ISSN: 2278-0181
NCNTCE-2015 Conference Proceedings

Experimental Investigation on Geopolymer Concrete by using GGBS

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***Abstract:*-This Experimental study behaviour of geopolymer concrete by using GGBS. The geopolymer was activated with sodium hydroxide, sodium silicate and heat. The experimental investigation has been done on mechanical properties of geopolymer concrete with various alkaline solution ratios the ratio of fly ash, Ground granulated Blast Furnace Slag, fine aggregate & coarse aggregate for Geopolymer concrete is taken as 1:1:2. The geopolymer is designed for 14molarity.Geopolymer is an inorganic alumino-hydroxide polymer synthesized form predominantly silicon and aluminium materials of geological origin and by product materials such as flyash (with low calcium). In this paper an attempt is made to study strength properties of geopolymer concrete using low calcium flyash and replacing of Msand Ground granulated Blast Furnace Slag in 3 different percentages. Sodium silicate (103 kg/m^3) and sodium hydroxide of 8 molarities (41kg/m^3) solutions were used as alkalis in all 3 different mixes. The alkaline solution is used for the present study was the combination of sodium silicate and sodium hydroxide solution with the ratio 2.33 and the ratio of alkaline solution with fly ash is taken as 0.2, 0.3 and 0.4. The test specimens 100X100X100mm cubes prepared for compression test and 100 mm Diameter 200mm Length cylinders for split tensile test. The Specimen heat cured at 80^{0}C in an oven. The test conducted after 7days of casting which includes one day oven curing and 6days ambient temperature curing. The test result revelled the slump value was in the range of 90-135 and was dependent on the Super plasticizer which is 2% mass of fly ash. The geopolymer with the alkaline solution of 0.4.With maximum (20%) replacement of Msand with slag achieved a maximum compressive strength of 85MPa for 28 days.**

Key words: Fly ash, Sodium Silicate, Sodium Hydroxide, Super plasticizer and Ground Granulated Blast Furnace Slag.

I) INTRODUCTION

Concrete is the most widely used construction material in the world. Ordinary Portland cement (OPC) has been traditionally used as the binding materials for concrete. The manufacturing of OPC requires the burning of large quantities of fossil fuel and decomposition of lime stone, which results in significant emissions of $CO_2$to atmosphere. In terms of reducing the global warming, the Geopolymer technology could reduce the CO_2 emission in to the atmosphere, caused by cement and aggregate industries about 80%. In this technology, the source material that is rich in silicon (Si) and Aluminium (Al) is reacted with a highly alkaline solution through the process of geopolymerisation to produce the binding material. The term “Geopolymer” describes a family of mineral binders that have a polymeric silicon-oxygen-aluminium framework structure, similar to that found in zeolites, but without the crystal structure. The polymerization process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Geopolymer concrete is emerging as a new environmentally friendly construction material for sustainable development, using flyash and alkali in place of OPC as the binding agent. This attempt results in two benefits. i.e. reducing CO_2 releases from production of OPC and effective utilization of industrial waste by products such as flyash, slag etc., by decreasing the use of OPC. In this paper investigates the Geopolymer concrete were produced under hot air oven curing. Performance aspects such as load carrying capacity, deflection and tensile stress at different stages are to be studied.

II) MATERIALS

The materials used for making concrete in this project were cement, fly ash, Sodium Silicate, Sodium Hydroxide, Ground Granulated Blast Furnace Slag, M-sand (fine aggregate), gravels (coarse aggregate) and Super plasticizer.

Fly Ash, an industrial by-product from Thermal Power Plants (TPPs).**Ground-granulated blast-furnace slag** (**GGBS** or **GGBFS**) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Sodium hydroxide also known aslye or caustic soda has the molecular formula NaOH and is a highly caustic metallic base. It is a white solid available in pellets, lakes, granules, and as a 50% saturated solution. Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbondioxide in air. Sodium hydroxide is used in many industries, mostly as a strong chemical in the manufacture of pulp and paper, textiles, drinking water, soap detergents and as a drain cleaner.

