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Effect of Different Aspect Ratio Steel Fiber in Slag based Geopolymer Concrete

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***Abstract*— Global warming is one of the most pronounced terms in this present century. Five to eight percent of the world's manmade Greenhouse gas emissions are from the Cement industry itself. Geopolymers are showing great potential and several researchers have critically examined the various aspects of their ability as binder system. Thus Geopolymer based Concrete is highly environment friendly and the same time it can be made as high performance concrete. The mixes of binder is combined alkaline solution of sodium hydroxide and sodium silicate with ground granulated blast furnace slag. So in this study an attempt is made to know the strength of geopolymer concrete by adding hooked end steel fiber in the mix . The acid attack of sulfuric acid is studied to check the durability properties of geopolymer concrete and change in mass of concrete. It has been concluded that the steel fiber used in geopolymer concrete upto 0.7% is improved compressive strength and flexural strength. Average 13% increases in compressive strength when added steel fiber in geopolymer concrete with different proportion and 8% increases in compressive strength in normal geopolymer concrete without steel fiber. The cost savings in production of M25 grade GPC is 2.15% compared to M25 grade of OPC which leads to maintain high strength element.**

Keywords*— Ground Granulated Blast Furnace Slag, Alkaline Liquid, Steel Fiber, Compressive Strength, Acid Attack.

1. INTRODUCTION

The term geopolymer was introduced by Davidovits to represent the mineral polymers resulting from geochemistry. The polymerization process involves a chemical reaction under highly alkaline conditions on Al-Si minerals, yielding polymeric Si-O-Al-O bonds. Poly(sialates) are chain and ring polymers with Si^{4+} and Al^{3+} in IV-fold coordination with oxygen and range from amorphous to semi crystalline with the empirical Formula as described by[1] ,

$$Mn(- (SiO_2)_z - AlO_2)_n : wH_2O$$

Where M is the alkaline element, the symbol – indicates the presence of a Bond, z is 1,2, or 3, and n is the degree of polymerization. Exact Mechanism by which geopolymer setting and hardening occur is not yet clear and is under research. The reaction of fly-ash with an aqueous solution contains NaOH and Na_2SiO_3 in their mass ratio, results in a material with 3D polymeric chain and ring structure consisting of Si-O-Al-O bonds. The schematic formation of geo-polymer material can be shown as described by Equation A and B and the end product of this process is an amorphous polymeric material Geopolymer concrete is a type of concrete which does not utilize any Portland cement in its production but, the binder is produced by the reaction of an alkaline liquid with a source material that is rich in silica and alumina.

2. CONSTITUENT MATERIALS OF GEOPOLYMER CONCRETE

Geopolymeric source materials (GSMs) are rich in silica and alumina, which could be natural minerals (such as kaolinite, clays, etc) or industrial by-products (such as fly ash, silica fume, slag, rice-husk ash etc). - Alkaline Activator Solution (AAS) based on alkali metals (commonly Sodium or Potassium) based. The most common AAS is a combination of alkali hydroxide (NaOH, KOH) and alkali silicate (Sodium or potassium silicate) minerals containing reactive oxides of silicon and aluminium can be activated by suitably formulated highly alkaline liquid to obtain inorganic polymeric binding material [Sindhunata, 2006]. The following are the constituents for ambient curing.

- Ground Granulated Blast Furnace Slag (GGBS),
- Fine aggregates (in the form of river sand),
- Coarse aggregates (in the form of crushed granite stone),
- Alkaline Activator Solution (combination of solutions of alkali silicates and hydroxides, besides distilled water)

A. Basic mixture proportions

No standard mix design approaches are yet available for GPCs. D.Hardjito, et al (2004), showed that the geopolymer paste binds the coarse aggregates, fine aggregates and other un-reacted materials together to form the GPC, and usual concrete technology methods to produce GPC mixes can be often employed Mixture proportions are characterized by an alkaline liquid to

