Study on Geopolymer Concrete using GGBS

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Abstract - *In recent year man is facing a series of interrelated problems like increasing population, rapidly degrading environment, depleting natural resources and high rate of demand for construction materials. So there is a need of alternative building material like geopolymer concrete to bring development economically, socially, environmentally. With increase in demand of concrete, more and more new methods and new materials are being developed for production of concrete. Sometimes certain additives are added to it to improve or alter some properties. A concrete using cement alone as a binder requires high paste volume, which often leads to excessive shrinkage and large evolution of heat of hydration, besides increased cost. With this view we have made an attempt is to replace cement by a mineral admixture, (i.e.), ground granulated blast furnace slag (GGBS) in concrete mixes to overcome these problems. This paper presents the workability study of concrete with GGBS as a replacement material for cement without the addition of Super plasticizer. Concrete grades of M_{25} have been taken for the work. The mixes were designed using IS Code method. GGBS replacement adopted was 0% to 25% in steps of 5%. Slump test is conducted to check its workability. Effect of replacement of cement by GGBS at various percentages on its strength is compared with conventional concrete*

Key Words: **GGBS (Ground Granulated Blast Furnace Slag), Geopolymer, Compressive strength, Ordinary Portland cement**

1. INTRODUCTION

1.1 General

Concrete is one of the most widely used construction materials. It is usually associated with Portland cement as the main component. The demand for concrete as a construction material is on the rise. It is estimated that the production of cement has increased from about 1.5 billion tons in 1995 to 2.2 billion tons in 2010 (Malhotra, 1999).

On the other hand, the climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission–– of greenhouse gases, such as CO_2, to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming (McCaffrey, 2002). The cement industry is responsible for about 6% of all CO_2 emissions, because the production of one ton of Portland Cement emits approximately one ton of CO_2 into the atmosphere (Davidovits, 1994c; McCaffrey, 2002).

Although the use of Portland Cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilization of supplementary cementing materials such as Fly Ash, Silica Fume, Granulated Blast Furnace Slag, Rice-Husk Ash and Metakaolin, and finding alternative binders to Portland Cement.

In this respect, the geopolymer technology proposed by Davidovits shows considerable promise for application in concrete industry as a binder alternative to the Portland Cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80% (Davidovits, 1994).

1.1 Objectives

a) To evaluate the different strength properties of geopolymer concrete mixture with G.G.B.S replaced in percentage to cement. b) To study the gain of compressive strength with age. c) To study the plot of compressive strength V/S percentage variation of GGBS. d) To reduce the usage of ordinary Portland cement and to improve the usage of the other by product G.G.B.S (Slag).

1.2 Production and Composition of GGBS

The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminates impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates. To obtain a good slag reactivity or hydraulicity, the slag melt needs to be rapidly cooled or quenched below 800 °C in order to prevent the crystallization of merwinite and melilite. To cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet streams of water or air under pressure. Alternatively, in the pelletization process the liquid slag is partially cooled with water and subsequently projected into the air by a rotating drum. In order to obtain a suitable reactivity, the obtained fragments are ground to reach the same fineness as Portland cement.

The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%). In general, increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength. The MgO and Al_2O_3 content show the same trend up to respectively 10-12% and 14%, beyond which no further improvement can be obtained. Several compositional ratios or so-called hydraulic indices have been used to correlate slag composition with hydraulic activity; the latter being mostly expressed as the binder compressive strength.

2. MATERIALS AND MATERIAL TESTING

2.1 Cement

Type of cement used: Birla (plus) 53Grade IS: 8112

2.1.1 Fineness test:

Apparatus: Standard 90-micron IS sieve (IS: 460-1962)

Table No: 2.1.1.1

Sl. No	Sample taken (gms)	Sieved for (minutes)	Weight retained (gms)	% weight retained
1	100	15	2.5	2.5
2	100	15	2.5	2.5

Result: Fineness of cement is 2.5.

2.1.2 Standard Consistency Test:

Preparation of sample:

Take 400gms of cement and 25% of water by weight of cement. Prepare a paste of cement taking care that time of gauging is not less than 3 minutes and not more than 5 minutes. The gauging shall be completed before any sign of setting occur. The gauging shall be counted from the time of adding water to dry cement until commencing to fill the Vicat mould.

