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An Experimental Investigation on GGBSand Flyash Based Geopolymer Concrete with Replacement of Sand by Quarry Dust

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Abstract
Extensive research is currently going on to evaluate geo-polymer in civil engineering application. The project aims at making ecofriendly concrete and increasing the strength of the concrete. Cement, the second most consumed product in the world, 5% – 8% of world's man made greenhouse gas emission are from the cement industry itself. It is well known that cement production depletes significant amount of natural resources and release of large volume of carbon dioxide. On the other hand, coal burning power plants produce huge quantities of fly ash. Most of the fly ash is considered as waste, dumped in landfills and GGBS exhibits cementitious as well as pozzolanic characteristics so it is quite right in choosing of fly ash and GGBS for concrete mix. Due to over exploitation of river sand for the construction, resulting in river bed erosion. So government frames more restrictions in exploiting them. In order to overcome this issue we use to replace river sand by quarry dust. Alkaline liquids are used as the binding materials, alkaline liquids used in this study for the polymerization are the solution of Sodium Hydroxide and Sodium Silicate, molarity of Sodium Hydroxide 10 M is taken to prepare different mixes. And the strength is calculated for each of the mix. Curing is done by placing specimens at room temperature. The specimen are tested at the age of 7, 14 and 28 days, the test includes compressive strength, split tensile strength and flexure strength. The test results shows that GGBS and Fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications.
Key Word: Geo-Polymer, Fly ash, GGBS, Alkaline Solution, Strengths.

I. INTRODUCTION

Concrete is the second most used material in the world after water. Ordinary Portland Cement (OPC) becomes an important material in the production of concrete which act as its binder to bind all the aggregate together. However, the utilization of cement causes pollution to the environment and reduction of raw material (limestone). The production of Portland cement worldwide is increasing 9% annually. The current contribution of greenhouse gas emission from Portland cement production is about 1.5 billion tonnes annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere. In India about 2.10 lakh thousands of metric tons of CO2 is emitted in the year of 2010. The cement industry contributes about 5% of total global carbon dioxide emissions. The cement is manufactured by using the raw materials such as lime stone, clay and other minerals, Quarrying of these raw materials is also causes environmental degradation.To produce 1 ton of cement, about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it. On the other side the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, we have to replace the cement with the industrial by products such as fly-ash, GGBS (Ground granulated blast furnace slag) etc. In this respect, the new technology geo-polymer concrete is a promising technique.

It is important to find an alternate binder which has less carbon footprint than cement.Geopolymer is an excellent alternative which transform industrial waste products like GGBS and fly ash into binder for concrete. The term geopolymer was first coined by Davidovits in 1978 to represent a broad range of materials characterized by chains or networks of inorganic molecules.

Geopolymers are chains or networks of mineral molecules linked with co-valent bonds. Geopolymer concrete is produced by a polymeric reaction of alkaline liquid with source material of geological origin or by product material such as GGBS and FLYASH.

On the other hand River sand, which isOne of the constituent used in the production of conventional concrete, has become expensive and also a scarce material. In view of this, there is a need to identify suitable alternative material from industrial waste in place of river sand. The utilization of quarry dust which is a waste material has been accepted as building material in many countries for the past three decades.

II. MATERIALS

A. Fly Ash

Fly ash is the waste obtained as a residue from burning of coal in furnaces and locomotives. It is obtained in the form of powder. It is a good pozzalona the colour of fly ash is either grey or blackish grey.

Table. I Properties of Fly ash

SI No	Property	Value
1.	Specific gravity	2.43
2.	Fineness	227.8 g/m^2
3.	Fineness modulus	5
4.	Density	1025.7 Kg/m^3

B. Ground granulated blast-furnace slag (GGBS)

GGBS is obtained by a by-product of iron and steel in blast furnace to produce a glassy, granular product that is then dried and ground into a fine powder.

Table.II Properties of GGBS

SI No	Property	Value
1.	Specific gravity	2.61
2.	Fineness	202.7 g/m^2
3.	Fineness modulus	7
4.	Density	2068.50Kg/m^3

C. Alkaline Liquids

The solutions of Sodium hydroxide and SodiumSilicate are used as alkaline solutions in the present study. Commercial grade Sodium Hydroxide in flakes form (97%-100% purity) and Sodium silicate solution having 7.5%-8.5% of Na_2O and 25% -28% and water of 67.5% - 63.5% are used in the present study.

D.Fine Aggregate

Fine aggregate used in this research is river sand. Fineaggregates are the aggregates whose size is less than4.75mm. Sand is generally considered to have a lowersize limit of about 0.07mm, also free from clay, mineralsand salt.

