Durability and Strength characteristics of Geo-polymer concrete using GGBS by varying molar concentration and water content in AAS

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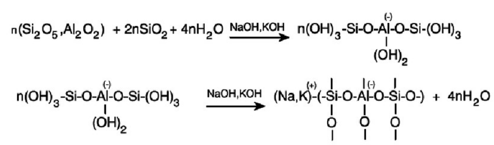
***Abstract*— This project deals with the experimental study to determine the properties of fresh and hardened concrete of geo polymer concrete which is totally cement free concrete which contains Granulated Ground Blast Furnace Slag (GGBS), active alkaline liquids like Sodium hydroxide, Sodium silicate solutions, fine aggregates as M-sand and coarse aggregates. Also varying the molar concentration and water content of the alkali activated solution. Also testing its compressive strength, flexural strength and its durability of the concrete by testing with Chlorine compound (Chloride attack Test).**

Keywords—Geo-polymer, GGBS, Durability, NaOH, Na_2Sio_3, AAS.

I. INTRODUCTION

The term geo-polymer was first coined by Davidovits in 1978 to represent a broad range of materials characterized by chains or networks of inorganic molecules. Geo-polymers are chains or networks of mineral molecules linked with co-valent bonds. Geopolymer is produced by a polymeric reaction of alkaline liquid with source material of geological origin or by product material such as fly ash, rice husk ash, GGBS etc. Because the chemical reaction that takes place in this case is a polymerization process, Davidovits coined the term 'Geopolymer' to represent these binders. Geo-polymers have the chemical composition similar to Zeolites but they can be formed an amorphous structure. He also suggested the use of the term 'Poly (sialate)' for the chemical designation of geopolymers based onsilico-aluminate. Sialate is an abbreviation for siliconoxo aluminate. Geopolymerization involves the chemical reaction of alumino-silicate oxides (Si2O5, Al2O2) with alkali polysilicates yielding polymeric Si–O–Al bonds. The most common alkaline polysilicates used in the geo-polymerization is the combination of Sodium hydroxide/ Potassium hydroxide and Sodium silicate/ Potassium silicate. This combination increases the rate of reaction.



equation 1

Equation 1 shows an example of poly condensation by alkali into poly (sialatesiloxo). The last term of Equation 1 indicates that water is released during the chemical reaction that occurs in the formation of geo-polymers. This water, expelled from the geopolymer matrix during the curing and further drying periods, leaves behind discontinuous nano pores in the matrix, which provide benefits to the performance of geopolymers. The water in a geopolymer mixture, therefore, plays no role in the chemical reaction that takes place; it merely provides the workability to the mixture during handling. This is in contrast to the chemical reaction of water in a Portland cement mixture during the hydration process. Unlike ordinary Portland/pozzolanic cements, geo-polymers do not form calciumsilicate- hydrates (C-S-H) for matrix formation and strength, but utilise the polycondensation of silica and alumina precursors and a high alkali content to attain structural strength. Therefore, geo-polymers are sometimes referred to as alkali activated alumino silicate binders.Ease of Use.

II. OBJECTIVE

- To study the effect of change in molarities of AAS on strength of concrete.
- To study the effect of curing temperature and curing period on geo-polymer concrete.
- To determine the strength and workability after the complete replacement of cement to GGBS.
- To compare properties with conventional concrete.

- Conserve land, used for disposal of coal combustion products.
- Durable infrastructures construction.
- To reduce carbon-di-oxide emition by replacing OPC from GPC.

III. SCOPE OF THE PAPER

- Development of high strength Geopolymer concrete manufactured with silicates and hydroxides of potassium.
- Investigations on the effect of varying percentage of reinforcement on flexural and shear capacity of reinforced Geopolymer concrete beams.
- Shear strengthening of reinforced Geopolymer concrete beams with fiber wrapping.
- Study on the addition of various fibres in Geopolymer concrete and their effect on enhancement of strengths.
- The flexural behaviour of reinforced Geopolymer concrete beams including Flexural strength, crack pattern, deflection, and ductility.
- The behaviour and strength of reinforced Geopolymer concrete slender columns subjected to axial load and bending moment.

IV. MATERIALS USED

1. Granulated Ground Blast Furnace Slag (GGBS).

It is an industrial waste material which is obtained from quenching molten iron from a blast furnace in water or steam. It is highly cementitious and high in calcium silicate hydrates which improves the strength and durability of the concrete. 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.

2. M-Sand.

This is also known as manufactured sand which is a replacement for normal river sand. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm.

3. Coarse Aggregate.

Coarse aggregate is obtained normally from hard granite stone by crushing. The crushed aggregate is of angular shape and graded as a construction material. The size of aggregate is more then 4.75mm, 20mm down passing aggregates are used in this study.

4. Alkali Activated Solutions.
   a. Sodium Hydroxide (NaOH).
   b. Sodium Silicate (Na_2SiO_3).
5. Sodium Chloride (NaCl).
6. Water.

