THE EVOLUTION OF ALKALI-ACTIVATED GROUND BLAST FURNACE SLAG AND FLY ASH BASED GEOPOLYMER

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ABSTRACT

The need to reduce the global anthropogenic carbon dioxide has encouraged researchers to search for sustainable building materials. Cement, the second most consumed product in the world, contributes nearly 7% of the global carbon dioxide emission. Geopolymer concrete (GPC) is manufactured using industrial waste like fly ash, GGBS is considered as a more eco-friendly materials.The feasibility of production of geopolymer concrete using fly ash is evaluated in this study Additionally, the effect of replacement of fly ash with bottom ash at varying percentage on strength of Geopolymer concrete is also studied. The effect on strength, durability, workability of fly ash -GGBS based geopolymer concrete has also been evaluated. The alkaline liquids used in this study for the geopolymerization are sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). molarity of sodium hydroxide solution is 12M. The geopolymer concrete.specimens are tested for their compressive strength at the age of 3, 7 and 28 days.

Keyword: - *Geopolymer concrete, Ground granulated blast furnace slag(GGBS), FLY ASH, Super plasticizers.*

1. INTRODUCTION

Geopolymers are new materials for fire- and heat-resistant coatings and adhesives, medicinal applications, high-temperature ceramics, new binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation and new cements for concrete.

The properties and uses of geopolymers are being explored in many scientific and industrial disciplines: modern inorganic chemistry, physical chemistry, colloid chemistry, mineralogy, geology, and in other types of engineering process technologies.

Geopolymers are part of polymer science, chemistry and technology that forms one of the major areas of materials science.

Polymers are either organic material, i.e. carbon-based, or inorganic polymer, for example silicon-based.

The organic polymers comprise the classes of natural polymers (rubber, cellulose), synthetic organic polymers (textile fibers, plastics, films, elastomers, etc.) and natural biopolymers (biology, medicine, pharmacy). Raw materials used in the synthesis of silicon-based polymers are mainly rock-forming minerals of geological origin, hence the name:geopolymer.

The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere which leads to global warming conditions. A need of present status is, should we build additional cement manufacturing plants or find alternative binder systems to make concrete? On the other scenario huge quantity of fly ash are generated around the globe from thermal power plants and generally used as a filler material in low level areas. Alternative binder system with fly ash to produce concrete eliminating cement is called "Geopolymer Concrete".

Geopolymer is a type of amorphous alumino-Hydroxide product that exhibits the ideal properties of rock-forming elements, i.e., hardness, chemical stability and longevity. Geopolymer binders are used together with aggregates to produce geopolymer concretes which are ideal for building and repairing infrastructures and for precasting units, because they have very high early strength, their setting times can be controlled and they remain intact for very long time without any need for repair. The properties of geopolymer include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance. These high-alkali binders do not generate any alkaliaggregate reaction. The geopolymer binder is a low-CO2 cementious material.

2. TEST PROCEDURE:

In this work, low-calcium (ASTM Class F) fly ash and GGBS based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods as in the case of OPC concrete. The silicon and the aluminium in the lowcalcium fly ash react with an alkaline liquid that is a combination of sodium Hydroxide and Potassium Hydroxide solutions to form the geopolymer paste that binds the aggregates and other unreacted materials.

2.1 Materials:

Geopolymer concrete can be manufactured by using the low-calcium (ASTM Class F) fly ash obtained from coal-burning power stations. Most of the fly ash available globally is low-calcium fly ash formed as a by-product of burning anthracite or bituminous coal. GGBS formed as a by-product of aluminum industry. Commercial grade Potassium Hydroxide in pallets form (97% -100% purity) and sodium Hydroxide solution (Na2O=18.2%, SiO2=36.7%, Water = 45.1%) were used as the alkali activators. The potassium Hydroxide pallets were dissolved in the required amount of water according to the desired molarity. Locally available aggregate and fine river sands were used as aggregates for the concrete. Note that the mass of water is the major component in both the alkaline solutions. For improving the workability of the concrete superplasticiser was used.

2.2 Mixture Proportions:

The different mixture proportions used to make the trial geopolymer concrete specimens in this study are given in Table.