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GGBS by mass of 0.35 and aggregate to total mass proportion of approximately 75% with the nominal strengths. The Alkaline liquid to GGBS ratio should be taken 0.4. The silicon and the aluminium in the GGBS are activated by a combination of sodium hydroxide and sodium silicate. Below table shows the mix proportion of concrete (kg/m^3) which is carried out for research work. The steel fiber proportion should be taken 0.5% and 0.7% with different aspect ratio like 40, 50 and 60.
Steel fiber = 0.5 % of GGBS = 1.97 kg/m^3
Steel fiber = 0.7 % of GGBS = 2.76 kg/m^3

Table 1 mixture proportions

Ingredients		Units	GPC
GGBS		kg/m^3	394
Fine Aggregate		kg/m^3	647
Coarse Aggregate	20mm	kg/m^3	721
	10mm	kg/m^3	480
Sodiun Silicate		kg/m^3	113
Sodium Hydroxide		kg/m^3	46
Extra water		kg/m^3	59.1

3. FRESH GEOPOLYMER CONCRETE

Fresh geopolymer concrete has been reported to be highly viscous and cohesive with low workability fresh geopolymer concrete became stiff in a short time, thus implying a short initial setting time. To improve the workability of mortar, superplasticiser or extra water can be added. As such, extra water gives higher workability than addition of superplasticiser upt0 15% with GGBS. The density of the geopolymer concrete was 2380 ±60 kg/m3.

4. FACTORS AFFECTING STRENGTH OF GEOPOLYMERS

In the table the other mix proportion should be same. There should be variables in parametric study.

Table 2 mixture proportions of parametric study

Mix	NaOH (kg)	Na_2SiO_3 (kg)	Extra Water (kg)	Compressive strength (N/mm^2)	
				7 days	14 days
1	52.5	106	39.4	14.39	19.34
2	52.5	106	59.1	15.25	22.91
3	46	113	59.1	16.39	25.55
4	46	113	39.4	15.58	23.66

A. Sodium silicate to Sodium hydroxide ratio

The effect of variation in sodium silicate to sodium hydroxide by mass on compressive strength of concrete has been observed by comparing results of M25 grade slag based geopolymer. On compressive strength For Na_2SiO_3 to NaOH ratio of 2.5, geopolymer concrete shows higher compressive strength. The Na_2SiO_3 to NaOH ratio of 2.0 has been able to reduction in compressive strength as compared to that of ratio 2.5.

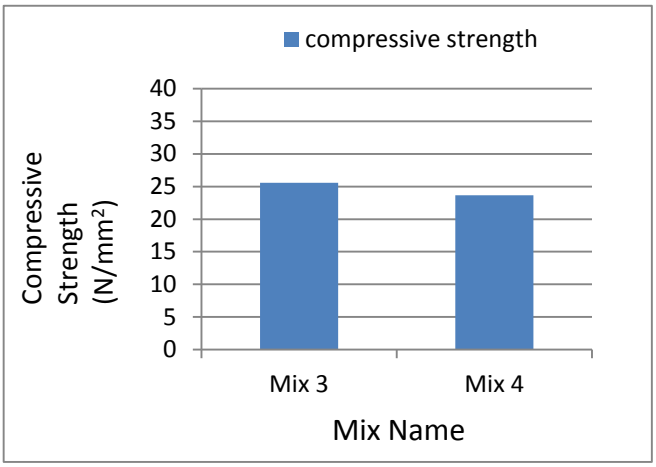

Figure 1 Compressive strength of Sodium silicate to Sodium hydroxide ratio

B. Water to geopolymer solids ratio.

Water in geopolymer concrete mix does not take any part in the chemical reaction. In opc concrete, water in the mix chemically reacts with the cement to produce a Paste that binds the aggregates. The chemical reaction that occurs in geopolymers Produces water that is eventually expelled from the binder. It has been observed that Additional water content in the geopolymer concrete mixture affected the properties of concrete in the fresh state as well as in the hardened state. In case of slag based geopolymer concrete water content is more require as compare to the fly ash based geopolymer concrete. Thus, 15% water is used for proper workability. The effect of water content of mix on compressive strength of geopolymer concrete can be observed by comparing results of M25 grade slag based geopolymer concrete. The concrete mixes have been cast using additional water of 15% by mass of slag.

