ISSN (Print 0974-2115) (Online 2349-8552)
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Behaviour of Flyash-Phosphogypsum and GGBS Blended Geopolymer Concrete in Acidic Environment

P. Chowdaiah[1*], H. Sudarsana Rao[2], Vaishali G Ghorpade[3]
[1]Department of Structural Engineering, JNTU CEA, Anantapur, India
[2, 3] Department of Civil Engineering, JNT University, Anantapur, India
***Corresponding author: E-Mail: chow4309@gmail.com**

ABSTRACT

It is desirable to reduce CO_2 emission through the greater use of substitutes for Ordinary Portland Cement (OPC). Geopolymers are new promising binders manufactured by activation of solid aluminium silicate source material with a highly alkaline activating solution and aided by heat. Flyash consideredbeingwaste material rich in silica and alumina used as the base material for the manufacture of Geopolymer concrete. Geopolymer concrete results (Davidovits, 1988) from the reaction of base material which is high content of silica and alumina with alkaline liquid. An experimental study was conducted to evaluate the acid resistance of Geopolymer concrete with partial replacement of Flyash with GGBS and Phosphogypsum (PG). The objective of the present study is to develop Geopolymer concrete with Flyash and with partial replacement of Flyash by GGBS and Phosphogypsum. GGBS and Phosphogypsumwere used to replace Flyash in fourdifferent proportions i.e. 2.5, 5, 7.5, 10%.The Geopolymer concrete specimens were cured in ovenat temperature of 60^{o}C for 24 hours and then air cured for 28 days (Hardjito, 2005). The Geopolymer concrete specimens were immersed in 5% concentrated solution of Hydrochloric Acid (HCL) and Magnesium Sulfate ($MgSO_4$) for 30, 60, 90 days (Bakharev, 2005). The residual compressive strength and loss weight due to acid exposure have been measured and reported in this paper to evaluate the behaviour of blended Geopolymer concrete.

KEY WORDS: Geopolymer concrete, Fly ash, Residual Compressive strength, Weight loss, Acid exposure.

1. INTRODUCTION

Portland cement is the main component of making concrete. The cement industry becomes responsible for CO_2 emissions because the manufacture of one ton of Portland cement produces approximately one ton of carbon dioxide to the atmosphere the main elements of Geopolymers are the source materials and the alkaline liquids. The source materials for Geopolymers content of silica and aluminium is high (Davidovits, 1991). The alkaline liquids are formed by soluble alkali metals that are usuallySodium or potassium based. In general. The ratio of Alkali Liquid / Flyash is 0.4 and that for Na_2Sio_3/ NaoH is 2.5 as the cost is lesser when compared to potassium, sodium is used. The alkaline liquid used react with the Silica (Si) and Aluminium (Al) in Flyash and produce binders. Because of the polymerization process taking place, Davidovits given the term "Geopolymer" to represent these binders .In the present work, Phosphogypsum and GGBS minerals are used as admixtures as partial replacement of Flyash. Compressive strength of cubes is investigated under chloride and sulphate attack. Steam curing, Heat curing and curing at ambient temperature are the three methods generally used to cure the Geopolymer concrete. It takes days to cure the concrete in ambient temperature. Steam curing requires boiler and fire wood to generate steam. Throughout this research, Heat curing is adopted to cure the Geopolymer concrete elements at 60^{0}c for 24 hours (Hardjito, 2005) in a heat curing chamber. The heat curing enhances the compressive strength of Geopolymer concrete by about 15%, established by Hardjito and Rangan (2005) than steam curing and also attains its full strength in 24 hours. This is in contrast to 28 days curing of cement concrete elements and hence Geopolymer concrete can also be termed as "One day Concrete" (Hardjito, 2005).

Literature Review: Hardjito (2005), conducted various experiments to study the materials and mixture proportions, the making process and impact of various parameters on hardened Geopolymer concrete.

