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Performance of Slag (GGBS) And Fly-Ash Based Concrete on Property of Concrete Pavement

Rohit Kumar[1]*, Vishal Chandrakar[2]

[1]M. Tech, Civil Engineering Department, Shri Shankaracharya technical Campus, Bhilai-490020 Chhattisgarh, INDIA,

[2]Assistant Professor, Civil Engineering Department, Shri Shankaracharya technical Campus, Bhilai-490020 Chhattisgarh, INDIA.

Abstract

The present aims to find out the most acceptable way to utilize the waste materials which is produced from different sources like industries as the replacement of cement for highway construction purposes. A no of trail have been done across the world to identified the adverse effects of different waste materials on environment as well as on human health also. The basis of different studies, it was revealed that the production of cement on large scale is also responsible for causing several diseases to the human and the water pollution. Therefore, it is the need of the situation to utilize the different waste material as an alternative of cement. For the same purpose several studies were conducted across the world. Consequently, different waste materials were found to be appropriate ranging for the highway. For this purpose a materials like as Blast furnace Slag (GGBS) and fly ash considered as industrial waste materials. they having content of Silicon (Si), Aluminum (Al) and calcium oxide (CaO) can be used with activating them through alkaline solutions to making binder material in concrete called Geopolymer concrete. The details of Geopolymer concrete making and different properties are analyses. A method based on results from the trial samples has been adopted to make Geopolymer Concrete and the different parameters affecting the properties of Geopolymer concrete were understood. Waste materials which were Fly-ash and GGBS were selected as the main materials for activating using Alkaline Solution through the process known as polymerization, which can reduce our dependability on environment polluting Portland cement for making concrete. Due to its environment friendly properties this concrete can be one of the solution to global warming due to modernization.

Keywords: *Geopolymer concrete(GPC); Fly-ash(FA);GGBS (ground granulated blast furnace slag);Alkaline solution, waste material (WM)..*

** Corresponding author*

1. Introduction

Concrete is among the frequently used material requiring Cement as the common binding material and lots of environment concerns are related to cement production. Professor J. Davidovits proposed in 1978, the concept of geo polymerization process can be used to produce a binder to make concrete through a reaction between alumina and silica containing compounds from industrial waste materials and alkaline solutions known as geo polymerization reaction[1].To study the various parameters of Geopolymer concrete, which can be cured on-site conditions, was the basic idea behind the project and influence of variations in relative proportion of ingredients into the concrete properties.

Cement is being used since nearly 12 million years, as the best binding material of different concrete[14].Generally,huge quantity of natural materials (Limestone's, boulders etc.) are required in producing Cement in Cement manufacturing industries and pollutants are released into the atmosphere, which severely affects the health of living organisms when inhaled. Due to number of power plants being operational in Chhattisgarh State of India the availability of Fly-ash and GGBS is high which requires effective disposal if it can't be utilized in other effective ways. By proper utilizing the industrial waste material the required energy and cost can be reduced which will help in better waste management. This will reduce the amount of greenhouse gases released into the atmosphere and also the costs associated with it will be reduced[9]. The complete reduction of environment polluting cement usage cannot be achieved till now."Geopolymer concrete" can be a better solution to the polluting cement if better technology could be developed for its development.

Fly-ash is considered better among the available raw materials because of easily availability and improvement in physical properties it provides in Geopolymer concrete[2]. Geopolymer concretes made using only Fly ash were obtained by curing at high temperatures of about 60°C-70°C leading to its usage restriction. Therefore, Geopolymer concrete is made with a combination of fly-ash and GGBS, which can be cured at ambient temperature conditions. Normal concrete has been made having M25 grade and M35 grade concrete using OPC as binder. The basic factor leading to applicability of any technology is the cost involved with it, keeping that in view economic feasibility studies was carried out by comparing Geopolymer concrete cost with conventional concrete cost as per the 28th day strength requirements so that the wider applicability of Geopolymer.

2. Experimental Program

2.1Materials

2.1.1 Fly Ash and Slag (GGBS)

In geopolymer concrete pulverized siliceous fly-ash obtained from National Steel Power Corporation (NSPCL), Bhilai, India, with specific gravity of 2.3 and Slag (GGBS) after grinding it to be used in concrete without more reduction in the workability has been used. GGBS was having the specific gravity of about 2.8 obtained from the, Bhilai Steel Plant(BSP),Chhattisgarh, India. Both materials were used as the binder material in concrete. Table1 gives the composition of oxides of GGBS and Fly Ash. The variation in the properties of concrete due to Fly-ash and GGBS was understood from the trial experimental works. The oxide composition of GGBS shows that lime (CaO) content is more in GGBS which provides the higher compressive strength, [10].