Sodium silicate is the common name for a compound sodium metasilicate, Na_2SiO_3, also known as water glass or liquid glass. It is available in aqueous solution and in solid form and is used in cements, passive fire protection, refractories, textile and lumber processing, and automobiles.

The artificial sand produced by proper machines can be a better substitute to river sand is called as M-sand.M-sand is used for fine aggregate which reduce the river sand scarcity. 20mm coarse aggregates are used.

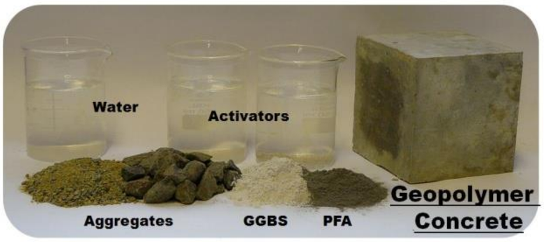


Figure-1 Materials

SAMPLE PREPARATION

The main sample preparation is fly ash. The fly ash is collected in most of the old power plants in India through wet system, since it is cheaper than any other mode of transport. In the wet system, fly ash is mixed with water and sluiced to the settling ponds or dumping areas near the plant. However, due to limited disposal area many of the TPPs are in the process of converting to dry collection system (through ESP's) particularly the NTPC Power Plants. ESP's are most popular equipment and widely used for emission control today which enables the collection of dry fly ash. In the dry collection system, after arresting the fly ash in the ESP, it is taken to the silos for storage by pressurized or vacuum pneumatic system.

PARTICLE SIZE DISTRIBUTION

Size(µm)	Percent by wt.
10.00	27.19
20.00	42.35
30.00	52.07
40.00	58.48
45.00	61.27
50.00	64.11
60.00	69.71
70.00	74.50
80.00	78.08
90.00	82.55

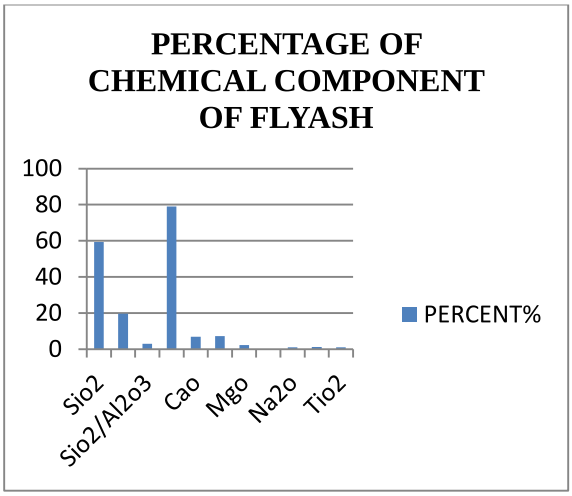
III) MATERIALS PROPERTIES

3.1 CHEMICAL ANALYSIS OF FLY ASH

Fly ash with current annual generation of approximately 108 million tones and its proven suitability for variety of applications as admixture in cement/concrete/mortar, lime pozzolana mixture (bricks/blocks) etc. is such an ideal material which attracts the attention of everybody. Cement and Concrete Industry accounts for 50% Fly Ash utilization, the total utilization of which at present stands at 30MT (28%). The other areas of application are Low lying area fill (17%), Roads &Embankments (15%), Dyke Raising (4%), Brick manufacturing (2%) etc.

CHEMICAL COMPONENT	**PERCENT%**
Sio_2	59.32
Al_2o_3	19.72
Sio_2/Al2o3	3.01
Sio2+Al2o3	79.04
Cao	6.90
Fe2o3	7.22
Mgo	2.23
S03	0.36
Na2o	1.11
K2O	1.27
Tio2	1.00
Mno2	0.18
P2o5	0.1
Sro	0.23
Bao	0.22
Moisture content	0.08
Loss on ignition	0.15