Bakharev (2005), given on investigation on durability of Geopolymer materials manufacture of Class F flyash and alkali activators. When specimens were immersed in 5% concentrated of acetic acid and sulphuric acids. The evaluation weight loss, compressive strength and deterioration and microstructures changes main parameters in the investigation.

Song (2006), conducted various experiments and data presented on durability of geopolymer concrete when specimens are exposed to 10% HCl solution up to eight weeks. Class F flyash based Geopolymer concrete initially cured for 24hr at 70^{0}c the compressive strength of 50mm cubes at age of 28 days the range is 53MPa to 64MPa after exposed to 10% HCL solution. Samples tested at 28, 56 days.

Anurag Mishra (2008), conducted various experiments and presented the results to study on weight loss and properties of Geopolymer concrete. The tests were conducted on GPC by variation of NaOH concentration and curing period. Total nine mixes were prepared with 18M, 12M, 16 Molarity of NaOH and curing periods 24hr, 48hr, 72 hours. Compressive strength and weight loss and tensile strength tests were conducted on each mix.

2. EXPERIMENTAL PROGRAMME

Materials and Mix Proportions:

Flyash: Fly ash belonging to class-F attained from RTPP Station in Andhra Pradesh was used in this programme having specific gravity of the fly ash was 1.975.

Alkaline Liquid: A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid.

Natural fine aggregate: Nearby available river sand passing through 4.75 mm IS. Sieve with having fineness modulus of 2.74. The specific gravity of the fine aggregate is found to be 2.61.

Natural coarse aggregate: Granite metal with 50% passing through 12.5mm and retained on 10mm sieve and 50% passing through 20mm and retained on 12.5mm sieve was used. Crushed granite aggregate available from local sources with a fineness modulus of 6.73, and water absorption of 0.72% in saturated surface dry condition has been used. The specific Gravity of coarse aggregate is found to be 2.75. The maximum size of the coarse aggregate was 20mm.

Water: Potable fresh water available from local sources free from inorganic materials was used for mixing and curing of all the mixes for this investigation.

Super plasticizer: The super plasticizer used in this experiment is Naphthalene Sulphonate based super plasticizer. It is manufactured by MYK SCHOMBURG, Hyderabad. MYK Save mix SP200 complies with IS: 9103:1999 standard having Specific Gravity of 1.24

GGBS and Phosphogypsum: The GGBS and Phosphogypsum are bought commercially from Chennai. The specific gravity of GGBS and Phosphogypsum are 2.9 and 2.35 respectively.

Acids: Acids are used in the investigation Hydrochloric acid (HCl) and Magnesium sulfate ($MgSO_4$) of 5% concentration.

Mix Design of Geo Polymer Concrete: The mix proportion of Geopolymer concrete has been carried out by using1: 1.405: 3.28 and the relative mix proportions presented in table.1.

Table.1. Geopolymer concrete mix proportions

Materials	Quantity Kg/m^3
Fly Ash	394.3
C.A 20 mm	906
C.A 10 mm	388
F.A	554
NaOH Solids	14.135
Na_2Sio_3 Solids	48.85

Methodology:

Preparation of Alkaline Liquid: Sodium hydroxide (NaOH) and Sodium silicate (Na_2SiO_3) were used as alkaline liquids. The molarity of NaOH used for the present study was 10. The ratios of Na_2SiO_3 to NaOH selected was 2.5. A solution of 10M of sodium hydroxide is prepared by dissolving 415g of sodium hydroxide pellets in a litre of water and stored separately.

Casting of Geopolymer concrete specimens: The size of the specimens used for the present study was 150 mm x 150 mm x 150 mm. Phosphogypsum and GGBS were mixed with sand, coarse aggregates and the alkaline liquid were poured to dry mix and mixed thoroughly to form homogenous mixture (Bakharev, 2005). The required quantity of super plasticizer was added as 3% by mass of flyash. Once the mixing process was over the mould was filled by the fresh Geopolymer concrete in three layers and compacted well. In each mix nine specimens were cast to test the compressive strength of concrete.