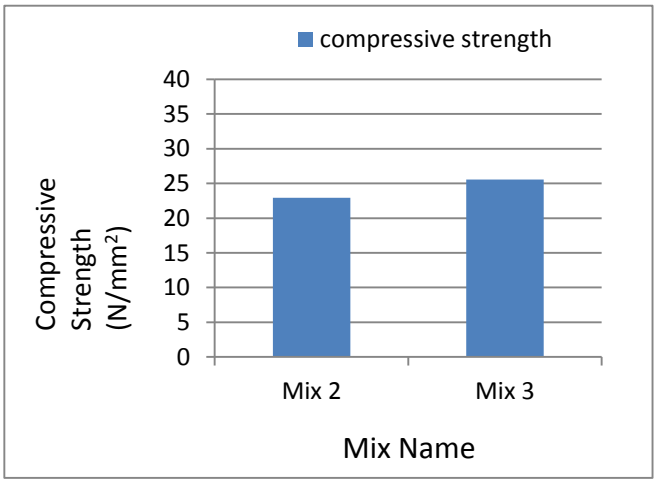

Figure 2 Compressive strength of Water to geopolymer solids ratio

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5. RESULT AND ANALYSIS

GPC1,GPC2,GPC3 defines the 0.5% usage of steel fiber with Aspect Ratio 40,50,60 respectively.
GPC4,GPC5,GPC6 defines the 0.7% usage of steel fiber with Aspect Ratio 40,50,60 respectively.
And GPC7 defines the normal geopolymer concrete without steel fiber.

A. Mechanical Properties

In comparison between 28 days and 56 days, Average 13% increases in compressive strength when added steel fiber in geopolymer concrete with different proportion and 8% increases in compressive strength in normal geopolymer concrete without steel fiber.

Table 3 Compressive Strength result

Compressive Strength (N/mm^2) At 28 Days						
GPC1	GPC2	GPC3	GPC4	GPC5	GPC6	GPC7
29.62	32.03	30.66	30.58	33.59	31.60	29.42
Compressive Strength (N/mm^2) At 56 Days						
GPC1	GPC2	GPC3	GPC4	GPC5	GPC6	GPC7
34.05	36.97	34.90	35.89	38.94	36.95	32.01

Slag based geopolymer concrte with 0.7% steel fiber usage of 50 aspect ratio gives better results in terms of compressive strength as compare to other two aspect ratio and 9% increase in compressive strength.
Slag based geopolymer concrte with 0.5% steel fiber usage of 50 Aspect ratio gives better results in terms of compressive strength as compare to other two Aspect ratio and 7% increase in compressive strength.
But 0.7% steel fiber usage of 50 Aspect Ratio gives the better result than the 0.5% steel fiber usage of 50 Aspect Ratio in terms of compressive strength.
Comparison of normal geopolymer concrete and steel fiber usage geopolymer concrete, there should be 12% compressive strength increases.