Table 1 Elements present in the materials



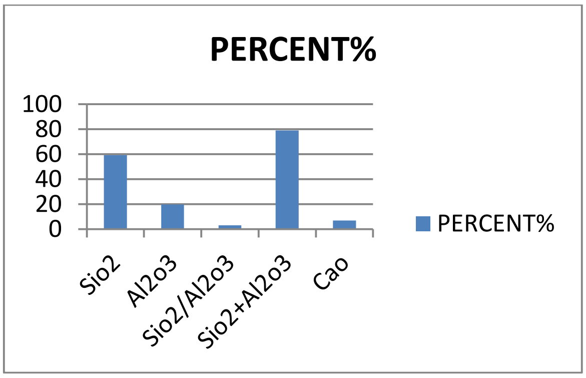
Graph 1Elements presents in materials

3.2 CHEMICAL ANALYSIS IN GGBS SLAG

This 'granulated' slag is then dried and ground to a fine powder. GGBS cement is added to concrete in the concrete manufacturer's batching plant, along with Flyash, aggregates and water. The normal ratios of aggregates and water to cementitious material in the mix remain unchanged. GGBS is used as a partial replacement for Msand, on a one-to-one basis by weight. Replacement levels for GGBS vary from 1% to up to 10%. Typically 10% is used in most instances.

CHEMICAL COMPONENT	PERCENT%
Sio_2	35-38
Al_2o_3	15-18
Cao	40-42
Fe_2o_3	0.2
Mgo	12

Table 2 Elements present in the materials



Graph 2Elements presents in materials

3.3 SPECIFIC GRAVITY

Specific gravity bottles like density bottle, pyncometer bottles are used for finding the specific gravity of ggbs, fly ash, M-sand, coarse aggregates. The result of specific gravity is indicated in table (2)

	GGBS Slag	Fly ash	Fine aggregate	Coarse aggregate
Specific gravity	2.7	2.28	2.66	2.74

Table 3 Specific gravity of the materials

3.4 FINENESS TEST

The fineness and standard consistency tests were conducted on cement, fly ash, M-sand and coarse aggregate. The fineness test results for OPC grade is less than 10. The cement, fly ash and other material contents have satisfied the recommendations of OPC. The standard consistency test is to find out the percentage of water to be added to the cement.

Description	GGBS Slag	Fly ash	Fine aggregate	Coarse aggregate
Fineness test	4.5%	1.69%	4.17%	1.96%

Table 4 Fineness & standard consistency

3.5 SLUMP TEST

The slump test is used to find the consistency of the fresh concrete. It measures the consistency or the wetness of concrete. The inside of the mould and its base should be moistened at the beginning of every test. This test is conducted for both Ordinary cement and geopolymer cement. The slump values are in table(5)

Slump value (mm)	Geopolymer concrete		
	0.2	0.3	0.4
	72	76	83

Table 5 Slump values

3.6 COMPACTION FACTOR TEST

It is also used for finding the consistency of the concrete. The upper and the lower moulds have to be cleaned and oiled for the easy flow of the concrete. The compaction factor value is indicated in table (6)

Compaction Factor	Geopolymer concrete		
	0.2	0.3	0.4
	0.83	0.89	0.93

Table 6 Compaction factor test

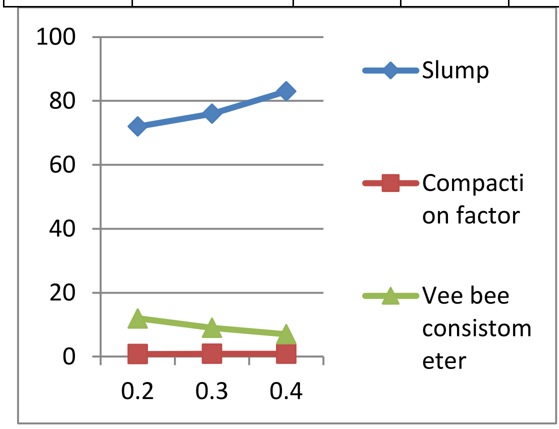
3.7 Vee-Bee CONSISTOMETER TEST

This test is used to find the compactibility of freshly mixed concrete. The test changes the shape of the concrete from cone to cylinder using vibration. The compactibility values are in table (7)

Vee Bee Consistometer test	Geopolymer concrete		
	0.2	0.3	0.4
	12	9	7

Table 7Vee Bee consistometer test

Sl. No	M-Sand replaced with GGBS	Geopolymer concrete with alkaline solution ratio (N/mm²) 7days		
		0.2	0.3	0.4
1	10%	52.5	59.5	72.2
2	15%	54.8	64.7	76.2
3	20%	56.0	67.5	79.9
Final mix		54.4	63.9	76.1



