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INVESTIGATION AND COMPARSION OF STRENGTH OF CONCRETE BASED ON GGBS AND FLY ASH AGAINST ACID ATTACK

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ABSTRACT

Cement is one of the components for attributing carbon dioxide gas in to the atmosphere .To reduces the global temperature these cementious materials (GGBS and Fly Ash) are used as partial replacements for cement. Objective of this project is to investigate the mechanical properties of concrete by replacing cement with GGBS (80%) and low calcium Fly ash (20%) exposed to ambient temperature at 7, 14, 28, 56 and 91days.For the polymerization process a molarity of 8 and 10M solutions prepared with Sodium Hydroxide (NaOH) and sodium silicate (Na_2Sio_3). Cubes of size 150mm x 150mm x 150mm are used for determining compressive strength of concrete and 150mm x 300mm moulds are used for determining tensile strength of concrete. Concrete casting is done for both molarities 8 and 10M with ratio of alkaline/ GGBS-Fly Ash as 0.35 and 0.45. Compressive strength at the age of 7, 14,28,56,91 days was determined. Ordinary Portland cement concrete is also prepared for comparison of test results. For acid attack on concrete two different solutions are prepared i.e., a solution of 5% Sodium chloride(NaCl) and a solution of 10% Sodium sulphate(Na_2So_4).For Acid attack cast iron moulds of size 100mm x 100mm x100mm were used. Cubes placed in water and acid solution for comparison of results. From the experimental results it was observed that with the increase in molar concentration considerable change is shown in mechanical properties of GPC.

Keywords: Geo-Polymer, GGBS, Fly Ash, Sodium Hydroxide, Sodium Silicate, Sodium Chloride, Sodium Sulphate, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Davidovits is the one who researched and introduced Geopolymer Concrete to this world. Various cementious materials are evolved for to prepare Geoploymer concrete such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin etc.,. Cement is one of mostly used material in this world, due to the production of 1 ton of cement 1 ton of carbon dioxide released in to the atmosphere. Carbon dioxide is one of the gas which is responsible for Global Warming.Now a day's world is really getting polluted with carbon dioxide gas which are releasing from various industries. So, by using slag and Fly ash as partial replacement for cement the emission of carbon dioxide to atmosphere will be minimized. In this technology cement is completely replaced with two products (GGBS and Slag) which were obtained as by products from industries. For getting binding nature between these products an alkaline solution which is prepared with a molarity of 8

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and 10 M with Sodium Hydroxide (NaoH) and sodium silicate (Na_2Sio_3).Sodium Hydroxide which is available in pellets and sodium silicate is available in liquid form. These materials are taken from the local suppliers.

II. MATERIALS USED

- Ground granulated blast furnace slag (GGBS)
- Fly ash
- Sodium hydroxide
- Sodium silicate
- Aggregates

a) Fine aggregate

b) Coarse aggregate

2.1 Ground granulated blast furnace slag

Ground Granulated Blast Furnace Slag is the material which is using widely as replacement of Ordinary Portland Cement. Ground Granulated Blast Furnace Slag is mainly formed with the compounds called calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. Compressive strength of concrete is more when compared with the concrete made from ordinary Portland cement(OPC). It has same chemical compounds like the ordinary Portland cement have. Heat can be easily liberated during mixing of concrete. So, heat of hydration is relatively less with respect to OPC

Table 1: Chemical Composition of GGBS With Respect To Cement

Chemical compound name	Cement (%)	GGBS (%)
Calcium oxide (CaO)	63	40
Silicon di-oxide (SiO2)	20	35
Aluminum oxide(Al2o3)	6	10
Magnesium oxide(MgO)	1.5	8

2.2 Fly Ash

Fly ash is the most available product on this earth and widely used as a supplemental of cement. It is obtained as a by product from coal industry. Generally coal contain carbon compounds. Coal which is obtained from natural resources contains some impurities like having organic compounds on its surface. For removing those impurities coal is get burned. During burning process more weight compounds settle downs and light weight particles just fly in the air. Particles which fly in air are collected and thus we obtain fly ash. Fly ash has two classes i.e, Class C and Class F. Each has class has their own properties.

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Table 2: Chemical composition of Fly Ash

Oxides	Percentages
SO_3	0.28
Mgo	0.81
Na_2O	0.27
K_2O	0.83
LOI	6.23
Fe_2O_3	4.0
Sio_2/Al_2o_3	1.5
CaO	1.2
Sio_2	52.0
Al_2o_3	33.9

2.3 Sodium Hydroxide (NaOH)

Sodium hydroxide is taken from the local suppliers.Sodium hydroxide is choosen because of cheaper in its cost. Sodium hydroxide is available in the form of pellets(Solid form). Amount of pellets and quantity of water to dissolve those pellets are entirely based on Molarity concentration that we have choosed. Solution needs to be prepared 24 hours before the concrete mix to be done.