Irregularities	Unit	Mix 1 0%	Mix 2 10%	Mix 3 20%	Mix 4 30%	Mix 5 40%	Mix 6 50%
Fly ash	Kg/cum	430	387	344	301	258	215
GGBS	Kg/cum	0	43	86	129	172	215
Fine aggregate	Kg/cum	515	515	515	515	515	515
Coarse agg.	Kg/cum	1095	1095	1095	1095	1095	1095
Alkaline/F.A	-	0.35	0.35	0.35	0.35	0.35	0.35
Naoh/Na2sio3	-	2.5	2.5	2.5	2.5	2.5	2.5
Plasticizer		11.85	11.85	11.85	11.85	11.85	11.85
Molarity	-	12 M	12 M	12 M	12 M	12 M	12 M

Table 1: Mixing proportion

DESCRIPTION	Compressive strength test	Split tensile test	Flexural test	Durability test
Specimen Size(mm)	Cube (150x150x 150)	Cylinder (150 Dia. & 300 Height)	Beam (100x100 x500)	Cube (150x150x 150)
No. of Specimen	3	3	3	3
Days of Testing	3, 14, 28	3, 14, 28	3, 14, 28	3, 14, 28
Total No of Specimen	9	9	9	9
Volume of each Specimen (Cum)	0.003375	0.0053	0.005	0.003375
Volume for all specimen	0.0405	0.0636	0.0600	0.0405

Table 2: Quantity estimation and planning of experiment

2.3 Mixing and curing:

Mixing of all the materials were done manually in the laboratory at room temperature. The fly-ash and aggregates were first mixed homogeneously and then the alkaline solutions which were made one day before and superplasticiser were added to the mixture of fly ash,GGBS and aggregates. The sodium Hydroxide and sodium silicate solutions were first mixed with each other and stirred to obtain a homogeneous mixture of the solutions before adding them to the solids.Fig 2 adding of alkaline solution into the dry mixtures. The mixing of total mass was continued until the binding paste covered all the aggregates and mixture become homogeneous and uniform in colour. typical dry mixture of solids that was used to make the cube (150x150x150mm) specimens. The fresh geopolymer concrete was used to cast cubes of size 150x150x150mm to determine its compressive strength. Each cube specimen was cast in three layers by compacting manually as well as by using vibrating table. followed by further compaction on the vibrating table. The specimens were wrapped by plastic sheet to prevent loss of moisture and placed in an oven. Since the process of geopolymerisation needs curing at high temperature, the specimens were cured at two different temperature 60C for 24 hours in the oven, as shown in They were temperature cured for 24 hours then left to open air (room temperature 25C) in the laboratory until testing.

NAOH

NA2SIO3

Mixing of NAOH & NA_2SIO_3

Casting of cubes

Geopoylmer cubes

Break cube

3. TEST RESULTS:

In the present work, the effects of various salient parameters on the compressive strength of lo fly ash -GGBS based geopolymer concrete are discussed by considering ratio of alkaline solution is 2.5 constant . The parameters considered are as follows:

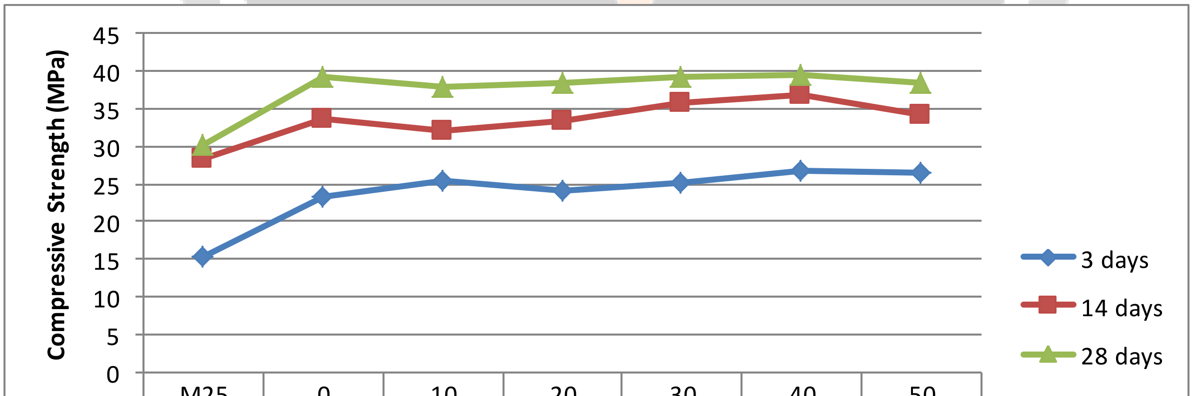
1. Concentration of Sodium Hydroxide (NAOH) solution, in Molar
2. Ratio of sodium Hydroxide solution to-Sodium silicate solution, by mass
3. Curing temperature
4. Effect of Wet-Mixing Time
5. Influence of handling time on compressive strength
6. Effect of super plasticizer on compressive strength
7. Effect of super plasticizer on slump of concrete
8. Effect of water-to-geopolymer solids ratio by mass on compressive strength

All the cube moulds were tested for compressive strength using the compression testing machine in laboratory. Compressive strength of concrete cubes were tested at the age of 3, 14, and 28 days.