Table.III Properties of Fine aggregate

SI No	Property	Value
1.	Specific gravity	2.60
2.	Fineness modulus	4.35
3.	Shape	Diamond
4.	Surface texture	Smooth
5.	Sieve analysis	ZONE II

E. Quarry Dust

The quarry dust is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes.

Table. IV Properties of Quarry dust

SI No	Property	Value
1.	Specific gravity	2.34
2.	Moisture content	Nil
3.	Fineness modulus	14
4.	Sieve analysis	ZONE II

F. Coarse Aggregate

The aggregates most of which are retained on the4.75mm IS sieve are termed as coarse aggregates.20mm and 12.5mm size of coarse aggregate is used.

Table.V Properties of Coarse aggregate

SI No	Property	Value
1.	SpecificGravity	2.90
2.	Finenessmodulus	7.2
3.	WaterAbsorption	8.5%
4.	ParticleShape	Angular
5.	Impact value	9.10%
6.	CrushingValue	17.8

III. METHODOLOGY

A. Preparation of Alkaline solution

In this research work the strengths of Geopolymer concrete is examined for the mixes of 10 Molarity of sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 10 Molarity of solution 400 g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution. Volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

B. Mix Proportion

As there are no code provisions for the mix design of geopolymer concrete, the density of geo-polymer concrete is assumed as 2400 Kg/m^3. The rest of the calculations are done by considering the density of concrete. The total volume occupied by fine and coarse aggregate is adopted as 70%. The alkaline liquid to fly ash and GGBS ratio is kept as 0.4. The ratio of sodium hydroxide to sodium silicate is kept as 2.5.The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete.

Table. VI Mixing Proportion

Mix ID	**GGBS (kg/m^3)**	**Flyash (kg/m^3)**	**Fine aggregate (kg/m^3)**		**Coarse aggregate (kg/m^3)**		**Alkaline solution (kg/m^3)**	**NaOH / Na_2SiO_3**	**Molarity of NaoH**
			Sand	**Quarry dust**	**10 Dn**	**20Dn**			
GC1	515	-	504	-	470	706	206	2.5	10M
GC2	257.50	257.50	504	-	470	706	206	2.5	10M
GC3	515	-	-	504	470	706	206	2.5	10M
GC4	257.50	257.50	-	504	470	706	206	2.5	10M
CC	492.50 (Cement)		701.50		458	687	W/C = 0.4	Water = 197kg/m^3	
Super plasticizer = 5 kg/m^3 for Each mix proportions									

Table. VII Quantity estimation and planning of experiment

Description	**Compressive Strength Test**	**Split Tensile Strength**	**Flexural Test**
Specimen Size	Cube(150x150x150)	Cylinder(150 Dia&300Ht)	Prism(150x150x750)
No. of Specimens	3	3	3
Days of Testing	7,14,28	7,14,28	7,14,28
Total No. of Specimen	9	9	9
Volume of Each Specimen (Cum)	0.003375	0.0053	0.0169
Volume of All Specimen (Cum)	0.0304	0.0477	0.1521
Total Volume of Concrete = 0.23Cum for Each mix proportions			

C. Casting and Curing

Firstly, the fine aggregate, coarse aggregate, fly ash and GGBS are mixed in dry condition for 3-4minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super-plasticizer is added to the dry mix. Water is taken as 10 % of the cementious material (fly ash and GGBS). The super plasticizer is taken as 3% of the cementious material.

The mixing is done forabout 6- 8 mins for proper bonding of all the materials. After the mixing is done, specimens are casted by giving proper compaction in three layers. For the curing, the cubes are demoulded after 1 day of casting and they are placed in room temperature for 7, 14 and 28 days.

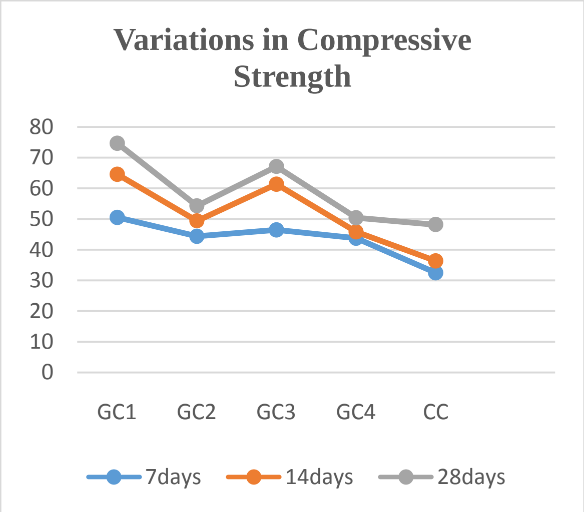
Fig.1 Compressive Test

IV. RESULTS

The specimens are tested at the age of 7, 14 and 28 days of curing.

