STUDY ON STRENGTH AND DURABILITY ASPECTS OF GEOPOLYMER CONCRETE

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Abstract – *Concrete is till now most fashionable material in construction industries and one of the most environmentally harmful materials. Due to environmental concerns of cement industry, there arises a strong need to make use of alternate technology which is sustainable. Geopolymer is an alternative material which can act as a binder by replacing cement. In this experimental work have analysis the strength and durability properties of fly ash and ground granulated blast furnace slag (GGBS) based geopolymer concrete and also the cost comparison with the normal concrete. The concentration of sodium hydroxide is 13 molarity(M) solutions kept a constant to prepare the mix and alkaline liquid to binder ratio as 0.40, but changing ratio of sodium hydroxide (NaOH)to Sodium silicate (Na_2Sio_3) 1.50, 2.00 and 2.50. The cube compressive strength was calculated for different alkaline activator solution for different mix Id. i.e. $F_{100}G_0$, $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$ and $F_{60}G_{40}$, (Where F and G are, respectively, Fly Ash and GGBS and the numerical value indicates the percentage of replacement of fly ash by GGBS). The cube specimens are taken of size 100 mm x 100 mm x 100 mm. ambient curing of concrete at room temperature was adopted. In total 45 cubes were cast for different mix Id and the cube specimens are tested for their compressive strength at age of 7 and 28 days respectively. The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix. It was observed that the mix Id $F_{60}G_{40}$ gave maximum compressive strength of 66 MPa was observed for ratio of NaOH to Na_2Sio_3 2.50. Thus the geopolymer concrete have a relatively higher strength and better durability.*

Key Words: **Geopolymer concrete, Fly ash, GGBS, Alkali Activators, Sorptivity**

1. INTRODUCTION

Concrete is the most commonly used construction material, its usage by the communities across the globe is second only to water. The worldwide demand for Ordinary Portland Cement (OPC) would increase further in the future. OPC production is a major contribution to carbon dioxide emissions. The global warming is caused by the total green house emission to the earth atmosphere contributing greatly to the global warming. Many efforts are being made in order to reduce or replace the use of OPC in concrete. These efforts are being made to utilization of supplementary cementitious materials such as fly ash, GGBS, silica fume and rice- husk ash etc. In terms of reducing the global worming the geopolymer technology could reduce the CO2 emission to the atmosphere cause by cement about 80%. The word Geopolymer introduced to the world by Davidovits in year 1980s, proposed that binders could be produced by a polymeric reaction of alkaline liquids with the Silicon and the Aluminum in source materials of geological origin or by-product materials such as fly ash and GGBS, he termed these binders as “Geopolymer”.

1.1 Need for the Study

- To find an alternative for the ordinary Portland cement.
- To reduce CO2 emission and produce eco-friendly concrete.
- To achieve a high strength concrete compared with conventional concrete.
- To achieve a new type of concrete which is flexible in nature.

2. LITERATURES ON GEOPOLYMER CONCRETE

An attempt is made to get the information regarding the work already done in the area of geopolymer concrete and replacement of cement with other materials. Following research articles are presented.

Suresh.G.Patil, Manojkumar reported in this paper to study effects of several factors on the properties of fly ash based geopolymer concrete on the compressive strength and alsi the cost comparison with the normal concrete. The test results indicated that the highest compressive strength 54Mpa was observed for 16M of NaOH, ratio of NaOH to Na2Sio3 2.5 and alkaline liquid to fly ash ratio of 0.35, lowest compressive strength of 27Mpa was observed for 8M of NaOH ratio of NaOH to Na2Sio3 is 1 and alkaline liquid to fly ash ratio of 0.40.

Matghew Sudhakar and Natarajan presented the increase of GGBS content, Compressive Strength is gradually increases. In this Coal Ash and GGBS Combination is taken along with 15M Alkaline Solution and total replacement of about 30% is taken into consideration and Higher Compressive Strength up to 57Mpa is achieved .However the cost of GGBS added Geopolymer is 7% Higher than OPC but when we Consider Strength aspect, it is almost 3 times than OPC at 7 days.