Figure: fly ash

Figure : GGBS

Table1: Chemical Composition of typical Indian slag & Fly Ash(Ref.: Central pollution control board of India)

Oxides %	**GGBS**	**Fly Ash**
SiO_2	33.41	48.7
Al_2O_3	20.05	14.31
Fe_2O_3	0.89	3.51
CaO	34.24	1.03
MgO	8.86	0.39
SO_3	NIL	0.14
Na_2O	0.16	0.21
K_2O	0.82	0.79
TiO_2	NIL	1.13

2.1.2 Coarse aggregate

Coarse aggregates used were locally available aggregates supplied from the stone crushing site belonging to zone-II as per the IS-standards, Coarse aggregates used have the specific gravity of about 2.72 and a combination of 60:40 was used for 20mm and 10mm coarse aggregates, decided on the basis of trials done with different proportions leading to better workability and strengths.

2.1.3 Fine aggregate

Locally available river sand with the specific gravity of about 2.62 were used. The fine aggregates of predetermined quantity was taken as per the mix. Sieve analysis as per IS 2386:1963 was performed to understand the physical property of sand. From the results of sieve analysis, the sand was belonging to Zone-II specification of IS 383:1970.

2.1.4 Alkaline Activator Solution

Prof. J. Davidovits was1st person worldwide to discover Geopolymer Concrete by activating the industrial waste materials using alkaline activators of Geological origin. The Common activators includeNaOH, Na2SO4,. The mostly used alkaline activators in geopolymer concrete are a mixture of sodium hydroxide (NaOH) or potassium hydroxides(KOH) and Silicates of Sodium (Na2SiO3) or Silicates of Potassium (K2SiO3). The alkaline solution to be prepared at least 24 hours before mixing because at the time of mixing of Sodium Silicate Solution (Na2SiO3) solution with Sodium hydroxide solution (NaOH) huge amount of heat is generated which will create difficulty if made on the spot. Molarity of Sodium hydroxide Solution (NaOH) was calculated by multiplying its molecular mass (NaOH, 1+23+16=40) with the molarity number required per liter of the solution. Approximately 97% purity sodium hydroxide (NaOH) in flakes form supplied by the local supplier of Raipur(C.G.) and silicate solution (Na2SiO3) with approx., 61.7% of water which was bought from soap manufacturing industry in Raipur(C.G.) were used. For making the NaOH solution, NaOH in solid flakes form were mixed with water of required molarity in a heat resistant container. This was prepared approximately 24 hours before the scheduled casting of concrete.

3. Mix proportions for Concrete

Conventional concrete mix:

M25 and M35 grades conventional concrete was made by using 43-grade OPC as per the recommendations of mix design under code IS10262-2009, to compare the different properties of OPC concrete with Geopolymer concrete, Super plasticizer was used as chemical admixture in both the grades of concrete.

Geopolymer concrete mix:

As there is no standard procedure for Indian condition's or IS code available for the mix designing of Geopolymer Concrete, a rigorous mix design process was adopted based on the available literatures and trials were done to select a proper mix design, [6]. The specimen were kept for curing for 28 days at ambient conditions

For comparing Geopolymer concrete with control mix, Geopolymer concrete with varying mix proportion of FLY ASH and GGBS was pre pared. The combination ratio of fly ash and GGBS as binder was selected by conducting concrete cube test with varying ratios as shown in Table 2.different Fly ash to GGBS ratio were selected for Geo-polymer concrete mix design. The mixing procedure used for Geopolymer concrete is similar to that of conventional OPC concrete. Mixing of all the materials have been done in the laboratory at room temperature.

Table 2: Proportion of mixes per m^3 of Concrete

Ingredients	**Conventional concrete kg/m3**		**Geopolymer Concrete (kg/m3) (Fly ash/GGBS)**						
	M25	M35	90/10	80/20	70/30	60/40	50/50	40/60	30/70
OPC	350	400	-	-	-	-	-	-	-
Fly Ash	-	-	339.3	301.6	263.9	226.2	188.5	150.8	113.1
GGBS	-	-	37.7	75.4	113.1	150.8	188.5	226.2	263.9

Fine aggregate		700.79	666.65	670	670	670	670	670	670	670
Coarse aggregate (CA)		1245.86	1238	1152	1152	1152	1152	1152	1152	1152
CA	20mm	747.52	742.80	691.20	691.20	691.20	691.20	691.20	691.20	691.20
	10mm	498.34	495.20	460.80	460.80	460.80	460.80	460.80	460.80	460.80
Super plasticizer		7.00	8.00	-	-	-	-	-	-	-
Na2SiO3		-	-	91.2	91.2	91.2	91.2	91.2	91.2	91.2
NaOH		-	-	73	73	73	73	73	73	73
W/C (S)		0.40	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Water		140	140	75	75	75	75	75	75	75