Curing of Geopolymer concrete specimens: After the specimens were cast they were kept in hot air oven properly by steel plates with a constant temperature of 60^0C for a period of 24 hrs (Hardjito, 2005). Then the specimens were taken out and kept in room temperature for the desired period. The molarity used for the present study was kept constant as 10 for all the mixes. Since alkali activators were used for the study the specimens were kept in hot air oven for thermal curing to a temperature of 60^o C and after that the specimens were cured at ambient temperature for the 28 days.

Placing of specimens under acidic environment: After curing the specimens were immersed in 5% concentrated solution of hydrochloric acid and magnesium sulphate for 30, 60, 90 days then specimens are removed and measured the weight reductions and compressive strength of each specimens.

3. RESULTS AND DISCUSSIONS

Acid resistance: The acid resistance of geopolymer concrete is evaluated. To study the acid attack in the present programme immersion technique is adopted. After casting and curing, cubes of size 150mmx150mmx150mm specimens are immersed in HCl solution. The concentration of Hydrochloric acid solution is 5%. The evaluation is conducted after 30, 60, 90 days. The solution is kept at normal temperature and the solution is stirred regular interval. The weight of Geopolymer concrete decreases when placed in acid solution. The compressive strength pure flyash specimens after 28 days is 50N/mm^2. After immersed in HCl solution strength was reduced. The residual compressive strength and weight loss of Geopolymer concrete partially replaced with Phosphogypsum and GGBS immersed in HCL solution is presented in table.2 &3.

Table.2. Residual compressive strengths and % weight loss of GGBS blended specimens in 5% concentrated HCl

% Replacement of Flyash with GGBS	Residual Compressive strength (N/mm^2)			% of weight loss		
	30 days	60 days	90 days	30 days	60 days	90 days
0	41	39	37	0.8	2.4	5.4
2.5	43	41	39	1.4	3.6	5.9
5	45	42	40	1.5	3.9	6.1
7.5	40	37	35	1.8	4.2	6.4
10	38	35	33	1.9	4.5	6.6

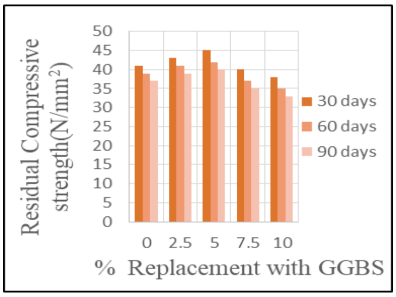

Figure.1. Residual Compressive strength in HCl Vs % Replacement with GGBS

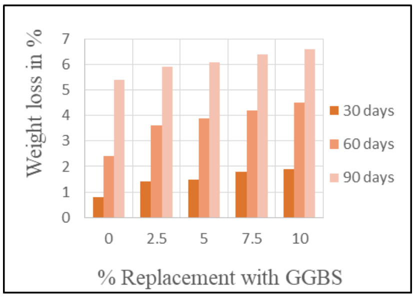

Figure.2. %Weight loss in HCl solution Vs % Replacement with GGBS

Table.3. Residual compressive strengths and % weight loss of Phosphogypsum blended specimens in 5% concentrated HCl

% Replacement of Flyash with Phosphogypsum	Residual Compressive strength (N/mm^2)			% of weight loss		
	30 days	60 days	90 days	30 days	60 days	90 days
0	41	39	37	0.8	2.4	5.4
2.5	42	40	38	1.2	3	4.4
5	40	38	37	1.6	3.6	4.8
7.5	38	36	35	1.9	4.1	5.3
10	37	35	33	2.1	4.5	5.9

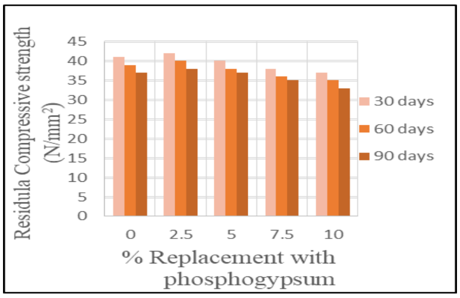

Figure.3. Residual Compressive strength in HCl Vs % Replacement with Phosphogypsum