2.4 Sodium Silicate (Na_2SiO_3)

Sodium Silicate is available in liquid form and it is taken from the local suppliers. Water content present in sodium silicate is 50% by its mass. Mixing of two solutions (Sodium hydroxide, Sodium Silicate) gives alkaline solution. This solution is known as Alkali activator.

2.5 Aggregate

Among the total volume of concrete aggregates occupy about 75% to 78%. So, aggregates plays major role in obtaining strength to the hardened concrete. Aggregates which are the durable, strong, chemically inert and well graded which are used for construction.

Aggregates are classified as fine aggregates and coarse aggregates:

- Sand which passes 4.75 mm Indian Standard sieve by the Indian strandard code 383-1970
- Aggregate are those which remain on Indian Standard sieve 4.7mm are termed as Coarse aggregate.

Fine aggregates are locally supplied and are conforming to Zone-III as per Indian standard 383-1970. Coarse aggregates are also locally supplied and conforming to Zone-III

III. MIX PROPORTION AND EXPERIMENTAL WORK

3.1 Mix design for Geopolymer concrete

For Geopolymer concrete there is no proper mix design as cement have because GPC involves more number of binders such as GGBS, Fly Ash, sodium silicate, sodium hydroxide, water. So, whatever the mix design procedure is adopted for OPC same is adapted to this Geo polymer concrete. In GPC also aggregates occupies 75% to 78% of the volume of the concrete. In this project for a molarity of 10M alkali to GGBS-Fly ash ratio is

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taken as 0.35 and for molarity 12M alakali to GGBS-Fly ash ratio is taken as 0.45.With the help of above ratios (0.35 and 0.45) we can find how much alkali solution is required for binding the materials together.

Fig 1

Fig 2

Fig 1&2: Geopolymer Concrete Mix According to Mix Design

Table 3: Mix proportions

Constituents	Density (kg/m3)
GGBS	256
Fly Ash	64
Coarse aggregate	1287.14
Fine aggregate	671.16

3.2 Preparation of Alkaline Activator Solution

Alkaline Activator Solution is prepared with two chemical compounds namely Sodium hydroxide (NaOH), Sodium Silicate (Na_2SiO_3). Sodium hydroxide is available in the form of solid particles (pellets) that are in small rounded shape. These pellets need to be dissolved in water. Amount of water required to dissolve these pellets is depend upon the molarity that we choose. Sodium hydroxide in pellets form need to dissolve in water for 24 hrs. The alkaline liquid to GGBS-Fly ash ratio is kept as 0.35 and 0.45.The ratio of sodium hydroxide to sodium silicate is kept as 50:50. For $1m^3$(8M-0.35) mix proportions are considered as: GGBS= 330kg, FlyAsh =83kg, Coarseaggregate 20mm = 733.3kg, and10mm = 366.9kg, Fineaggregate = 685.3kg, water = 186liters. For Alkaline liquid to GGBS - Fly ash 0.35 ratio, Alkaline Solution = 413.3x0.35=144.65grams.Na_2SiO_3 = 144.65/2 = 72.33 grams. Quantities of NaOH (solids and water) were taken from Journal presented by RAJAMANE N.P et.al (2015), for 8M$NaOH_{solids}$=25.5and $NaOH_{water}$ = 74.5.Therefore $NaOH_{solids}$ = 0.255x72.33 =18.44gms, $NaOH_{water}$ = 0.745x72.33=53.88 grams. Water to be added = Total water- $NaOH_{water}$-Na2SiO3/2(Sodium silicate is in liquid form; in this 50% will be water and remaining 50% will be only sodium silicate)=186-53.88-72.33/2=95.95 litres. Similarly same procedure is adopted for the 8M-0.45, 10M-0.35and 10M-0.45.One hour before the mixing, sodium silicate solution need to be prepared. Both solutions are needed to mix now. Mix proportions are shown in table 3 and 4.

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Fig 3 **Fig 4**

Fig 3 & 4: Preparation Of Alkaline Activator Solution

IV. PREPARATION OF ACID

For Acid attack an acid is prepared with two chemical compounds namely Sodium chloride (NaCl), Sodium sulphate (Na_2So_4). A cube size of 100mm x 100mm x 100mm is used. By doing mix design quantity of components (GGBS, Fly Ash, Fine aggregate and Coarse aggregate) can be known. Concrete casting is done for both molarities 8 and 10M with ratio of alkaline/ GGBS-Fly Ash as 0.35 and 0.45. Conventional concrete is also made for to compare test results. In this project acid is prepared for 5% of NaCl and 10% of Na_2So_4.