Table. VIII Average Compressive Strength

MIX/AGE	7 days	14days	28days
GC1	50.54	64.59	74.67
GC2	44.38	49.41	54.25
GC3	46.50	61.33	67.10
GC4	43.75	45.81	50.39
CC	32.50	36.33	48.15

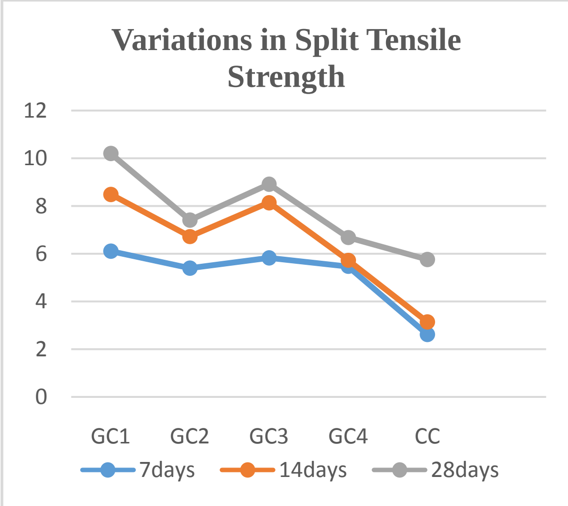


Graph.1 Variation in Compressive Strength

Fig.1 Split tensile crack

Table. IX Split Tensile Strength

MIX/AGE	7 days	14days	28days
GC1	6.11	8.49	10.20
GC2	5.40	6.72	7.41
GC3	5.83	8.14	8.91
GC4	5.47	5.73	6.68
CC	2.62	3.14	5.76

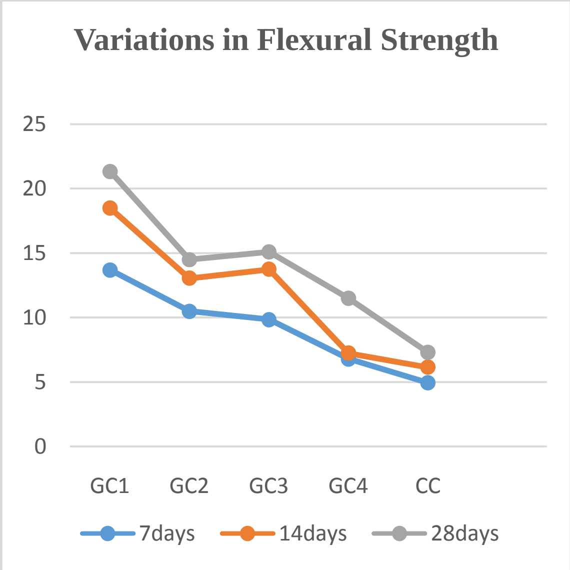


Graph.2 Variation in Split Tensile Strength

Fig.3 Flexural Test

Table. XFlexural Strength

MIX/AGE	7 days	14days	28days
GC1	13.70	18.50	21.35
GC2	10.50	13.05	14.50
GC3	9.85	13.75	15.10
GC4	6.80	7.25	11.50
CC	4.95	6.15	7.30



Graph.3 Variation in Flexural Strength

D.Discussions

Based on the results obtained in the experimental investigation, the following conclusions are found.

The GGBS and Fly ash based Geopolymer concrete gained strength with earlier time period at ambient temperature.The necessity of heat curing of concrete was eliminated by incorporating GGBS and fly ash in a concrete mix.The strength of geopolymer concrete was increased percentage of GGBS in a mix.It was observed that the mix Id GC1 gave maximum compressive strength of 74.67Mpa. GGBS and Fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications.

Due to the high early strength Geopolymer Concrete shall be effectively used in the precast industries,so that huge production is possible in short duration and the breakage during transportation shall alsobe minimized. The Geopolymer Concrete shall be effectively used for the beam column junction of areinforced concrete structure. Geopolymer Concrete shall also be used in the Infrastructure works. Inaddition to that the Flyash shall be effectively used and hence no landfills are required to dump theflyash. Apart from less energy intensiveness, the GCs utilize the industrial wastes for producing the binding system in concrete. There are both environmental and economical benefits of using flyash and GGBS.

The government can make necessary steps to extract sodium hydroxide and sodium silicate solutionfrom the waste materials of chemical industries, so that the cost of alkaline solutions required for thegeopolymer concrete shall be reduced.

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