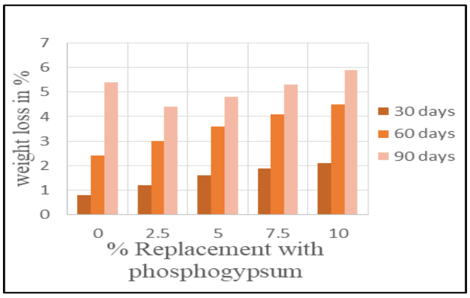

Figure.4. %Weight loss in HCl Vs % Replacement with Phosphogypsum

Effect on compressive strength and weight loss of GPC specimens immersed in HCl: The residual compressive strength of geopolymer concrete specimens blended with GGBS subjected to HCl environment condition are presented in table.2. The variations of residual compressive strength and weight loss of these specimens with respect to % replacement with GGBS is presented in figures. It can be observed from fig.1, the residual compressive strength of GPC specimens blended with GGBS increased up to 5% level their after decreasing trend is observed. It also observed that the residual compressive strength decrease with increase in number of days of immersion in 5% concentrated HCl solution. From figure.2, observed that the weight loss of specimens increased with increase in GGBS content.

In case of Geopolymer concrete specimens blended with Phosphogypsum it is observed that residual compressive strength marginally increased for 2.5% blending and their after decreasing trend is observed. Similarly weight loss of specimens increased by increase % of blending of phosphogypsum in HCl solution. Hence it is concluded blending of GGBS is more beneficial than phosphogypsum in view of durability.

Sulphate resistance: The sulphate is present in the soil in various forms such as sodium, potassium and magnesium. The sulphate attack is a common occurrence in normal and industrial conditions. Magnesium sulphate salt of 99% concentration is taken as 5%. The cubes are prepared with 10 M concentrated sodium sulphate salt of 415g is dissolved in 1 litre of water to keep the specimens completely immersed inside the $MgSO_4$ solution for 30, 60, 90 days. The weight of mineral replaced was Phosphogypsum and GGBS in place of Flyash in respective percentages measured. The compressive strength of without replacement of phosphogypsum and GGBS is 50N/mm^2. The residual compressive strength and weight loss are given in table.4 & 5.

Table.4. Residual compressive strengths and % weight loss of GGBS blended specimens in 5% concentrated $MgS0_4$

%Replacement of Flyash with GGBS	Residual Compressive strength (N/mm^2)			% 0f weight loss		
	30 days	60 days	90 days	30 days	60 days	90 days
0	41	39	37	1.3	3.6	5.1
2.5	43	40	38	1.7	4.1	5.5
5	45	41	39	2.3	4.8	6.2
7.5	47	44	41	2.9	5.5	6.9
10	48	45	42	3.4	6.2	7.4

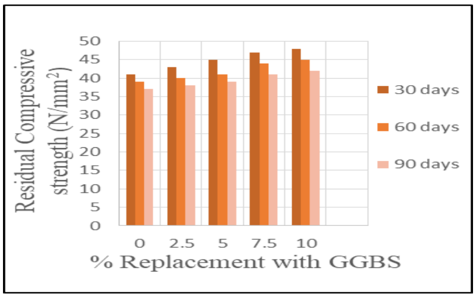

Figure.5. Residual Compressive strength in $MgSO_4$ Vs % Replacement with GGBS

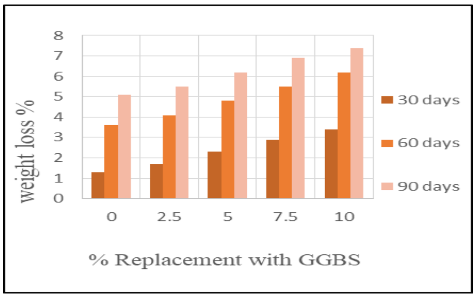

Figure.6. %Weight loss in$MgSO_4$ Vs % Replacement with GGBS

Table.5. Residual compressive strengths and % weight loss of Phospho gypsum blended specimens in 5% concentrated $MgS0_4$