Table No: 2.1.2.1

Sl No	Sample Taken (in Gms)	% of Water	Gauging Time in (Min)	Reading on Vicat Apparatus
1	400	25	3	30
2	400	29	3	25
3	400	32	2	7

Result: The standard consistency of cement is 32%

2.1.3 Specific gravity of cement

Mass of cement taken=60 g

Initial reading r_1=0.7

Final reading r_2=20.5

Sp. gravity=mass of cement taken/difference in reading;

Specific gravity=mass/ (r_2-r_1)

Result: Specific gravity of cement = 3.13

2.1.4 Setting Time

The sample is prepared using percentage of water as 0.85 times the standard consistency. The plunger is replaced by square needle of 1mm the needle is lowered gently to touch the surface of paste and it is released quickly to penetrate into paste. Initially the needle penetrates fully into the paste. This procedure is repeated at the interval of 5 min, for the same cement paste at different locations until the needle fails to penetrate the cement by 5+/-0.5 mm from the bottom of the mould.

For final setting time the square needle is replaced by another needle with annular attachment. The penetration procedure is to be repeated for the same cement paste until the needle fails to make an impression on cement paste.

Cement sample taken =400g

Mass of water=0.85P×400=102 ml

Results:

a) Initial setting time for cement = 128 min

b) Final setting time for cement = 244 min

2.1.5 Determination of soundness of Portland cement (In accordance with IS 4031 - 1968, clause - 5)

Prepare a neat cement paste by gauging 400 grams of cement with 0.78 times the water required to give a paste of standard consistency, taking care that the time of gauging is not less than 3 minutes nor more than 5 minutes and gauging shall be completed before any signs of setting occur.

Fill the Le-chatelier moulds with the cement paste gauged, the mould resting on the glass sheet. Cover the mould with another piece of glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of 27 $\pm$ 2 ° C and keep there for 24 hours.

Measure the distance separating the indicator points. Submerge the mould again in water at the temperature 27 $\pm$ 2 ° C. Bring the water to boiling, with the mould keep submerged in 25 to 30 minutes and keep it boiling for 3 hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points. The difference between these two measurements represents the expansion of the cement. The observations and calculations may be tabulated as shown in table no. 3.3.The expansion shall not be more than 10mm for 43 and 53 grade OPC.

Table No: 2.1.5.1

Weight of cement	Water	Vol. Of water (cc)	Indicator readings		Soundness of cement (mm)
			Initial (mm)	Final (mm)	
100	24.96	24.96	33	34	1

Result: Soundness of cement= 1mm

2.1.6 Determination of compressive strength of cement mortar

Materials:

Portland cement of 200 grams, Ennore standard sand of 600 grams, Water = $(\frac{P}{4}+3)\%$ of combined weight of cement and sand. Where, P is the consistency of standard of cement paste.

Preparation of test specimen:

Place, on a non-porous plate, the mixture of cement and standard Ennore sand, in the proportion of 1:3 by weight (200 gm of cement and 600 gm of sand for 1 cube or 1.25 kg cement + 3.75 kg sand with 200 gm extra for wastage during preparation of 6 cubes). Mix cement and sand dry with a trowel for one minute and then with water until the mixture is of uniform colour for a period of at least 3 minutes and it should not exceed four minutes. The mould would be given a coat of petroleum jelly at the joints and the base and the interior faces with thin coating of oil. Keep the mould on the vibration machine and clamp it. Fill the mould with the cement mortar and prod it for 20 times in 8 sec, using a poking rod to eliminate the entrained air and honey combing. Then compact the mortar by vibration for 2 min., at the speed of 12,000 $\pm$ 400 vibrations/ minute. At the end of the vibration, remove the mould together with the base plate from the machine and finish the top surface of the cube.

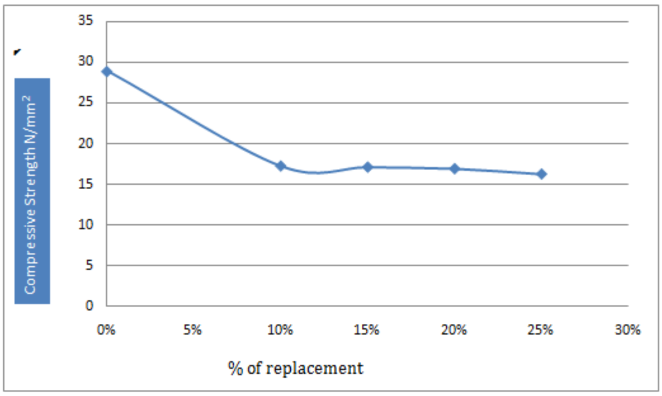
Curing: Keep the filled moulds at a temperature of 27 $\pm$ 2 ° C in a humidity chamber at 90% RH for 24 hours. At the end of this period remove them from the moulds and immediately submerge in clean fresh water and keep there until prior to testing.