Graph 3 Fresh concrete tests for various replacements

3.8 PREPARATION OF MIX DESIG

Mix proportion for Geopolymer concrete-1m^3

Geopolymer concrete mix ratio for 1m^3 is indicated in table (8)

Water/ Flyash Ratio	Super plasticizers	Alkaline solution Ratio	Fly ash in Kg	Fine Aggregate (M-sand) Kg	GGBS Slag	Coarse Aggregate Kg
0.15	2%	0.2	600	480	120	1200
0.15	2%	0.3	600	480	120	1200
0.15	2%	0.4	600	480	120	1200

Table 8Geopolymer concrete mix

Alkaline solution preparation for Geopolymer concrete- 1m^3

Alkaline solution preparation for Geopolymer concrete is indicated in table(9)

Alkaline solution Ratio	Quantity of Water In Kg	Quantity of NaOH In Kg	Quantity of Na_2Sio_3 In Kg
0.2	24	12.88	84
0.3	34.5	19.5	126
0.4	46	26	168

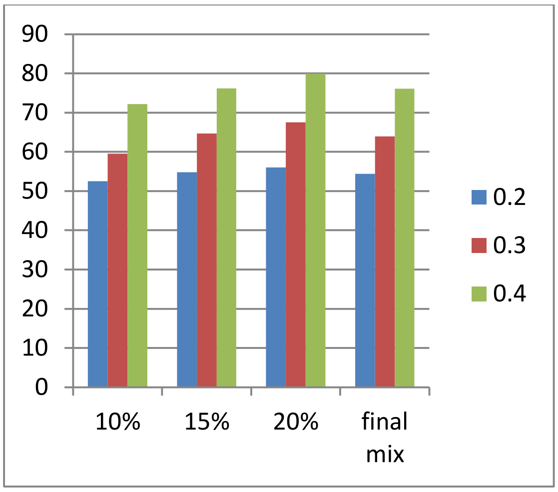
Table 9Alkaline solution preparation ratio

4. COMPRESSION TEST

The compression test on cement concrete cubes (100 X 100 X 100 mm) carried out after 7,14 days of water curing meanwhile the Geopolymer concrete cubes (100 X 100 X 100 mm) tested after 7 & 14 days of curing which includes one day hot air oven curing at 80°C for and ambient curing in room temperature. The Compression tests values after 7days are indicated in table (10a) and (10b).

Sl. no	M-Sand replaced with GGBS	Geopolymer concrete with alkaline solution ratio(N/mm²) 7days		
		0.2	0.3	0.4
1	10%	8.96	9.54	10.95
2	15%	10.08	11.28	12.30
3	20%	11.11	12.80	14.92
Final mix		10.05	11.20	12.72

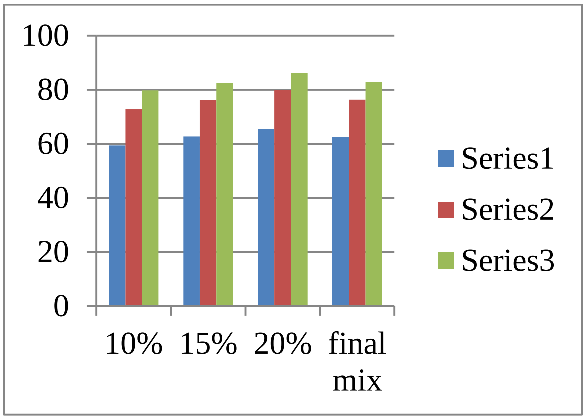
Table no-10a: COMPRESSION TEST (7 days)



Graph-4a: COMPRESSION TEST (28 days)

Sl.no	M-Sand replaced with GGBS	Geopolymer concrete with alkaline solution ratio (N/mm^2)28days		
		0.2	0.3	0.4
1	10%	59.4	72.8	79.8
2	15%	62.7	76.2	82.5
3	20%	65.5	79.9	86.2
Final mix		62.5	76.3	82.8