4.1 Quantity of NaCL needs to be added in water

Capacity of tub need to dip the concrete blocks x 1000 x 5% of NaCl

4.2 Quantity of Na_2So_4 needs to be added in water

Capacity of tub need to dip the concrete blocks x 1000 x 10% of Na_2So_4

From 4.1 and 4.2 quantity of NaCl and Na_2So_4 need to add with water can be known. Separate solutions need to prepared namely NaCl and Na_2So_4 .Blocks need to remove from moulds one day after the casting of GPC and CC. Now all blocks (GPC and CC) which were prepared need to place in Acid solution. For comparision cubes also placed in water. At the age of 56, 91 days compressive strength is noted.

Fig 5: Preparation of acid solution **Fig 6: Casting of cubes specimen for acid attack**

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Fig 7: Cubes placed in water and acid

Fig 8: Compression testing

V. RESULTS

In this investigation, compression test and split tensile test was carried on the specimens. In this paper to investigate the strength of GPC 4 mixes was carried having molarity 8 and 10M with ratio of alkaline/ GGBS-Fly Ash as 0.35 and 0.45.

5.1 Compression test:

Cast iron steel moulds having cube size of 150mm X 150mm X 150mm are used for to find out the compressive strength. For each mix proportion 3 cubes are prepared and these are tested at an age of 7, 14,28,56,91 days. 75 cubes of size 150mm X 150mm X 150mm are prepared.

5.1.1Against Acid Attack

For acid attack for each mix proportion 3 cubes are prepared with a size of 100mm x 100mm x 100mm and these are tested at an age of 56,91 days. For determining compressive strength at 56,91 days total 90 cubes are prepared.

5.2 Split Tensile Strength:

For split tensile strength, cast iron moulds having 100mm diameter and 300mm high are used. For each mix proportion 3 cylinders are prepared and these are tested at an age of 7,14,28,56,91 days. Total 75 cylinders are prepared at all ages.

Four different mixes are prepared (GGBS as 80% and Fly Ash as 20%) with molarity of 8 and 10M. Mix proportions for cubes and cylinders are shown in Tables 4 and 5.

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Fig 9 **Fig10**

Fig 9&10: Testing of cylinder specimen for Split tensile strength.

Table 4: MIX PROPORTIONS (For 3 Cubes)

Materials		Mix 1	Mix 2	Mix 3	Mix 4
GGBS(kg)		3.37	3.37	3.37	3.37
Fly Ash (kg)		0.84	0.84	0.84	0.84
Fine aggregate (kg)		8.90	8.90	8.90	8.90
Coarse aggregate (kg)	20mm	11.28	11.28	11.28	11.28
	10mm	5.64	5.64	5.64	5.64
Total water (litre)		1.90	1.90	1.90	1.90
Alkaline/GGBS-Fly Ash		0.35	0.45	0.35	0.45
Alkaline Solution (kg)		1.47	1.47	1.47	1.47
Na_2SiO_3/ NaoH		50:50	50:50	50:50	50:50
Na_2SiO_3(gm)		737	947.5	737	947.5
NaOH(gm)		737	947.5	737	947.5
NaOH solids		187.94	241.61	225.52	289.93
NaOH (water)		549.06	705.88	511.48	657.56
NaOH		8M	8M	10M	10M
Water to be added		0.98	0.72	1.02	0.77

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Table 5: MIX PROPORTIONS (For 3 Cylinders)

Materials		Mix 1	Mix 2	Mix 3	Mix 4
GGBS(kg)		5.18	5.18	5.18	5.18
Fly Ash (kg)		1.3	1.3	1.3	1.3
Fine aggregate (kg)		13.59	13.59	13.59	13.59
Coarse aggregate (kg)	20mm	17.35	17.35	17.35	17.35
	10mm	8.68	8.68	8.68	8.68
Total water (litre)		2.92	2.92	2.92	2.92
Alkaline/GGBS-Fly Ash		0.35	0.45	0.35	0.45
Alkaline Solution (kg)		2.27	2.92	2.27	2.92
Na_2SiO_3/ NaoH		50:50	50:50	50:50	50:50
Na_2SiO_3(gms)		1135	1460	1135	1460
NaOH (gms)		1135	1460	1135	1460
NaOH solids		289.42	372.3	347.31	446.76
NaOH water		845.57	1087.70	787.69	1013.24
NaOH		8M	8M	10M	10M
Water to be added		1.50	1.10	1.56	1.17