Curing of Geopolymer concrete:

After casting the specimens of Geopolymer concrete they were kept for hardening before demolding. After attainment of sufficient strength the demolding of cubes was done and kept at ambient temperature for curing before carrying out the tests. Here making of Geopolymer concrete which cured at on-site situations was the main aim, which was achieved by using Slag(GBBS). Here no external curing is used which reduces some cost and increases its applicability in water scarce areas. Normal water curing was adopted for curing of conventional concrete made using OPC.

3. Testing, Result and brief discussion

4.1 Slump cone apparatus test for workability of Geopolymer concrete

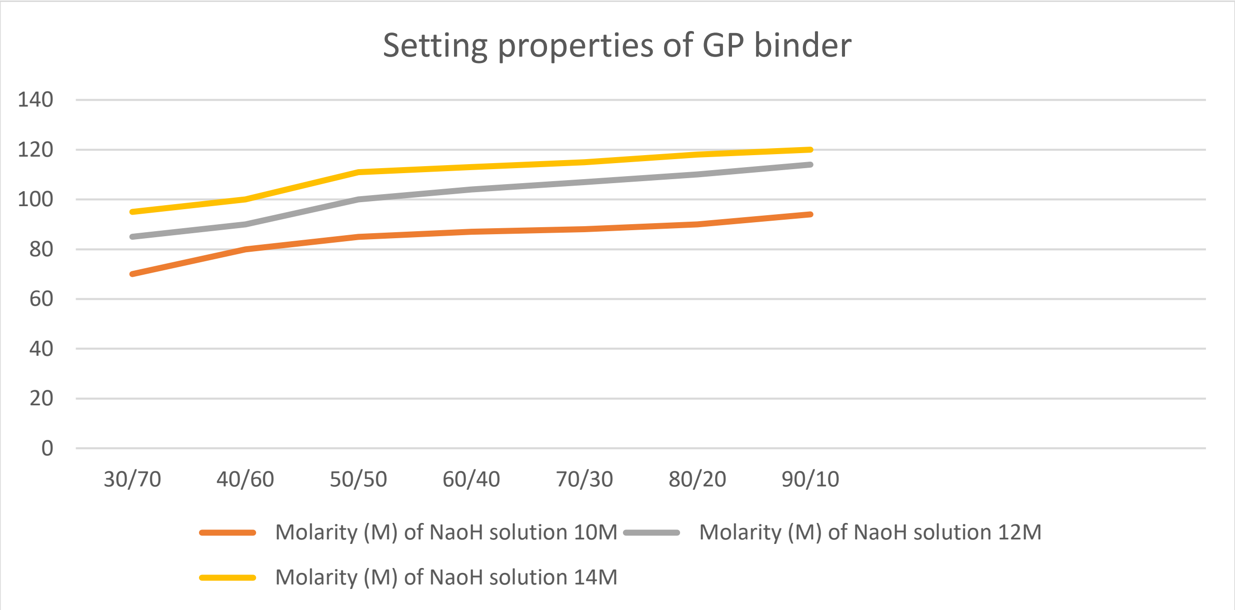
Here it has been observed that as the percentage of GGBS increases in the mix the slump value decreases and similar trend is observed with the increase in molarity of Sodium Hydroxide (NaOH). The mix was prepared without using any admixtures because admixtures were found to be less effective in case of Geopolymer concrete as per the trial experiments.

4.2 Setting time test

Vicat's apparatus was used for determining Geopolymer binder setting time. Same procedure was used here which is used for cement. Setting behavior of Geopolymer paste was studied for different sodium hydroxide molarities (10M, 12M, 14M) and for different proportions of GGBS and fly-ash in Geopolymer binder. Table shows the results for different setting times of different binders of Geopolymer concrete. It was observed that with the increase in the concentration of sodium hydroxide solution i.e., molarity resulted in higher setting time was achieved. The setting behavior of Slag with the alkaline solution is faster than the fly ash, thus using Slag along with fly-ash in binder, higher early strength Geopolymer concrete can be obtained

S. No.	**Material combination**	**Setting time (minutes)**

	FA (%)	GGBS (%)	Molarity (M) of NaoH solution		
			10M	**12M**	**14M**
1	30	70	70	85	95
2	40	60	80	90	100
3	50	50	85	100	111
4	60	40	87	104	113
5	70	30	88	107	115
6	80	20	90	110	118
7	90	10	94	114	120



4.3 Compressive strength test

As per IS 516-1959 the compressive strength was tested for Geopolymer concrete cubes at 7th and 28th days of casting and results of test are shown in Table3.A comparison of M25 and M35 grades conventional concrete with 50/50 and 40/60 (Fly Ash/GGBS) proportioned Geopolymer concrete was carried out and the strength variation are calculated, as given in Table5, where the Sodium hydroxide molarity was fixed at 14M due to workability and consistency requirements. Compressive strength tested using 100mm size cubes in compression testing machine.