V. METHODOLOGY

The methodology adopted to achieve above objectives comprise of following steps.

- In the present study we are using concrete mould of size (150X150X150) mm and (150X300) mm.
- The specimens are casted for some grade concrete with 100% replacement of cement by ground granulated blast furnace slag.
- Manufacturing procedure is same as the conventional concrete.
- Alkali activated solution is a polymer reacted solutions which is formed by two monomer chemicals like sodium hydroxide and sodium silicate, which acts as a binder element in the preparation of geo-polymer concrete.
- Alkali activated solutions are prepared based on the molarities, in this study 4M, 5M and 6M solutions of AAS are used.
- These AAS solutions are further tested by replacing certain amount of water to each of the molar solutions, 0% water replaced solutions, 15% water replaced solutions and 30% water replaced solutions in each molarities.
- Prepared and casted specimens are de-moulded after the concrete is completely set, normally 24 hours.
- The de-moulded specimens are then kept for curing ambientely in an average temperature of 60 ^{o}C.
- Curing period considered in this study are 3days, 7days and 14 days.
- After the curing period of respective specimens they are tested for compression and split tensile strength.
- After the complete curing period some of the specimens are immersed in 5% sodium chloride solution for the period of 90 days to determine there durability characteristics.

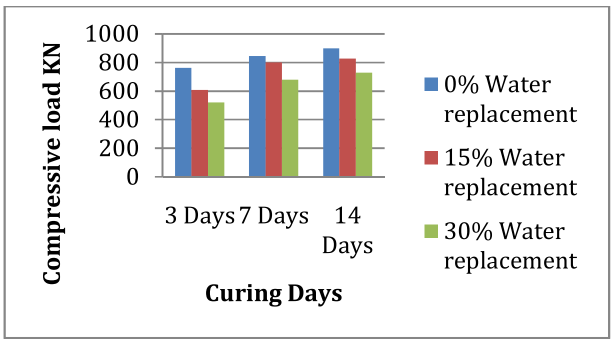
VI. RESULTS AND DISCUSSION

Compressive test

The cube specimens were tested by placing centrally over the loading plate in compression testing machine (CTM) of capacity 2000KN at the loading rate of 1.0mm/min. Compressive strength comparison of different mixes at 3, 7 and 14 days. Reference mix 6M with 0% water substitution has highest compressive strength then other mixes. Compressive strength of specimens increased with ages.

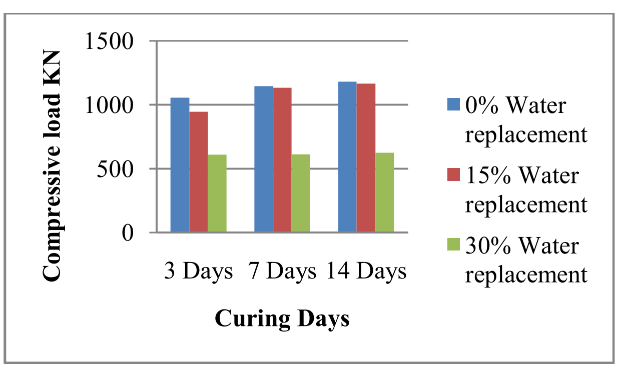
SL.NO	% of water added to AAS	CURING DAYS	Compressive load (KN)
1	0	3	761.67
2		7	846.67
3		14	898.33
4	15	3	608.33
5		7	800
6		14	826.67
7	30	3	521.67
8		7	680
9		14	730.33

table 1 – 4M Solutions.



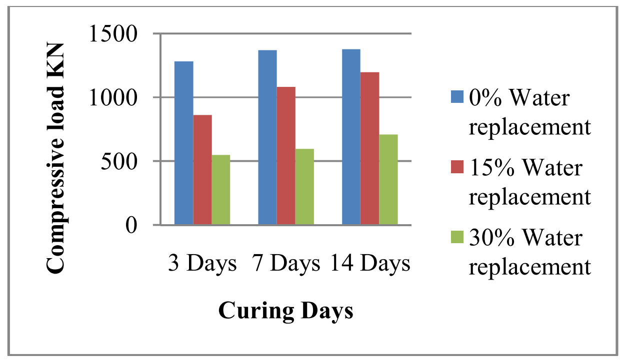
SL.NO	% of water added to AAS	CURING DAYS	Compressive load (KN)
1	0	3	1056.67
2		7	1146.67
3		14	1182.33
4	15	3	946.67
5		7	1133.33
6		14	1164.67
7	30	3	610
8		7	613.33
9		14	624.67

table 2 – 5M Solutions.



SL.NO	% of water added to AAS	CURING DAYS	Compressive load (KN)
1	0	3	1280
2		7	1370
3		14	1376.67
4	15	3	860
5		7	1083.33
6		14	1196.67
7	30	3	546.67
8		7	593.33
9		14	706.67

table 3 – 6M Solutions.