Table 6: Compressive Strength of GPC and CC for different ages at Ambient Curing

Mix	7 Days	14 Days	28 Days	56 Days	91 Days
Mix 1	29.59	36.11	41.37	43.70	46.43
Mix 2	29.33	35.76	43.68	44.74	49.84
Mix 3	29.18	34.81	42.07	44.39	49.54
Mix 4	30.95	37.24	45.32	48.85	51.19
Mix 5 (CC)	23.61	29.32	33.33	35.63	39.31

Table 7: Split Tensile Strength of GPC and CC for different ages at Ambient Curing

Mix	7 Days	14 Days	28 Days	56 Days	91 Days
Mix 1	1.88	2.35	2.74	2.93	3.17
Mix 2	1.97	2.28	2.78	2.95	3.19
Mix 3	2.03	2.63	3.03	3.27	3.63
Mix 4	2.11	2.67	3.15	3.31	3.74
Mix 5 (CC)	1.76	2.19	2.49	2.78	2.94

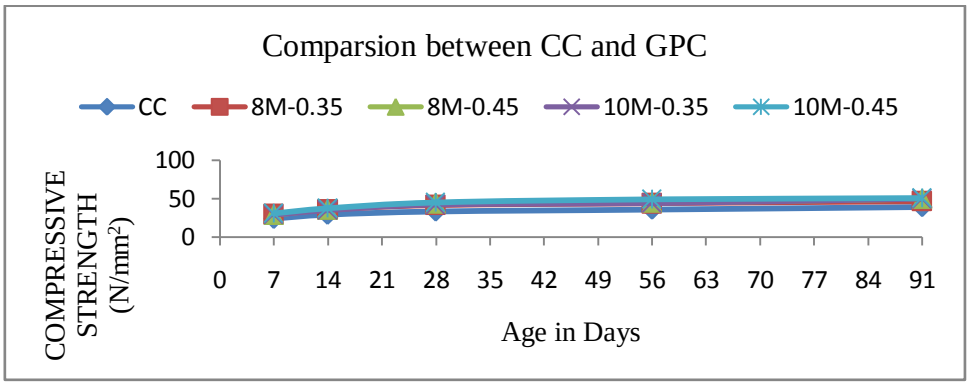
Mix1, Mix 2,Mix 3,Mix 4,Mix 5 are same as mentioned above.

Table 8 : Compressive Strengths of Geopolymer Concrete for different ages against Acid Attack

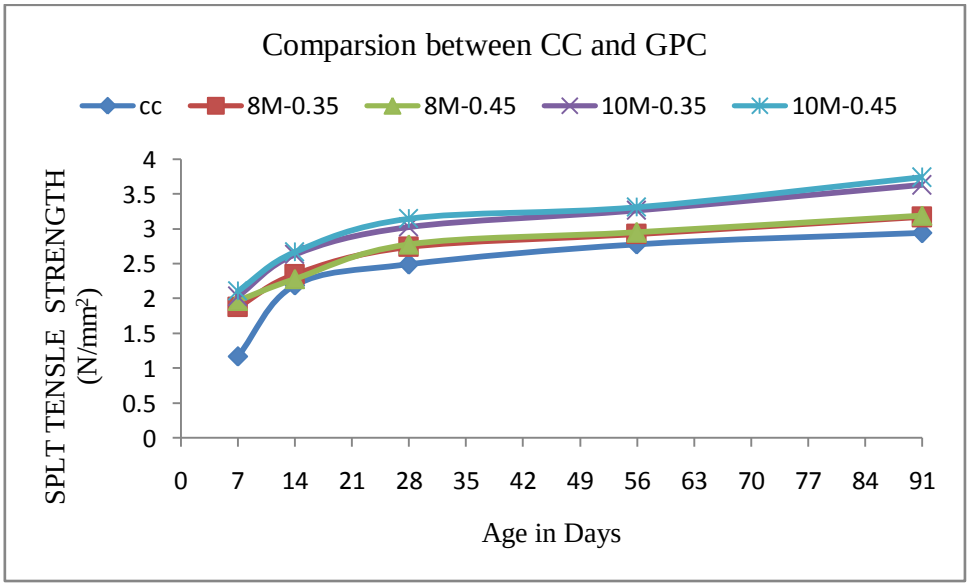
Mix	Water		NaCl (5%)		Na_2SO_4(10%)	
	56 Days	91 Days	56 Days	91 Days	56 Days	91 Days
Mix 1	44.92	46.18	38.35	41.98	39.13	42.18
Mix 2	46.27	50.16	42.51	46.25	44.18	45.04
Mix 3	49.73	54.17	43.93	44.87	40.93	42.67
Mix 4	52.64	59.77	45.03	46.19	41.97	45.62
Mix 5 (CC)	40.63	42.31	32.51	36.67	33.91	37.03

Mix1,Mix 2,Mix 3,Mix 4,Mix 5 are same as mentioned above.

