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Properties of Fly Ash based Geopolymer Mortar

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Abstract:- **This paper represents the effect of various parameters on the strength of fly based geopolymer mortar. Geopolymer mortar was produce by using unprocessed fly ash, activated with sodium silicates and sodium hydroxide solution. Solution to fly ash ratio was 0.2, 0.3, 0.35, 0.4, 0.5, 0.6, 0.7 & 0.8 and sodium silicates to sodium hydroxide ratio 1, 1.5, 2, 2.5 & 3 were used. The specimen were cured at temperature 40, 60, 80 & 100 ºC with rest period 1, 2, 3, 4, 5 & 6 days. The ultimate compressive strength (ie 38.65 mpa) were obtained at the solution to fly ash ratio 0.5 with sodium silicate to sodium hydroxide ratio 1.5, the curing temperature 80 ºC with rest period 4 days.**

Keywords: Geopolymer, activator solution, rest period, curing temperature.

INTRODUCTION

Development of country is majorly depends upon the infrastructures and in every infrastructure concrete plays a vital role. We cannot imagine the word without concrete. Use of concrete is second after the water. The production of cement increases as per increase the demand of concrete. The world wide consumption of concrete is estimated to be about 11.5 billion tons per year (Palomo) and year 2050 expects demand of 18 billion tons of concrete per year. The manufacturing of Portland cement releases carbon dioxide (CO_2) which is a significant contribution to green house effect. The production of every ton of cement contributes to production of one ton of CO_2.

Another effort to make environmentally friendly concrete is the development of inorganic alumina-silicate polymer, called geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash that are rich in silicon and aluminium (Davidovits). Fly ash, one of the source materials for geopolymer binders, is available abundantly world wide, but to date its utilization is limited. In 2011 the India coal ash production was 589 million tons annually, but its utilization was less than 15%. In the future, fly ash production will increase, especially in countries such as India and China. In India the production of the fly ash will be about 1373 million tons annually (ICC 2012). Accordingly, efforts to utilize this by-product material in concrete manufacture are important to make concrete more environmentally friendly. For instance, every million tons of fly ash that replaces Portland cement helps to conserve one million tons of lime stone, 0.25 million tons of coal and over 80 million units of power, not withstanding the abatement of 1.5 million tons of CO_2 to atmosphere. There are solution by using flyash as a substitute for portland cement. Due to more perccentage of silicon and aluminium, 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 alkaline sodium or potacium baced solution. Then polymerisation chemical reaction were form.

The mechanisum of geopolymerisation may consist of dissulution, transportation and polycondensation (Xu H, van Deventer) and take placethrough an exothermic process. The strength of geopolymer depends on the nature of source material, chemical composition, types of activator solution, solution to fly ratio, rest period, types of curing and curing temperature. This paper presents information on fly ash based geopolymer morter. The paper covers the material and chemical proportions, rest peroid, curing temperature and its optimasation as per the strength. In experimental work unprocessed fly ash were used as a source material which was collected form Sofiya thermal power plan, Amravati.

MATERIALS, MIXTURES AND TEST SPECIMEN

In this experimental work the experiments were carried out for optimasing the various parameters for the maximum strength. The parameters are, time between mixing of activator solution and casting, rest period, curing temp, activator soluion to fly ash ratio, sodium silicate to sodium hydroxide ratio. For geopolymer concrete the unprocessed fly ash, 90 % particle smaller than 45µ were used as a source material, produce from coal based Sofiya Thermal Power plant, Amravati, India. The chemical properties of fly ash are given in Table-1. Sodium based hydroxide and silicates were used as an alkaline activator. The sodium hydroxide (NaOH with 98% purity) flake form, and sodium silicate (Na_2SiO_3 with Na_2O = 14.3%, SiO_2 = 32.9%, H_2O = 52.8% and specific gravity 1.58) liquid form were used as an alkaline activator collected from locally supplier. Sodium Hydroxide of 14 molar was used for making alkaline activator solution with sodium silicates liquid. Both the chemicals were well mixed together and then added in the dry mix of fly ash and fine aggregate. For all trials both the chemicals steer equally (20 times) by using two jars for become a same effect of steering in all mixes. For casting the cubes of 70.6mm size were used. After 1 day of casting the cubes with mould were kept for temperature curing at 80 ºC for 24 hrs. Cubes were removed from the mold after cooling the cubes in oven. Then cubes were left in ambient temperature up to testing at 7 days. The surrounding temperature was 30 to 45 ºC

In geopolymer concrete the strength is depends on various factures, such as types of source material, fineness and chemical composition of source materials, types of activator solution, ratio of solution to source material, Na_2SiO_3 to NaOH, rest period, cruring temperature, types of curing and concentration of NaOH solution. In this

experiment fallow the methods of testing of cement for fly ash. First of all find the consistency of fly ash by using Vicats apparatus, and it found 29% water required for making a standard paste of fly ash. The following parameters were optimizing step by step.