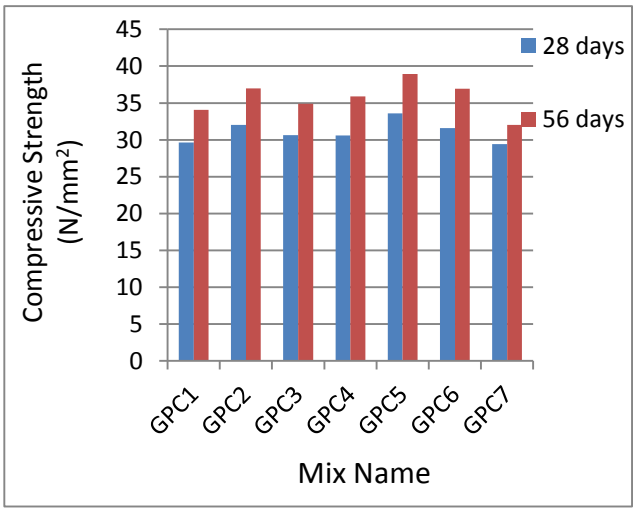

Figure 3 comparison of compressive strength result for all mixes

B. Durability Properties

It should be observed that there should be changed in mass of cube after acid attack.
The average density of slag based geopolymer concrete is changed after acid attack.
The compressive strength of the cube after acid attack should be decreased. 11% of compressive strength decreases in 0.5% usage of steel fiber and 9% compressive strength decreases in 0.7 % usage of steel fiber in slag based geopolymer concrete after 28 days of acid attack.
Normal Geopolymer concrete (without steel fiber) has decreases 19% the compressive strength more compared to steel fiber usage geopolymer concrete cube.

Table 4 Compressive Strength result after acid attack

Compressive Strength (N/mm^2) At 28 Days						
GPC1	GPC2	GPC3	GPC4	GPC5	GPC6	GPC7
29.62	32.03	30.66	30.58	33.59	31.60	29.42
Compressive Strength (N/mm^2) At 56 Days (After Acid Attack)						
GPC1	GPC2	GPC3	GPC4	GPC5	GPC6	GPC7
27.22	30.79	28.41	28.58	31.51	29.33	25.44

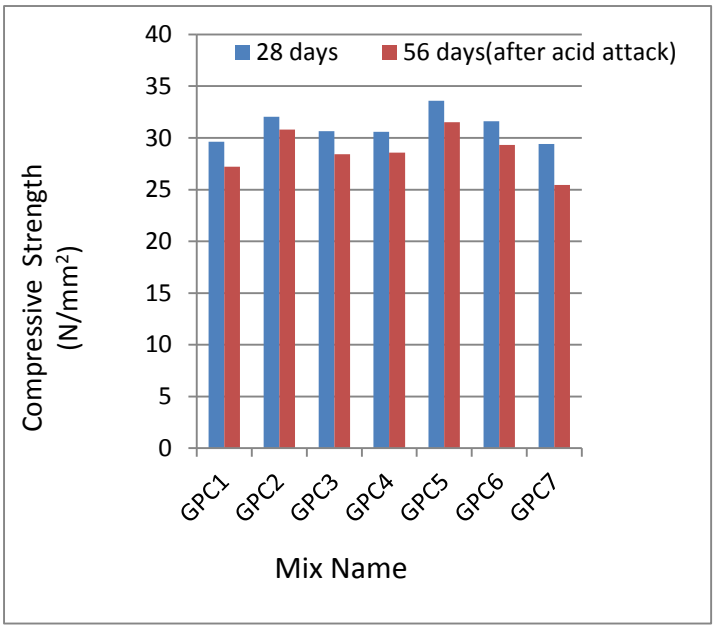

Figure 4 comparison of compressive strength result for all mixes after acid attack

6. CONCLUSION

The sodium silicate to sodium hydroxide ratio by mass equal to ratio 2.5 gives higher results as compared to ratio 2.0 for slag based geopolymer concrete. Compressive strength of slag based geopolymer concrete decreases with increase the water content. In case of slag 15 % water by mass of slag is require. The slump value of the fresh geopolymer concrete increases with the increase of extra water added to the mixture. The average density of slag

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based geopolymer concrete is similar to that of control concrete.0.7% steel fiber usage of 50 Aspect Ratio gives the better result than the 0.5% steel fiber usage of 50 Aspect Ratio in terms of compressive strength. In comparison between 28 days and 56 days, Average 13% increases in compressive strength when added steel fiber in geopolymer concrete with different proportion and 8% increases in compressive strength in normal geopolymer concrete without steel fiber. Normal Geopolymer concrete (without steel fiber) has decreases 19% the compressive strength more compared to steel fiber usage geopolymer concrete cube after acid attack. The weight loss of Geopolymer concrete is very low when geopolymer concrete mixes are exposed to 5% acid attack. Average 1.4% weight loss observed after acid attack. . The cost savings in production of M25 grade GPC is 2.15% compared to M25 grade of OPC which leads to maintain high strength element.

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