Ganapati Naidu.etl presented in this paper to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of GGBS result in higher compressive strength of geopolymer concrete 90% of compressive strength was achieved in 14 days.

Salmabanu Luhar etl. During this study, the water absorption and Sorptivity properties of fly ash based geopolymer concrete were studied in detail. The test result was found that the Sorptivity curve is less linear as compared to that of control concrete. That means the rate of absorption of geopolymer is less. Test results of water absorption test shows that the porosity of geopolymer concrete is less as fly ash is finer than OPC and results in to less water absorption than the control concrete.

3. MATERIALS USED

The constituent materials used in the present investigation were:

- Fly ash
- GGBS (Ground Granulated Blast Furnace Slag)
- Fine Aggregate
- Coarse Aggregate
- Alkaline liquid (NaOH,Na_2SiO_3)
- Super Plasticizer(SP)
- Distilled water and Preparation of Alkali Solution

3.1 Fly ash was taken from thermal power plant at KUDITHINI BELLARY THERMAL POWER STATION was used in the investigation. The specific gravity is 2.20.

3.2 GGBS ash was taken from Jindal Steel plant at Vidynagar; Ballari was used in the investigation. The specific gravity is 2.11 .

3.3 Fine aggregate locally available sand, free from silt and organic matters was used. The particle size of the sand used in this study was such a way that it passed through 4.75mm sieve conforming to zone III. The specific gravity was 2.55 and Fineness modulus was 2.59.

3.4 Coarse aggregate crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.84.

3.5 Super plasticizer to improve the workability of the mixes, a high range water reducing agent Fosroc conplast SP430 (SNF- Sulphonated Naphthalene Formaldehyde) 2% of fly ash is used.

3.6 Alkaline Solutions the solution of sodium hydroxide and sodium silicate are used as alkaline solutions in the present study. Commercial grade sodium hydroxide in pellets form and sodium silicate solution are used.

3.7 Preparation of Alkaline Solutions

The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid. A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. In this research work the compressive strength of Geopolymer concrete is examined for the mixes of 13 Molarity of sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 13 Molarity of solution 520 gm of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution has to be prepared 24 hours advance before use. Sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

4.0 MIX PROPORTIONS

The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete. First, the fine aggregate, coarse aggregate, GBS and fly ash is mixed in dry condition for 3- 4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with a ratio of 1:2.5 and super plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the specimens are casted by giving proper compaction in three layers.

Table - 1.0: Material requirement for 1 Cu.mt

Materials (Kg/m^3)	Mix Id		
	M1	M2	M3
Fly Ash and GGBS	394.30	394.30	394.30
Sodium hydroxide	63.22	52.68	45.41
Sodium silicate	94.83	105.37	112.65
Fine aggregates	554.40	554.40	554.40
Coarse aggregates	1293.00	1293.00	1293.00
Ratio of alkaline activator	1.5	2.0	2.5
Mix proportion ratio	1:1.40:3.28	1:1.40:3.28	1:1.40:3.28
Distilled water: 10% of cementitious material.			
Super plasticizer material: 2% of cementitious material.			

Figure - 1.0 Casting of Geopolymer Concrete.

Figure - 2.0 Cube specimens prepared for casting.

Figure - 3.0 Casting of GPC Cylinders.

Figure - 4.0 Specimens curing in Ambient Temperature.

5. TEST RESULTS

The various strength tests that are to be done listed as below.

- Compressive Strength
- Split Tensile Strength

Table - 2.0: Details of Test Specimens.