1) Time between preparations of activator solution (Na_2SiO_3 + NaOH) to mixing with fly ash.
2) Rest period
3) Curing temperature
4) Solution to Fly ash ratio
5) Sodium silicate to Sodium hydroxide ratio

For optimizing the above first parameters the other parameters kept constant and taken from literature survey. This other parameters are:

1) Solution to fly ash ratio = 0.35
2) Ratio of Na_2SiO_3 to NaOH = 1.5
3) Rest period = 1 day
4) Curing Temperature = 80 ºC
5) Curing Duration = 24 hrs.

For all parameters, the quantity of water was calculated by using the formula which was used for the cement mortar. That is [(P/4)+3] % of mass of total materials (ie. fly ash + Sand + total solids in activator solution). P is a standard consistency of Fly ash.

TIME BETWEEN PREPARATION OF ACTIVATOR SOLUTION AND MIXING

Most of the authors suggested that the activator solution should be prepared at least 1 day before to use for mixing. Because when we mix the sodium silicates with sodium hydroxide, the reaction start and the temperature increase and lot of heat produce. For completion of reaction and cooling the 1 day is sufficient. But in this experimental work the two types of solution were prepared and used, 1st – which is prepared before 1 day before of casting (ie. Mix A) and 2nd – which is prepared at the time of casting (ie. Mix B) and the results are given Table no. 2. It is found that, the 7 days compressive strength of mix A and Mix B almost same.

REST PERIOD

Different researchers suggested the different rest period from their work. The literature suggests the rest period ranges from 0 to 5 days. To know the optimum rest period the following parameters were studied. It is found that the 4 day rest period provide the maximum strength to the geopolymer mortar. If the rest period increases beyond 4 day, the compressive strength reduces. The results of effect of rest period on compressive strength is given in table no. 3.

TABLE 1: COMPOSITION OF FLY ASH (MASS %)

SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	TiO_2	MgO	P_2O_5	SO_3	LOI*
61.85	27.36	5.18	1.47	0.08	0.63	1.84	1	0.54	0.05	1

*Loss of Ignition

TABLE 3: EFFECT OF REST PERIOD ON COMPRESSIVE STRENGTH

Sr. No.	Mix	Rest Period (Days)	7 Days Compressive Strength (N/mm^2)
01	R1	0	9.47
02	R2	1	13.27
03	R3	2	18.27
04	R4	3	20.01
05	R5	4	23.47
06	R6	5	21.68
07	R7	6	18.88

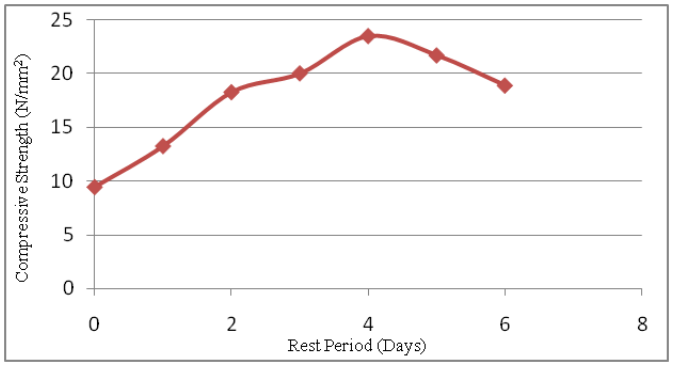

Figure 01: Variation of Compressive Strength with respect to Rest Period

CURING TEMPERATURE

Hot air oven were used for curing of geopolymer mortar. For optimization of curing temperature the mix proportion given in table no 2 were used, and only curing temperature were varied from 40 to 100 ºC. The curing period was 24 hrs. The curing was started after 1 day rest period, and tested at 7 days for compressive strength. It is found that the curing at 80 ºC temperature, mortar produce the maximum compressive strength. The effect of variation of curing temperature on compressive strength is given in table no. 04.

TABLE 04: EFFECT OF CURING TEMPERATURE ON COMPRESSIVE STRENGTH.

Sr. No.	Mix	Curing Temperature ºC	7 Days Compressive Strength (N/mm^2)
01	T1	40	8.32
02	T2	60	12.98
03	T3	80	14.36
04	T4	100	13.46

TABLE 2: EFFECT OF TIME OF PREPARATION OF ACTIVATOR SOLUTION COMPRESSIVE STRENGTH.

Sr. No.	Materials	Details		Series Details	7 Days Compressive Strength (N/mm^2)
1	Fly ash	600 gm		Mix A: Activator solution (Na_2SiO_3 +NaOH) mix together before 1 day of casting.	Mix A= 14.47
2	Fine Agg.	1800 gm			
3	Solution	210 gm			
4	Na_2SiO_3	126 gm			
5	NaOH	84 gm		Mix B: Activator solution (Na_2SiO_3 +NaOH) mix together at the time of casting.	Mix B = 14.50
6	Water	140 gm			
7	Rest Period	1 Day			
8	Curing Temp.	80 °C			
9	Curing Duration	24 hrs.			