Testing: Minimum three cubes to be tested for compressive strength after 3 days, 7 days and 28 days of curing. The average compressive strength at 3 days, 7 days, and 28 days shall not be less than 23Mpa, 33Mpa, 43Mpa for 43-grade cement and it shall not be less than 27Mpa, 37Mpa and 53Mpa for 53-grade cement. The observations and calculations may be tabulated as shown in table no 2.1.6.1.

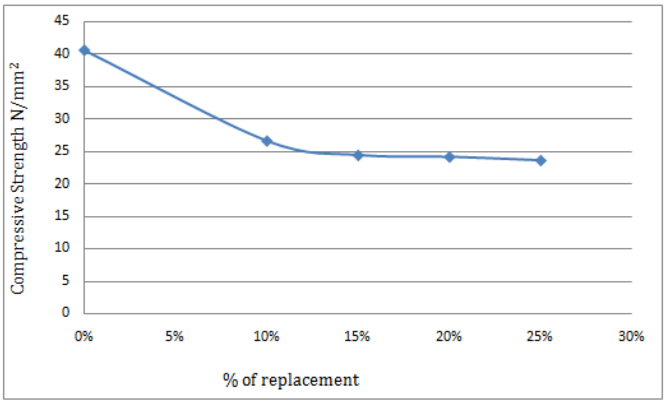
Mix 1:3 (by weight), P =32 %, W/c ratio =0.55, A =5000 mm^2

Table No: 2.1.6.1

Sl. No	No of days	Load (KN)	Compressive strength(N/mm^2)
1	3	126	28.93
2	7	234	40.6



Graph 2.1.6.1: Variation of compressive strength for 3 days



2.1.6.2 Variation of compressive strength for 7 days

Result:

3 days Compressive strength of cement = 28.93 N/mm^2

7 days Compressive strength of cement = 40.6 N/mm^2

2.2 Tests on fine aggregate

[As per IS 2386(part-6):1963]

2.2.1 Fineness modulus of fine aggregate:

Table No: 2.2.1.1

Sl.no	Sieve number	Mass retained	% retained	Cumulative % retained (f)	% passing
1	4.75mm	0	0	0	100
2	2.36mm	10	1	1.95	98.05
3	1.18mm	268	26.8	27.75	72.5
4	0.60mm	159	15.9	43.9	56.1
5	0.30mm	424.5	42.45	85.35	14.65
6	0.150mm	110.5	11.05	97.25	2.75
7	Pan	28	2.8	100	0

Results: Fineness modulus of fine aggregate=2.55

2.2.2 Bulk density:

Procedure:

Determine the volume of container and weigh the empty weight of the container. Fill the container with an aggregate without any tamping. Calculate the net mass of the aggregate in the container and compute the unit mass of aggregates in gm/cc by dividing the mass of aggregates in the container by the volume. Repeat the procedure by filling aggregates in three layers each layer being tamped 25times and level the surface.

Results: Bulk density of fine aggregate (loose state) =1.464gm/cc

Bulk density of fine aggregate (dense state) =1.587gm/cc

2.2.3 Specific gravity of fine aggregate

Procedure:

Empty weight of pycnometer is to be taken (W1) Gms. About 1/3 portion of the pycnometer is filled with an aggregate and it is weighed (W2)gms. Now the same pycnometer is to be filled with water and it is weighed (W3) Gms. The pycnometer is to be cleaned and filled completely with only water and it is weight is to be taken (W2).

Results: Specific gravity of fine aggregate =2.63

2.2.4 Water Absorption

Procedure:

Take 300g of oven dried sand; keep it in water for 24 hours. After 24 hours it is taken out and it dried it using gunny bag and take its weight as W1 grams. Then the sample is kept in an electric oven for 24 hrs at temperature of 105+/-5 degree Celsius and finally takes its weight as W2.

Water absorption= (W1-W2)/W2.

Results: Water absorption=1.149%

2.2.5 Surface Moisture

Procedure:

Take W_1 grams of sand and it is heated on an electric stove for about 30 minutes and keep it for cooling. Then it is weighed as W_2.

Surface moisture= $(W_1-W_2)/W_1$

Results: Surface moisture of sand = 0.3%

2.3 Tests on the coarse aggregates

2.3.1 Determination of specific gravity and absorption capacity of course aggregates

Procedure:

The procedure followed in the fine aggregate can be here also adopted.

