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Comparative Study of Compressive Strength and Durability Properties on Geopolymer Concrete using Ultra-Fine GGBS

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Abstract

The usage of practical advancement in structural building society has prompted the utilization of new materials with low environmental effects. One of the most commonly used construction material in the world is concrete, which is normally produced by OPC. However, the production of OPC has prompted ecological worries over the creation of CO2. Almost to create 1 ton of OPC 1 ton of CO2 is discharged to the atmosphere. With a specific end goal to diminish the utilization of OPC and CO2, the new concrete has been created, that is GEOPOLYMER CONCRETE. Latest research has demonstrated that it is conceivable to utilize fly ash or slag as a binder in concrete by activating them with alkali components through a polymerization procedure. This paper reports the point of interest of the test work that has been embraced to examine the strength and durability properties of ultra-fine slag and processed fly ash mortar mixes. At first specimens were casted for normal GGBS and fly ash in the ratio of 100:0, 75:25, 50:50, 25:75 and later for the best ratio (75:25), GGBS is replaced by ultra-fine GGBS by 7.5, 12 and 20%. Samples were compared with cured at ambient temperature and oven curing. The results showed that mix proportion of 20% replacement of ultra-fine GGBS gave the maximum strength for both oven and ambient curing (76.2 and 91.1 MPa). Even all the durability properties are within the permissible limits.
Keywords: Ultra-Fine GGBS, Geopolymer Concrete, Fly Ash, GGBS, Sodium Hydroxide, Sodium Silicate, AURO MIX 400 Plus

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I. Introduction

In 1978, Davidovits said that binders can be produced by alkaline liquids through polymerization reaction. These alternative binder material must contain high amount of Silicon (Si) and Aluminum (Al) which in turn react with alkaline liquid. Hence this concrete is named as Geopolymer Concrete (GPC). The commonly used binder

Geopolymerisation is a reaction that synthetically incorporates minerals (geosynthesis) that involves naturally occurring alumina – silicates. Any pozzolanic compounds which has high alumina and silica, which is readily dissolved in alkaline solution can act as a binder material in geopolymer concrete.

There are two stages of reaction in geopolymer concrete,

$$Al_2O_3 + SiO_2 \xrightarrow{\text{(20-90°C+ alkali silicate solution)}} \text{-Si –O –Al –O –} \xrightarrow{\text{(poly-condensation)}} \text{Alumino silicate}$$

The main issue of the utilization of fly ash as cement substitution materials is the need of heat curing to achieve structural integrity. Due to the similar properties of hydration product(C-S-H gel) of alkali activated slag, standard curing used for OPC can be used. Hence this paper reports the comparative information of strength and durability on the heat and ambient curing of different proportions of Ultra-fine GGBS, GGBS and processed Fly ash.

A. Remarkable Elements of Geo-Polymer Concrete

- Geopolymer concrete reduces CO_2 emission to the environment and it is a best alternative to ordinary Portland cement.
- Durability property is higher in Geopolymer concrete than in ordinary Portland cement.
- Percentage of water absorbed is lesser than the nominal concrete.
- Geopolymer concrete is an ecofriendly concrete.

II. MATERIALS USED

Ingredients required for production of Geopolymer concrete are:
- Binding source materials
- Aggregates consisting both fine and coarse aggregates
- Alkaline Activator solution

A. Binding Materials

Cementatious materials used in this Geopolymer concrete are
- Ultra-fine GGBS
- GGBS
- Processed fly ash

One of the main material used in this paper is Ultra-fine GGBS which is obtained from JSW, which is also called as Alcofine. Finess of ultra-fine GGBS used was 11500m^2/kg, Specific gravity was 2.85 and Residue remained on 45µ (wet sample) 1.18%. Ultra-fine GGBS is locally treated as equivalent to Micro Silica. Therefore this material used in the ratio of 7.5, 12 and 20%.

GGBS (Ground Granulated Blast furnace Slag) is the industrial waste obtained from steel plants, this material is also obtained from JSW. Finess was 320m^2/kg, Specific gravity was 2.87 and Residue remained on 45µ (wet sample) 4%.

Processed fly ash is also called as Ultra-fine fly ash. This is obtained from fine processing the normal fly ash (increasing the SiO_2%). Finess was 543m^2/kg, Specific gravity was 2.34, Residue remained on 45µ (wet sample) 3.80% and very high lime reactivity of 5.6.

B. Aggregates

The aggregates are the fundamental segments of the solid which enormously shifts the strength, density and different properties of the solid. Different types of aggregates are
- Fine aggregates: Fine aggregates used in this research was M sand conformed to grading zone 2. Particles passing through 4.75mm sieve were used in the concrete.
- Coarse aggregates: since cube size 100x100x100 is considered, 12.5mm down size well graded aggregates were used.