3.1 COMPRESSIVE STRENGTH RESULT:

% GGBS	3 days	14 days	28 days
M25	15.38	28.42	30.33
0	23.35	33.56	39.27
10	25.45	32.15	37.8
20	24.23	33.43	38.43
30	25.1	35.88	39.18
40	26.8	36.9	39.56
50	26.5	34.28	38.56

Table 3. Compressive strength test result

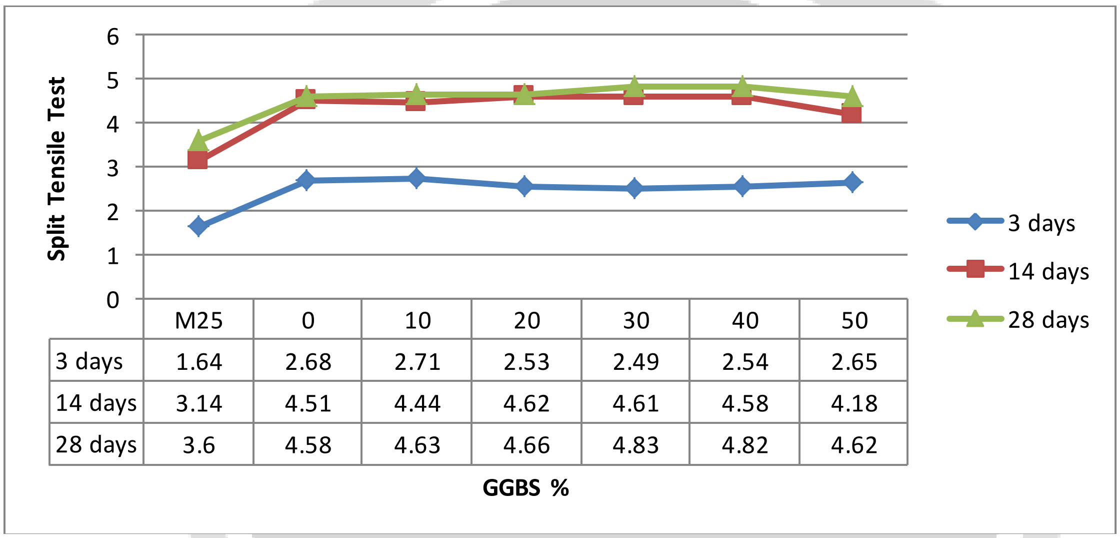


	M25	0	10	20	30	40	50
3 days	15.38	23.35	25.45	24.23	25.1	26.8	26.5
14 days	28.42	33.56	32.15	33.43	35.88	36.9	34.28
28 days	30.33	39.27	37.8	38.43	39.18	39.56	38.56

3.2 SPLIT TENSILE TEST RESULT:

% GGBS	3 days	14 days	28 days
M25	1.64	3.14	3.6
0	2.68	4.51	4.58
10	2.71	4.44	4.63
20	2.53	4.62	4.66
30	2.49	4.61	4.83
40	2.54	4.58	4.82
50	2.65	4.18	4.62