Calculations:

Empty weight of the pycnometer = W_1 =657.5gm

Weight of pycnometer + sample = W_2 = 1034.5 gm

Wt. of Pycnometer + Sample + water = W_3 = 1792 gm

Wt. of Pyconometer + Water = W_4 = 1558 gm

Specific Gravity $= \frac{(w_2-w_1)}{((w_4-w_1)-(w_3-w_2))}$ -------------- (4.5)

= 2.658

Results:

Specific gravity of coarse aggregate = 2.658

Water absorption of coarse aggregate = 0.396 %

2.3.2 Determination of bulk density (unit weight and voids of coarse aggregates)

In accordance with IS: 2386 (part III-1963)

Table no: 2.3.2.1

Sl.No	Description	Loose state	Dense state
1.	Final weight	12570gms	13000gms
2.	Bulk density	1.37 g/cc	1.55 g/cc

Results: Percentage of voids of coarse aggregate =44.48%

2.4 Tests on Fresh Concrete

Methods of measuring workability – slump test

The mould is placed on a smooth, horizontal, vibration free and non-absorbent surface. It is filled in 3 equal layers with the concrete to be tested, each layer being punned 25 times with a standard punning rod. Now the top layer is truck off and levelled with the top of the top of the mould and the cone is slowly lifted. A scale in mm measures the amount by which the concrete settles (slumps). The observations and calculations may be tabulated as shown in Table below.

Table no: 2.4.1

Materials used (kg)			Water/cement ratio	Water added in litres	Slump observed in mm
cement	F.A	C.A			
3.052	6.014	9.494	0.55	1.678	100

3. METHODOLOGY

3.1 Mix design for varied proportion of cement and GGBS

<u>10% GGBS and 90% Cement</u>

In ratio=1:1.97:3.10

Table no: 3.1

Materials	Values
Cement	1.526kg
Fine aggregates	3.007kg
Coarse aggregates	4.747kg
W/C ratio	0.55
Water	0.839 litres

Obtained slump: 94mm

<u>15% GGBS and 85% Cement</u>

In ratio=1:1.96:3.10

Table no: 3.2

Materials	Values
Cement	1.531kg
Fine aggregates	3.001kg
Coarse aggregates	4.747kg
W/C ratio	0.55
Water	0.842 litres

Obtained slump: 80mm

<u>20% GGBS and 80% Cement</u>

In ratio=1:1.96:3.09

Table no: 3.3

Materials	Values
Cement	1.535kg
Fine aggregates	2.994kg
Coarse aggregates	4.751kg
W/C ratio	0.55
Water	0.844 litres

Obtained slump: 95mm

<u>25% GGBS and 75% Cement</u>

In ratio=1:1.95:3.094

Table no: 3.4

Materials	Values
Cement	1.535kg
Fine aggregate	2.994 kg
Coarse aggregate	4.751 kg
Water/ cement ratio	0.55
Water	0.844 litres

3.2 Determination of compressive strength of concrete incorporating GGBS

Procedure:

First, cement and sand are mixed dry so as to obtain a uniform color. This mix is added to the C.A. and mixed thoroughly. Water is sprinkled on the mix and contents are mixed thoroughly to give a uniform consistency.

Slump test is also conducted.

Now this mix is placed in 6 number of cubes and 3 nos. of cylinders to cast the specimens and they are well compacted on a table vibrator.

The designed concrete mixes (as per **SP-23: 1983**) such as M_{20}, M_{25}, M_{30}, etc., may be cast to know their strengths at 3 days and 28 days. Specimens are marked appropriately.

After 24 hrs immerse the cubes and cylinders into the water tank for curing. After 7 days or 28 days of curing, the cubes and cylinders are taken out of water and air-dried. The cubes are tested for crushing strength and the cylinders for split tension test.

4. RESULTS AND DISCUSSION

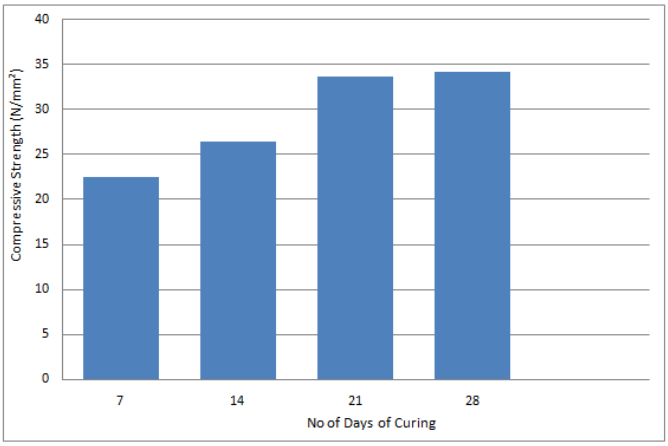
Compressive Strength Test

Compressive strength of geopolymer concrete and ordinary Portland cement concrete cubes were tested in compressive testing machine to determine its compressive strength. Before casting the mould respective tests are conducted on each material as explained before.

