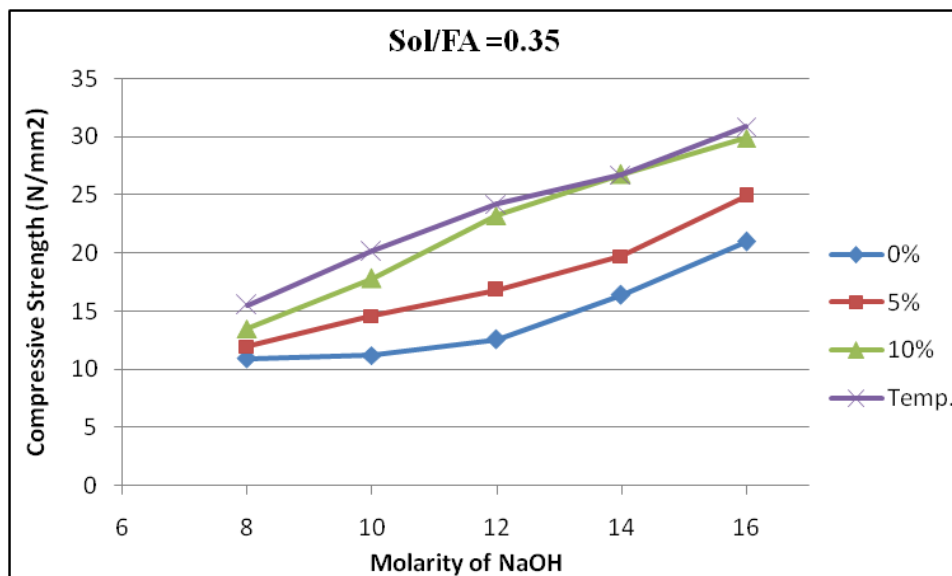


Fig. 5: Concentration of NaOH solution vs Compressive Strength of Geopolymer concrete for Sol./FA ratio 0.35

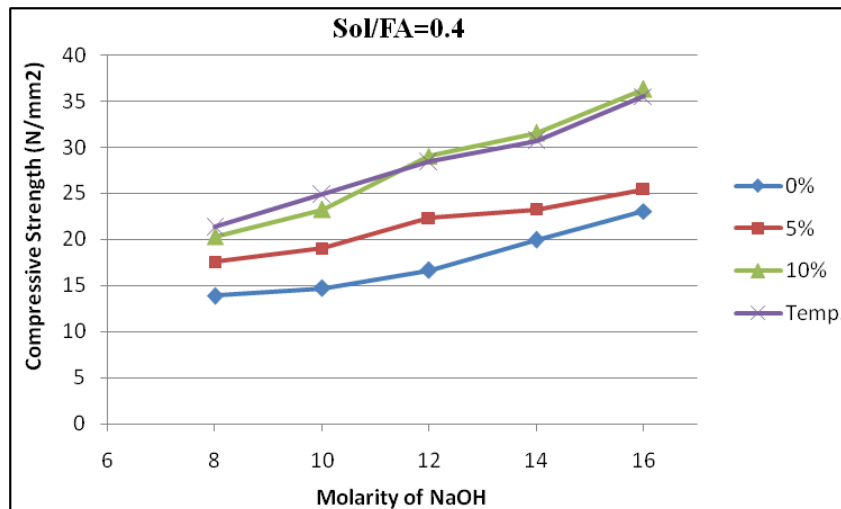


Fig. 6: Concentration of NaOH solution vs Compressive Strength of Geopolymer concrete for Sol./FA ratio 0.40

Figure 5 and 6 shows the graphical variation of compressive strength with respect to molarity of NaOH solution with solution to fly ash ratio 0.35 and 0.40 respectively. Mix with solution to fly ash ratio 0.4, the rate of increases of strength is similar in case of GPC with temperature curing and GPC with 10% OPC ambient curing. The results of 12,14 and 16 molar concentration of NaOH solution produce sufficient strength in case of 10% OPC with ambient curing for both solution to fly ash ratio.

IV. CONCLUSION

Following conclusions can be drawn from the above result and discussion.

1. The results indicated increase in compressive strength with increase in solution to fly ash ratio and molarity of NaOH solution.
2. Geopolymer concrete with 12, 14 and 16 molar of sodium hydroxide solution produce better compressive strength in ambient curing
3. At room temperature geopolymer concrete can achieve similar strength of geopolymer concrete with temperature curing by adding 10 percent OPC.

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