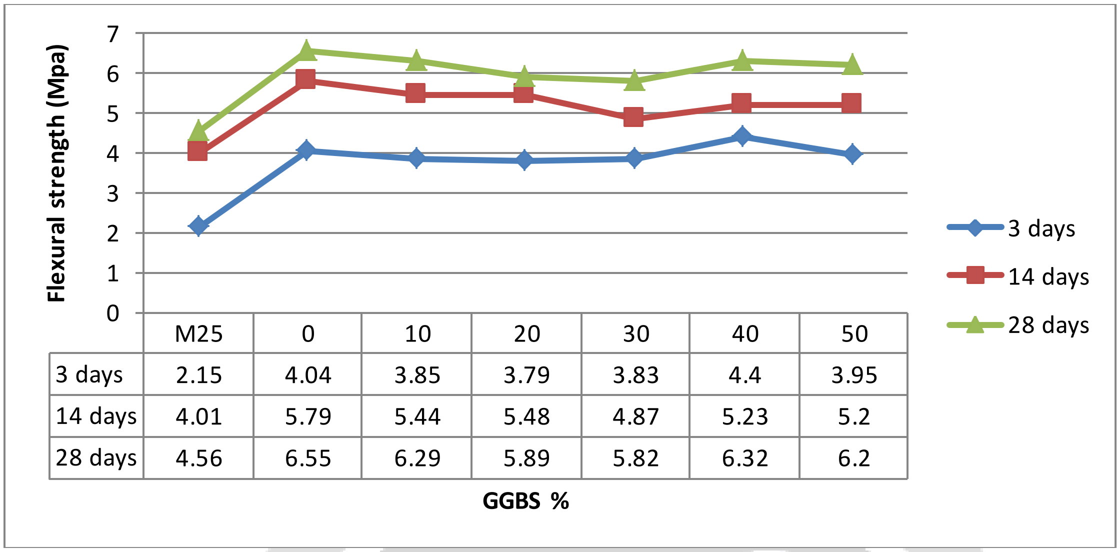
Table 4. Split tensile test result



3.3 FLEXURAL STRENGTH TEST RESULT:

% GGBS	3 days	14 days	28 days
M25	2.15	4.01	4.56
0	4.04	5.79	6.55
10	3.85	5.44	6.29
20	3.79	5.48	5.89
30	3.83	4.87	5.82
40	4.4	5.23	6.32
50	3.95	5.20	6.20

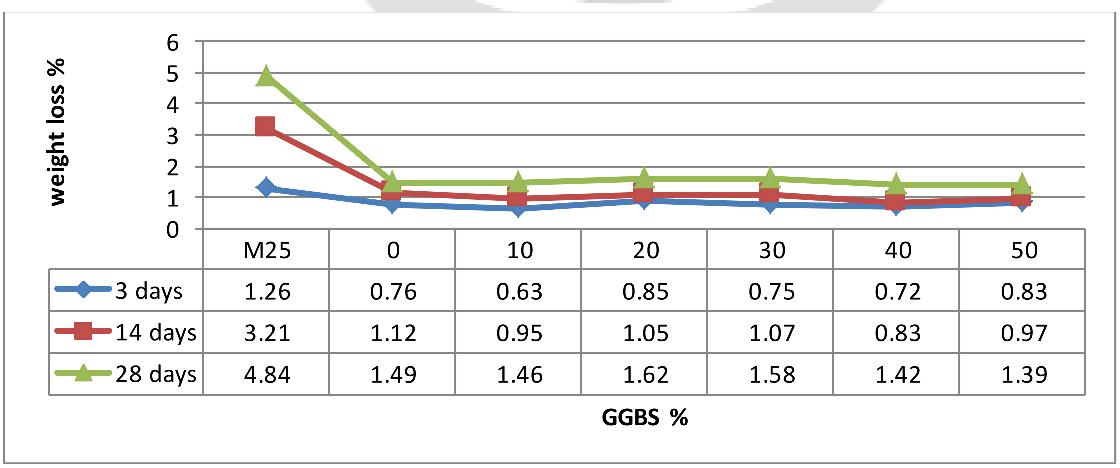
Table 5. Flexural strength test result



3.4 DURABILITY TEST RESULT:

% GGBS	3 days	14 days	28days
M25	1.26	3.21	4.84
0	0.76	1.12	1.49
10	0.63	0.95	1.46
20	0.85	1.05	1.62
30	0.75	1.07	1.58
40	0.72	0.83	1.42
50	0.83	0.97	1.39

Table 6. Durability test result



4. CONCLUSIONS:

• Compressive strength of GPC increases over controlled concrete by 1.5 times (M-25 achieves M-45)
• Split Tensile Strength of GPC increases over controlled concrete by 1.45 times.
• Flexural Strength of GPC increases over controlled concrete by 1.6 times.
• In Durability test, there is decrease in weight loss by 10 times (At 56 days % loss in weight has reduced from 5.66% to 0.60%).
• the performance of 40% replacement of GGBS with fly ash is good.
• Further good structural properties can be achieved with increase in polymerization temperature along with prolonged curing period in oven.

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