Compression test was conducted on both cement concrete and geopolymer concrete for 7,14,21,28 days.
Test results are tabulated as shown:

Table 4.1 Compressive strength of Conventional Concrete

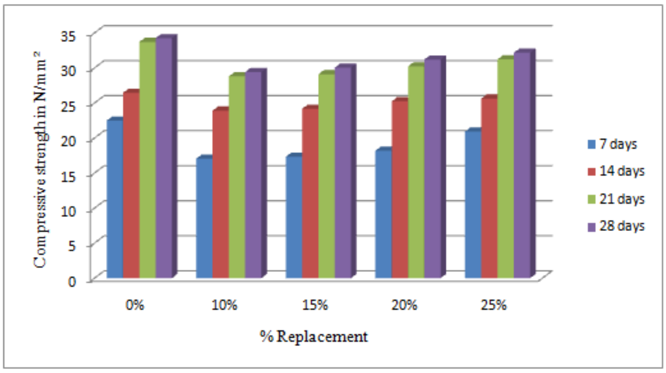
Sl no	Load (tonnes)	Area cm^2	Days	Compressive strength N/mm^2
1	50.6	22500	7	22.48
2	59.53	22500	14	26.45
3	75.86	22500	21	33.71
4	77.06	22500	28	34.25



Graph no: 4.1 Comparison of compressive strength of normal concrete

Table 4.2 Results of Compressive strength (N/mm^2) varied percentage of GGBS

% of replacement	7 days	14 days	21 days	28 days
0	22.48	26.45	33.71	34.25
10	17.06	23.91	28.80	29.42
15	17.33	24.17	29.11	30.04
20	18.19	25.24	30.22	31.20
25	20.91	25.64	31.24	32.17



Graph no: 4.2 Comparison of compressive strength for varied percentage of GGBS

5. CONCLUSION

The studies on Compressive strength of Geopolymer concrete made with replacing cement by Ground Granulated Blast furnace Slag(GGBS) shows decrease at lesser percentages of replacement of 10% and 15%. A slight increase in strength is observed with 20% replacement of cement with GGBS. A significant increase in compressive strength is observed when 25% of cement is replaced with GGBS. Comparison of the strengths of conventional concrete and Geopolymer concrete shows that even though geopolymer concrete cannot be treated as equivalent to concrete with ordinary Portland cement, presence of some percentage of GGBS up to 25% can yield the required strength. As GGBS is available almost free of cost, replacing cement with GGBS will definitely reduce the cost of producing concrete. This will also reduce the burden of disposal of GGBS produced at the steel plants. The use of eco-friendly GGBS as a replacement to cement shall also reduce the effects of CO_2 emission on the environment during the production of cement

6. REFERENCES

[1] T.W Cheng, J.P Chiu, "Fire-resistant geopolymer produced by granulated blast furnace slag"2002.

[2] V Supraja and M Kantharao (2010),-"Experimental study on Geo-Polymer concrete incorporating"-

[3] Peter W C Leung and H A Wong July (2010) -"Final report on durability and strength development of GGBS concrete".

[4] Ganapati Naidu P, A.S.S.N.Prasad, S.Adiseshu, P.V.V.Satayanarayana –July 2012.-"A Study on Strength Properties of Geopolymer Concrete with Addition of G.G.B.S".

[5] V.S.Tamilarasan, Dr. P. Perumal, Dr.J.Maheswaran (2012)-"Workability studies on concrete with GGBS as a replacement material for cement with and without superplasticiser

[6] James Aldred and John Day (2012). -"Is geopolymer concrete a suitable alternative to traditional concrete".

[7] IS 456 -2000 "Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi.

[8] IS 10262 -2009 "IS Method of Mix Design", Bureau of Indian Standards, New Delhi.

[9] Smitha.M Post Graduate student, Sri Krishna College of Technology, Coimbatore,India.Pin-641042."Experimental study on fibre reinforced high performance concrete with ggbs blended cement".

[10] IS 516 -1959 "Methods of Tests for strength of concrete", Bureau of Indian Standards, New Delhi.

[11] IS 383: 1970 "Specification for coarse and fine aggregates from natural source for concrete".

[12] Durai S. Assistant Divisional Engineer, Highway Department, Nammakal, Tamil Nadu, India., Remya M. Post Graduate Student, Department of Civil Engineering, Sri Krishna College of Technology,Coimbatore, India. "Experimental Investigation On High Perfomance Concrete Using Ggbs As Admixture"