Sl. No	Name of Test	Size of Specimen (mm)	Number of Specimen casted
1.	Compressive Strength (P/A)	100 x 100 x 100	66
2.	Split Tensile Strength (2P/πLD)	100 x 200	33
3.	Sorptivity Test	100 x 200	33
		Total	132

5.1Compressive Strength Test:

Concrete cubes are tested in compressive testing machine (200 Tonne capacity) to determine their compressive strength of 3 specimens at the age of 7th and 28th days with optimum percentage of GGBS and fly ash were given below in Table 3.0. From the test results, it was observed that the maximum compressive strength was obtained for mix M3 with 60% fly ash (F) and 40% GGBS (G).

Figure - 5.0 Compressive test on concrete cube.

Table - 3.0 Experimental results of compressive strength of cube at 7days of age in N/mm²

Mix Id	M1	M2	M3
F100G0	30.00	32.38	35.66
F90G10	34.37	38.40	42.34
F80G20	39.20	41.62	43.50
F70G30	41.00	43.28	45.67
F60G40	52.64	56.23	58.73

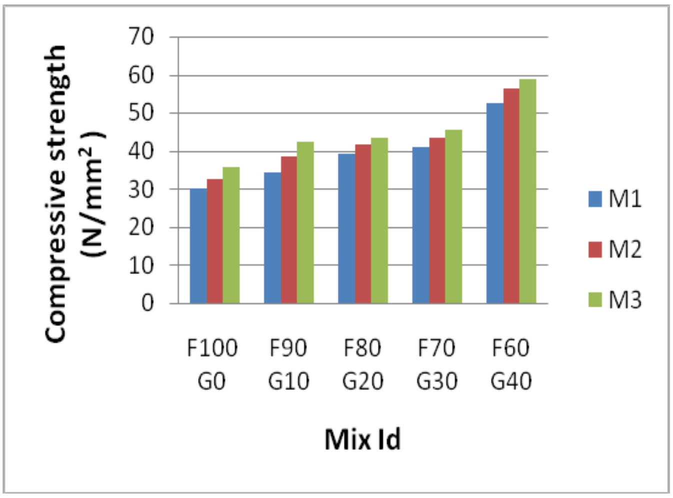

Chart -1: Cube compressive strength results at 7 days.

Table - 4.0 Experimental results of compressive strength of cube at 28 days of age in N/mm².

Mix Id	M1	M2	M3
F100G0	33.50	37.35	40.64
F90G10	39.63	42.50	48.00
F80G20	44.30	49.67	51.24
F70G30	49.52	51.38	58.67
F60G40	58.55	60.40	66.48

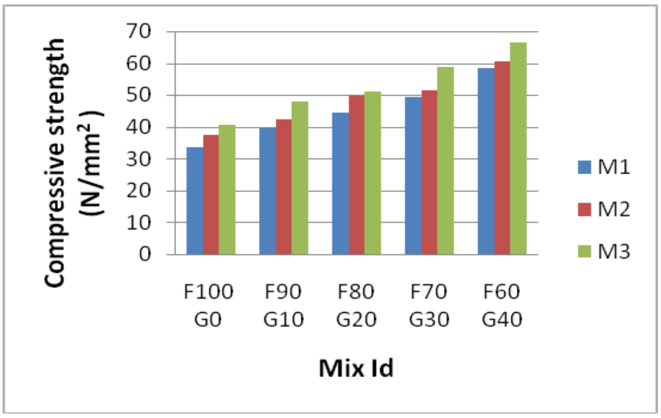

Chart -2: Cube compressive strength results at 28 days.

5.2 Split tensile strength test:

Tensile strength is one of the basic and important properties of concrete. Size of test sample of 10cm diameter, 20cm height cylindrical mould is used. The variation of split tensile strength at the age of 28th days with optimum percentage of Fly ash and GGBS were given below. It was observed that the maximum split tensile strength was obtained for mix M3 with 60% Fly ash and 40 % GGBS.

Figure - 6.0 Split Tensile strength test.

Table - 5.0 Split Tensile Strength results at 28 Days of age in N/mm².