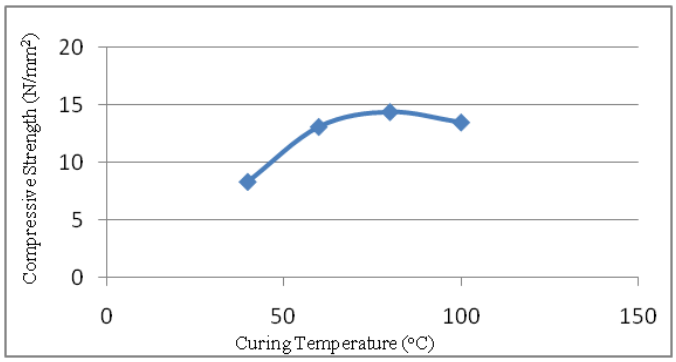

Figure 02: Variation of Compressive Strength with respect to Curing Temperature

SOLUTION TO FLY ASH RATIO AND Na_2SiO_3 TO NaOH RATIO

These are the major strength influencing parameters, same as to water cement ratio in cement concrete. most of the researcher suggested the solution to fly ash ratio 0.3, 0.35 and 0.4 and Na_2SiO_3 to NaOH Ratio1 to 2.5. It is depends upon the chemical composition of fly ash, molarity of NaOH solution, total solids in sodium silicates solution. To know the optimum ratio of Solution to Fly ash and Na_2SiO_3 to NaOH for ultimate strength the following ratio were used. The effect of Solution to Fly ash ratio on Compressive Strength is given in table no.5.

TABLE 5: EFFECT OF SOLUTION TO FLY ASH RATIO ON COMPRESSIVE STRENGTH

Na_2SiO_3/ NaOH	S/FA Ratio wise Compressive strength N/mm^2							
	0.2	0.3	0.35	0.4	0.5	0.6	0.7	0.8
1	2.54	8.89	14.38	23.21	30.56	28.02	26.42	24.55
1.5	1.81	9.96	13.84	24.81	38.65	35.04	32.63	30.77
2	2.81	10	17.32	23.87	37.85	36.33	34.86	32.51
2.5	1.61	8.16	11.84	18.59	34.37	30.69	27.64	25.15
3	1.67	6.49	11.64	18.26	29.63	24.87	22.3	20.54

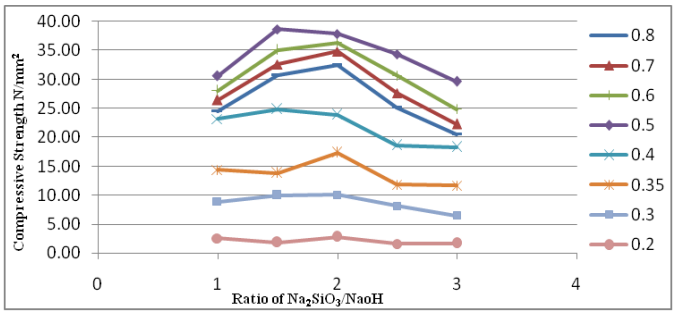

Figure 03: Variation of Compressive Strength with respect to Ratio of Na2SiO3 to NaOH.

OBSERVATION AND DISCUSSION

While doing this experimental work it is observed that, while mixing the mortar paste the mixing time increases increase the workability up to 4-5 min then stickiness increase and workability get reduce. Solutions to fly ash ratio increases then increase the workability of mortar. Also workability get increase in case of increase the ratio of Na_2SiO_3 to NaOH. Increase the solutions to fly ash ratio the darkness of color get increased. The figure no.03 represents, in case of solution to fly ash ratio 0.2, the compressive strength almost same for all the ratio of Na_2SiO_3 to NaOH. Solution to fly ash ratio increases the compressive strength get increase up to the ratio of 0.5 but after the 0.5 ratio the strength get reduce. The solution to fly ash 0.5 with Na_2SiO_3 to NaOH ratio 1.5 produces the maximum strength of mortar. Sodium silicates to sodium hydroxide ratio 1.5 produce the maximum strength in solution to fly ash ratio 0.4 and o.5. In case of solution to fly ash ratio 0.2, 0.4, 0.35, 0.6, 0.7 and 0.8 and 0.5, Sodium silicates to sodium hydroxide ratio 2.0 produce the maximum strength as compared to other respective ratios.

CONCLUSION:

1. The activator solution prepared before 1day produce the same strength as solution prepared at the time of mixing.
2. The mortar curing after 4 days rest period produce ultimate compressive strength at 7 days.
3. The mortar cubes cured at 80 °C temperature for 1 day gives the maximum compressive strength.

4. The solution to fly ash ratio 0.5 gives the ultimate strength to mortar for all ratios of sodium silicates to sodium hydroxide.
5. The mix with Sodium silicates to sodium hydroxide ratio 1.5 and 2.0 provide the maximum strength as compared to other ratio.
6. The solution to fly ash ratio 0.5 with sodium silicates to sodium hydroxide ratio 1.5 produces ultimate compressive strength at 7 days.

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