Table no -10b: COMPRESSION TEST (28 days)



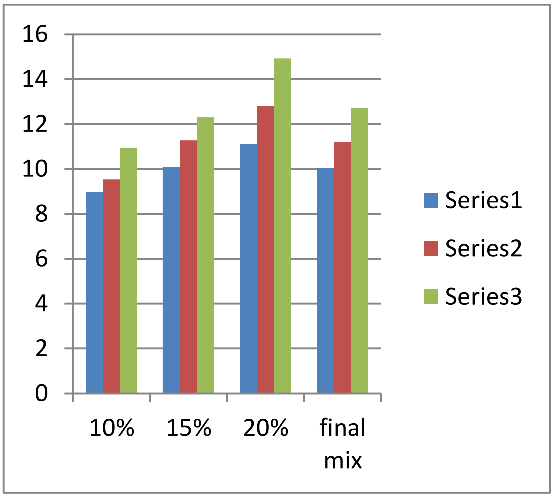
Graph4b: COMPRESSION TEST (28 days)

5. SPLIT TENSILE TEST:

The specimen size of 100 mm Diameter 200mm Length cylinders for split tensile test. The Specimen heat cured at 80^{0}C in an oven. The test conducted after 7days of casting which includes one day oven curing and 6days ambient temperature curing. The specimens were loaded continuously with uniform load and the failure load was recorded in table 12a and 12b

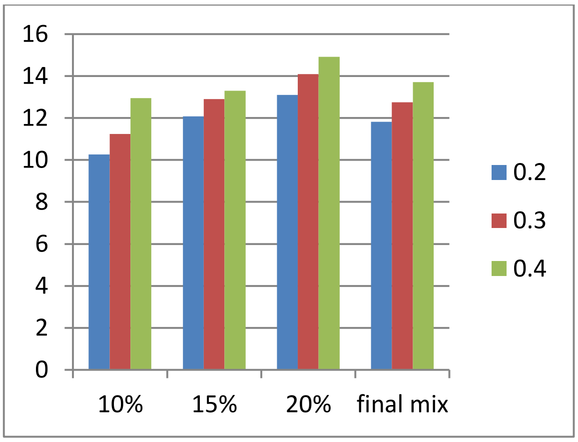
Table no-11a: SPLIT TENSILE TEST AFTER 7DAYS

Sl. no	M-Sand replaced with GGBS	Geopolymer concrete with alkaline solution ratio (N/mm^2)		
		0.2	0.3	0.4
1	10%	10.26	11.24	12.95
2	15%	12.08	12.91	13.30
3	20%	13.11	14.10	14.92
Final mix		11.82	12.75	13.72



Graph 5a: SPLIT TENSILE TEST AFTER (7DAYS)

Table no 11b: SPLIT TENSILE TEST AFTER 28DAYS



Graph-5b: SPLIT TENSILE TEST AFTER 28DAYS

CONCLUSION

On the basis of the results and discussion of this investigation following conclusions can be inferred:

Geopolymer concrete with alkaline ratio 0.2 and 0.3 has less workability, compression and split tensile values. Meanwhile 0.4 alkaline solution geopolymer concrete has little workability, compression and split tensile values greater than conventional concrete.

Geopolymer concrete requires less water content (0.15%) for the preparation of concrete and it doesn't need water curing.

M-sand replaced for river sand, So the scarcity of river sand can be avoided.

Moreover geopolymer concrete is eco-friendly, because it emits CO_2in the amount of78Kg/tone of geopolymer manufacturing. In the other hand, OPC emits CO2 in the amount of 900Kg/tone of OPC manufacturing.

Amount as an additive. Considering the intangible cost of disposal problem of fly ash and hidden cost of environmental protection, the methodology appears to be indeed successful. Fly ash is actually a solid waste. So, it is priceless. If it can be used for any purpose then it will be good for both environment and economy. Use of this fly ash as a raw material in Portland cement is an effective means for its management and leads to saving of cement and economy consequently. Hence it is a safe and environmentally consistent method of disposal of fly ash. However the rate of strength development is less, Due to lesser rate of strength de ash finds specific application in mass concreting e.g. dam construction.

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