C. Alkali Activators

Alkali activators are the combination of alkaline silicate solution and alkaline hydroxide solution. Sodium-based solutions were picked in light of the fact that they were less expensive than Potassium-based solutions.
- Sodium Hydroxide (NaOH)
- Sodium Silicate (Na_2SiO_3)

D. Sodium Hydroxide

Sodium hydroxide was in the form of pellets of 99% purity obtained from laboratory. Molarity of NaOH considered in this paper is 10M. Molecular weight of NaOH is 40. Hence to obtain 10M of NaOH, 10x40 =400 grams of NaOH pellets should be dissolved in 1 litter of water.

E. Sodium Silicate

Sodium Silicate is the solution which has soluble silicates in it, which is very important for achieving good strength. Chemical composition of Na_2SiO_3 solution was SiO_2 =32.39%, Na_2O = 17.12%, K_2O = 14.10%, Al_2O_3 = 1.19% and water = 27.7% by mass.

F. Superplasticizer

Superplasticizer is used to increase the flow of the Geopolymer concrete. Superplasticizer used in this research was AURO MIX 400 Plus, which is a high range admixture. Amount of plasticizer added was 1.5% by mass of cement.

III. MIX PROPORTION

The mix design of geopolymer concrete was carried out to test the specimens for the study of compressive strength and durability properties such as Permeability, Shrinkage, Abrasion, Acid attack, Sulphate attack, Water absorption and Sorptivity.

In this paper to get the optimum strength, extent of binder ratio has been fluctuated as appeared in beneath table.

Table - 1
Mix Binder Ratio

	BINDER %		
MIX ID	GGBS	Fly ash	UFGGBS
GPC1	100	0	0
GPC2	75	25	0
GPC3	50	50	0
GPC4	25	75	0
GPCUF1	67.5	25	7.5
GPCUF2	63	25	12
GPCUF3	55	25	20

Mix proportions for seven different mix designs are as given below.

Table – 2
Mix Design for Geopolymer concert

	CA (kg/m³)	FA (kg/m³)	GGBS (kg/m³)	Fly ash (kg/m³)	UFGGBS (kg/m³)	NaOH (kg/m³)	Na_2SiO_3 (kg/m³)
GPC1	1320.6	566.0	281.8	0.0	0.0	80.5	201.3
GPC2	1320.6	566.0	211.3	70.4	0.0	80.5	201.3
GPC3	1320.6	566.0	140.9	140.9	0.0	80.5	201.3
GPC4	1320.6	566.0	70.4	211.3	0.0	80.5	201.3
GPCUF1	1320.6	566.0	190.2	70.4	21.1	80.5	201.3
GPCUF2	1320.6	566.0	177.5	70.4	33.8	80.5	201.3
GPCUF3	1320.6	566.0	155.0	70.4	56.4	80.5	201.3

IV. RESULTS & DISCUSSIONS

Two different properties that has been tested are

- Compressive Strength
- Durability

A. Compressive Strength

The moulds of cast iron steel of size 100mm x 100mm x 100mm is used for specimens of compressive strength. Three cubes were casted for each mix proportion for both oven and ambient curing and tested on 1, 3, 7 and 28 days. From the test results, it was observed that maximum strength was achieved for mix GPCUF3 with 55% GGBS, 25% Fly ash and 20% UFGGBS.

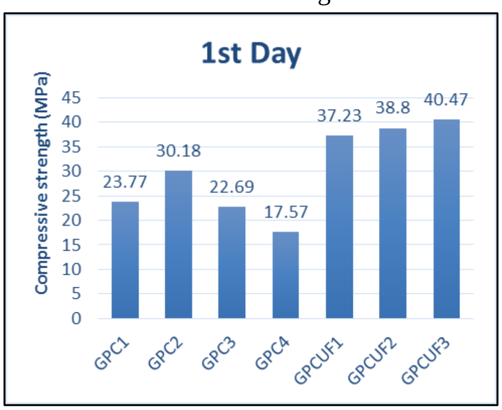

Fig. 1: 1st Compressive Strength

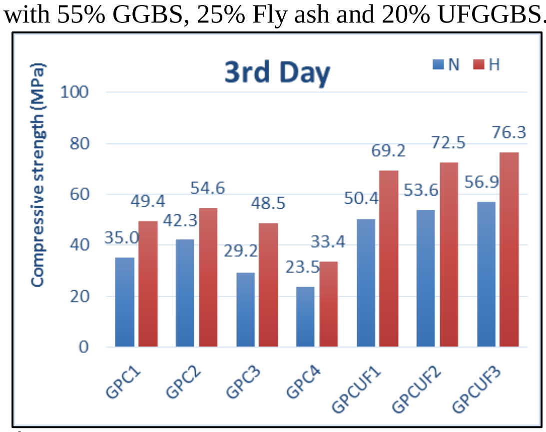

Fig. 2: 3rd Day Compression Strength for Oven and Ambient Curing.