%Replacement of Flyash with Phosphogypsum	Residual Compressive strength (N/mm^2)			% 0f weight loss		
	30 days	60 days	90 days	30 days	60 days	90 days
0	41	39	37	0.8	2.4	5.4
2.5	42	40	38	1.2	3	4.4
5	45	42	40	1.6	3.6	4.8
7.5	46	44	41	1.9	4.1	5.3
10	42	39	37	2.1	4.5	5.9

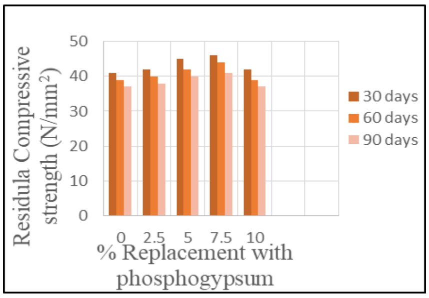

Figure.7. Residual Compressive strength in $MgSO_4$ Vs % Replacement with Phosphogypsum

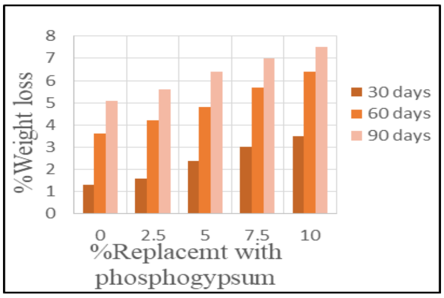

Figure.8. %Weight loss in$MgSO_4$ Vs % Replacement with Phosphogypsum

Effect on compressive strength and weight loss of GPC specimens immersed in $MgSO_4$: The residual compressive strength of geopolymer concrete specimens blended with GGBS subjected to sulphate ($MgSo_4$) environment condition are presented in table4. The variations of residual compressive strength and weight loss of these specimens with respect to % replacement with GGBS is presented in figures. It can be observed from fig.5, the residual compressive strength of GPC specimens in sulphate attack condition increased by increasing the percentage replacement of GGBS up to10%. It also observed that the residual compressive strength decrease with increase in number of days of immersion in 5% concentrated $MgSO_4$ solution. From figure.6, observed that the weight loss of specimens increased with increase in GGBS content.

In case of Geopolymer concrete specimens blended with Phosphogypsum sulphate attack condition it is observed that residual compressive strength marginally increased for 7.5% blending and their after decreasing trend is observed. Similarly weight loss of specimens increased by increase % of blending of phosphogypsum in $MgSO_4$ solution. Hence it is concluded blending of Phosphogypsum is more beneficial than GGBS in view of durability.

4. CONCLUSIONS

- Compressive strength of flyash based specimen without blending of minerals is 50N/mm^2. By blending of Phosphogypsum and GGBS compressive strength results were increased compared to without replacement under acidic and sulphate attack conditions. The percentage of weight loss increased using GGBS and Phosphogypsum with partially replacement with flyash in geopolymer concrete
- By increasing the percentage blending of Phosphogypsum and GGBS the percentage of weight loss is increased 30, 60, 90 days respectively when specimens immersed in $MGSO_4$ solution. The residual compressive strength increased up to 5% blending of GGBS with flyash. Their after residual compressive strength of cubes was decreased from 5 to10%. Hence, to get the optimum residual compressive strength of GGBS blended with fly ash in GPC is 5% against to acidic environment conditions.
- The residual compressive strength increased up to 7.5% replacement Phosphogypsum with flyash specimens attack by sulphate. Their after residual compressive strength of cubes was decreased from 7.5 to 10%. Hence, to get the optimum residual compressive strength of Phosphogypsum blended with fly ash in GPC is 7.5% against to sulphate environment conditions..
- The percentage of weight loss is more compared with acidic environment to sulphate environment.

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