Mix Id	M1	M2	M3
F100G0	2.65	2.95	3.49
F90G10	2.95	3.22	4.37
F80G20	3.30	3.83	4.68
F70G30	3.72	4.24	4.92
F60G40	4.20	4.48	5.60

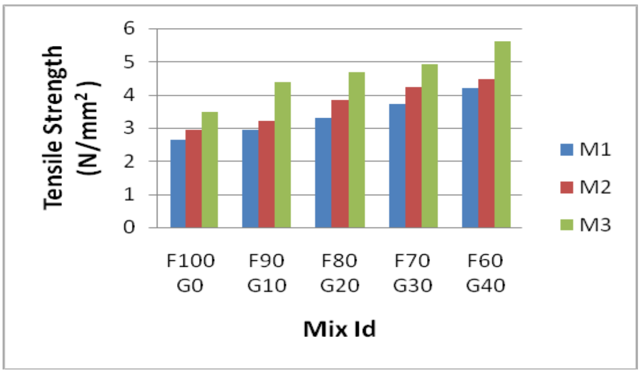

Chart -3: Split Tensile strength results at 28 days.

5.3 Sorptivity Test:

The Sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting and curing for 28 days. The specimen size 100mm dia x 2000 mm height after drying in oven at temperature of 100 + 10 °C were drowned as shown in with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting up to 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

$I=S.t^{1/2}$ therefore $S=I/t^{1/2}$

Where; S= Sorptivity in mm,

t= elapsed time in mint.

$I=\Delta w/Ad$ Δw= change in weight = W2-W1 W1 = Oven dry weight of cylinder in grams W2 = Weight of cylinder after30 minutes capillary suction of water in grams. A= surface area of the specimen through which water penetrated.

d= density of water.

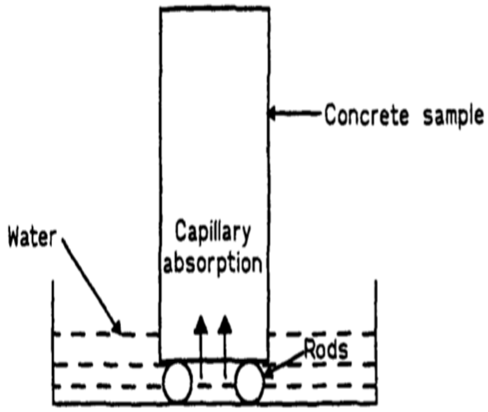

Figure - 7.0 Schematic of Sorptivity Test.

Figure - 8.0 Sorptivity Test.

Table - 6.0 Sorptivity results.

Mix Id	Dry Weight in grams (W1)	Wet Weight in grams (W2)	I 10^{-6}	Sorptivity in mm 10^{-6} mm/ min0.5
M1	3780	3800	1.60	0.40
M2	3730	3750	2.48	0.62
M3	3700	3720	3.59	0.89

6.0 COST ANALYSIS

Cost analysis for geopolymer concrete (GPC) and conventional concrete (CC). The cost of the geopolymer concrete is 04% higher than the conventional concrete.

Table 5.0 Cost Analysis for GPC and CC

Sl. No	Materials	Cost (Rs/Kg)	Total Amount For GPC (Rs/m³)	Total Amount of CC (Rs/m³)
1	Cement	7.00	---	2765.00
2	Fine aggregates	1.26	699.00	699.00
3	Coarse aggregates	1.2	1551.00	1551.00
4	GBS	0.20	110.00	---
5	Fly ash	0.11	44.00	---
6	NaOH	16.00	720.00	---
7	Na_2SiO_3	18.00	2016.00	---
TOTAL (Rs. Per Cu.mt)			**5140.00**	**5015.00**

7.0 CONCLUSION:

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

- When the ratio of alkaline solution (Na2SiO3/NaOH) increased then the strength of concrete also increase and maximum strength gain for 2.5 is 66.48 Mpa.
- Geopolymer concrete shows higher Sorptivity than cement concrete.
- The geopolymer concrete gained strength within 24 hours at ambient temperature without water curing.
- The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix.

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