Table5: Compressive strength results for different mixes

S.no.	Concrete mix (Fly-ash/GGBS)	7 day compressive strength (MPa)			28 day compressive strength (MPa)		
molarity	→	10M	12M	14M	10 M	12M	14M
1	90/10	-	-	-	13.3	14.5	16.2
2	80/20	-	-	-	14.7	15.9	17

3	70/30	6.5	7.0	7.8	19.2	21.2	24.6
4	60/40	6.8	7.5	8.4	18.4	22.7	26
5	50/50	7.2	8.4	9.5	21.7	25.2	31.1
6	40/60	8.3	9.6	13.2	24.8	28.6	40.2
7	30/70	9.5	11.8	13	28.6	35.4	44.6
8	M30	20.5			32.41		
9	M40	25.2			41.60		

Table 6: Compressive strength result variation

MIX	Binder Composition	Compressive Strength		Percentage variation	
		7 day	28 day	7 day	28 day
M30	OPC	10.5	32.41		
50/50	GPC	8.9	31.1	43.2%	4.01%
M40	OPC	13.2	41.60		
40/60	GPC	11.6	40.2	44.12%	3.36%

4.4 Splitting tensile strength testing:

IS 5816: 1999 was followed for testing the split tensile strength of concrete which is an indirect test for tensile strength of concrete and the cylindrical specimen were prepared having dimensions as 150mm dia. and 300mm length.After demolding the specimens split tensile strength test was performed using the compression testing machine where the specimen is kept at desired location and the load is applied, until the specimen failed and the load at failure is noted (P). After determining the load (P) the following equation was used for finding the splitting tensile strength.

Splitting tensile strength of concrete (MPa) = $\frac{2P}{\pi DL}$

Where, D is the diameter and L is the length of cylindrical specimen.

The splitting tensile test was carried for geopolymer concrete having fly ash and GGBS in proportion of 50:50, 40:60, and M30, M40 grades conventional concrete made with OPC grade-43 at the achievement of 28 day. The Splitting-tensile test results are as given in table 7 which shows a higher tensile strength for Geopolymer concrete.

Mix	**Binder composition**	**28 day tensile strength N/mm^2**	**Percentage increase**
OPC	M30	2.757	
GPC	50% fly ash + 50% GGBS	2.904	5.33%

OPC	M40	3.10	
GPC	40% fly ash+ 60% GGBS	3.32	7.21%

4. Conclusion

The conclusions that are drawn on the basis of experimental works carried on are as listed below:

- By using Geopolymer concrete as an alternative of Portland cement the CO2 emission gets reduced, leading to sustainable construction and production of the "Environment-friendly concrete".
- Presence of Slag, in Geopolymer concrete makes the polymerization process possible a tambient Temperature only and results in higher compressive strength, which provides on-site casting of Geopolymer concrete.
- By increasing in the molarity /concentration of Sodium hydroxide Solution (NaOH) (10M, 12M & 14M)better strength has been observed, but increasing molarity of solution increases the cost and it is required to fix the optimum molarity of NaOH.
- An inverse relationship between workability of Geopolymer concrete and molarity of sodium hydroxide solution has been found, and the similar trend of workability is also seen with the variation of Slag content into Geopolymer concrete, Here Geopolymer concrete with maximum amount of fly-ash has achieved maximum workability.
- The chemical admixtures are not found to be very useful in case of Geopolymer concrete workability unlike the Conventional Concrete made by using OPC, which may be due to the polymerization process going on after mixing of concrete ingredients.
- The split tensile test of Geopolymer concrete was conducted on cylindrical specimen gives more tensile strength than conventional concrete having approximately same compressive strength.
- Geopolymer concrete will be best solution for concreting in the water scarce areas and areas having high temperatures such as equatorial areas.
- The cost of Geopolymer Concrete is slightly on the higher side than the cost of OPC concrete for lower grades but for higher grades, the difference between costs was found to be less

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