VI. GRAPHS



Graph 1: Compressive Strength



Graph 2: Split Tensile Strength

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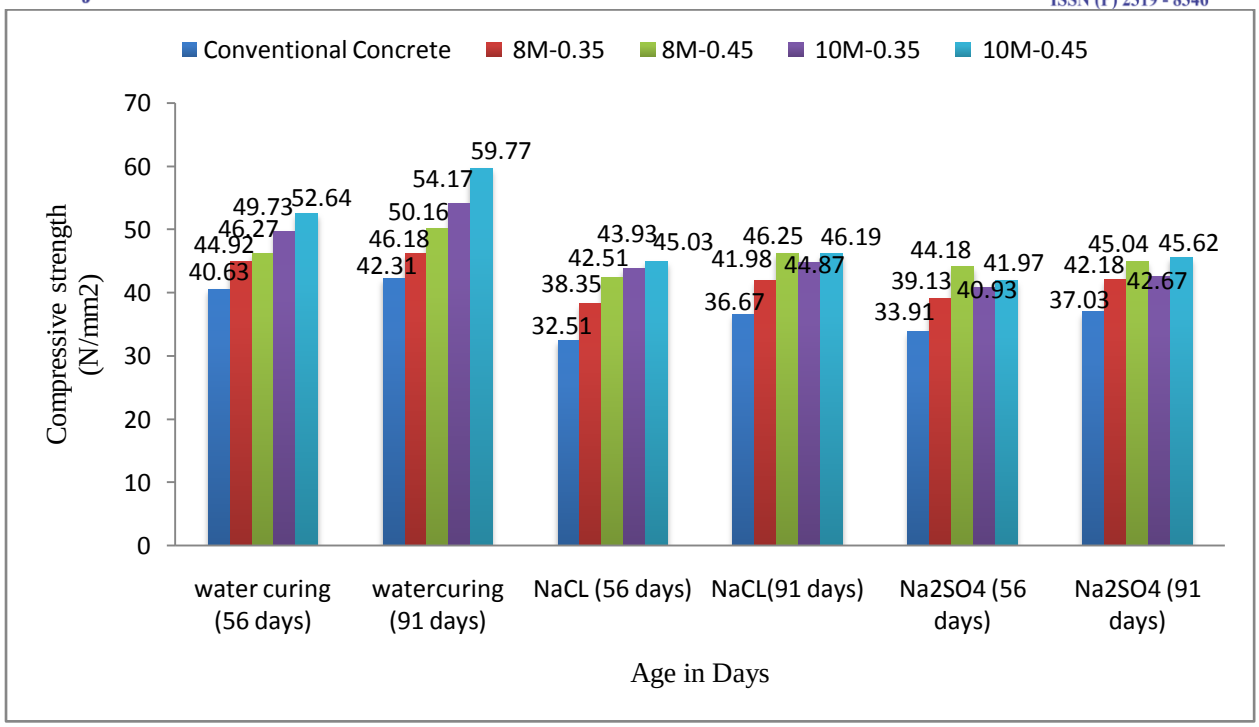

Graph 3: Compressive Strength Of Cubes When Placed In Water And Acid

VII. CONCLUSION

1. As concentration of NaOH increases strength also increases.
2. As the ratio of alkaline liquid by GGBS-Fly Ash ratio increases compressive strength increases.
3. The compressive strength and split tensile strength of Geopolymer concrete is more when compared with conventional concrete at ambient temperature.
4. By comparing the results of CC and GPC, GPC of 10M with alkaline to GGBS-Fly Ash ratio of 0.45 gives best results i.e. about 30.2% more for compressive strength and 27.2% of split tensile strength at 91 days.
5. When immersed in sodium chloride and sodium sulphate solutions for 56 and 91 days all molar shows reduction in strength when compared with strength obtained from the cubes placed in water.
6. The behavior of sress-strain curves for 10M-0.35 and 10M-0.45 having more brittle nature when compared to conventional concrete.
7. It was observed that Geopolymer concrete has an excellent resistance to acid attack when compared to conventional concrete.
8. From experimental results concluded that Geopolymer concrete possesses excellent Strength characteristics and durability for aggressive environment conditions when compare to conventional concrete.

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