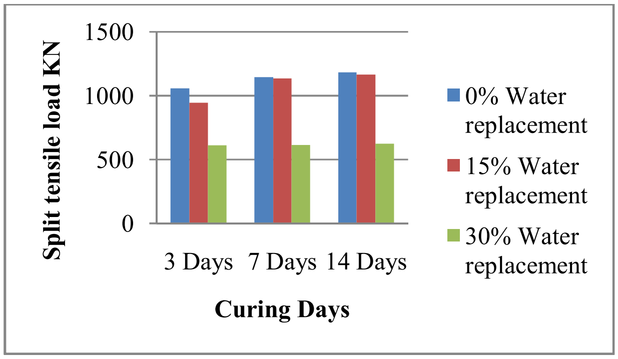


Split tensile test

The cylindrical specimens were tested in compressive testing machine (CTM) of capacity 2000KN for attaining split tensile strength. The specimens were placed between the base plate and uniform load is applied across the longitudinal section of the specimen. Split tensile strength comparison of different mixes at 3, 7 and 14 days were tested. The mix with 0% water content of 6M AAS solutions showed the highest split tensile strength.

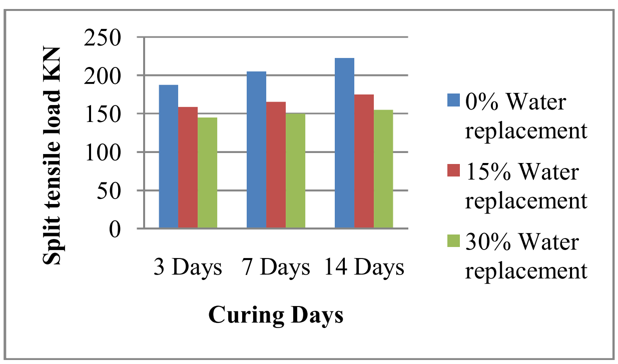
SL.NO	% of water added to AAS	CURING DAYS	Split tensile load (KN)
1	0	3	165
2		7	175
3		14	190
4	15	3	150
5		7	155
6		14	167.5
7	30	3	142.5
8		7	160
9		14	165

table 4 – 4M Solutions.



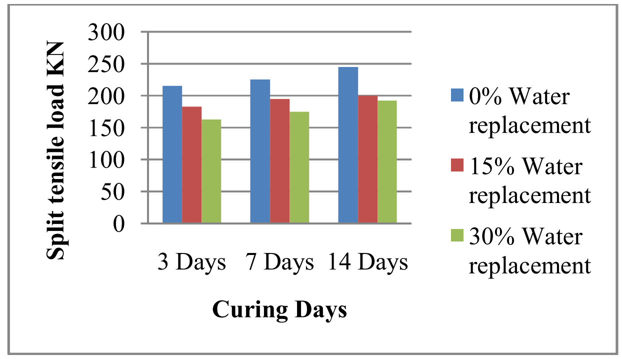
SL.NO	% of water added to AAS	CURING DAYS	Split tensile load (KN)
1	0	3	187.5
2		7	205
3		14	222.5
4	15	3	159
5		7	165.5
6		14	175
7	30	3	145
8		7	150
9		14	155

table 5 – 5M Solutions.



SL.NO	% of water added to AAS	CURING DAYS	Split tensile load (KN)
1	0	3	215
2		7	225.5
3		14	245
4	15	3	182.5
5		7	195
6		14	200
7	30	3	162.5
8		7	175
9		14	192.5

table 6 – 6M Solutions.



Durability test

It is the ability of resist weathering action, chemical attack and abrasion by maintaining its desired properties. It this study test was conducted against chloride attack. After the completion of the curing period the cubes are immersed in to a 5% sodium chloride solution for a time period of 90 days. Then they were tested for their loss in weight and loss in strength.
It was observed that the cured specimens loss their weight by 1 to 2.5% of their actual weight and 10 to 15% loss in their strength.

VII. CONCULSION

On the basis of the results and discussions of this investigation the following conclusions can be drawn.

- GGBS can be used as base materials to produce Geopolymer reactions using sodium hydroxide and sodium silicate based for +activator solution.
- The GPCs do not require Portland cement and hence, they can be considered as less energy intensive since Portland cement is a highly energy intensive material. Apart from less energy intensiveness, the GPCs utilize the industrial wastes for producing the binding system in concrete and thus can be considered as highly ecofriendly material.
- The compressive strength of GPC with equal proportions of GGBS was found to be comparable to the reference mix at the age of 3,7 & 14 days and thus can be considered as optional proportioning for making GPC using ground granulated blast furnace slag .
- The GPC are found to be highly acid resistant, since even after 90 days of immersion in sodium chloride solution , the specimens remained intact without any significant change in mass and shape. But in case of

OPCs, the specimens had deteriorated severely with very obvious external damaged surfaces accompanied by noticeable bulging. Therefore, GPC could be considered as superior to OPC concrete from the durability considerations.

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