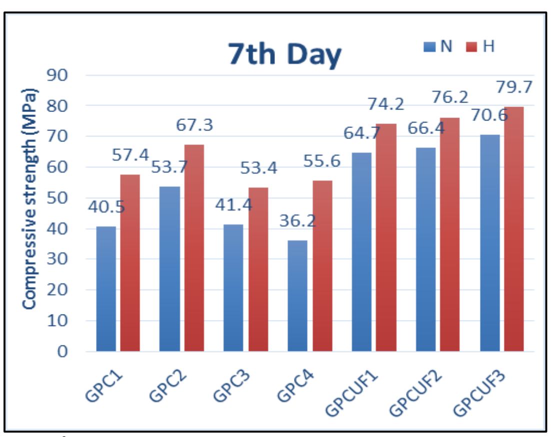

Fig. 3: 7th day compression strength for oven and ambient curing.

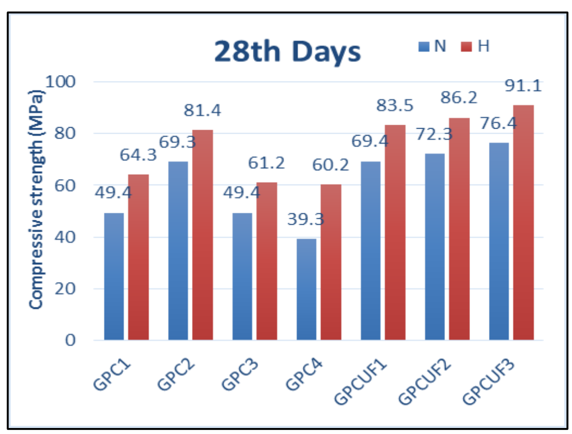

Fig. 4: 28th Day Compression Strength for oven and ambient curing

B. Permeability

Standard cube size of 150mm x 150mm x 150mm is casted for all the mix proportion and it is cured under ambient temperature for 28 days. This specimen is placed in the apparatus as shown in below figure and standard 5 bar pressure is applied and maintained for three days. Then specimens are broke and depth of penetration is measured form the side of pressure applied. GPCUF3 has the least penetration of 8.4mm. Observation made was as the percentage of ultra-fine increases voids in the concrete gets decreases and permeability value also decreases.

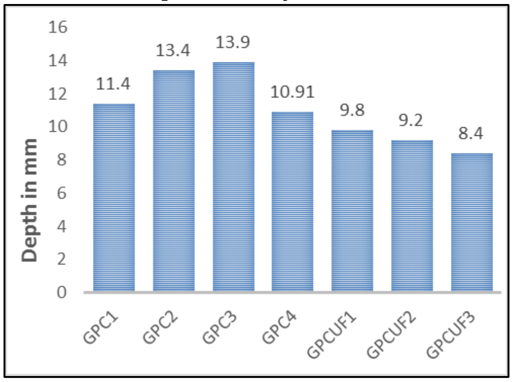

Fig. 5: Water Permeability test results

Fig. 6: Permeability test setup

C. Drying Shrinkage

Drying shrinkage is characterized as the contracting of a hardened concrete mixture because of the loss of capillary water. Drying Shrinkage is linearly proportional to the total water present in the fresh concrete. As the water in the fresh concrete increases, shrinkage also increases. Shrinkage also depends on the curing condition. In this paper we observed that, as we increase the ultra-fine material shrinkage decreases. This is because percentage of voids in the concrete decreases as ultra-fine GGBS is increased.

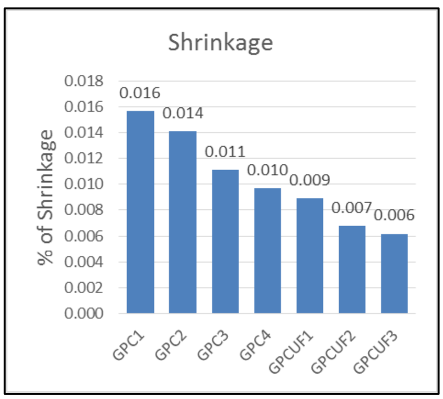

Fig. 7: Drying Shrinkage test results

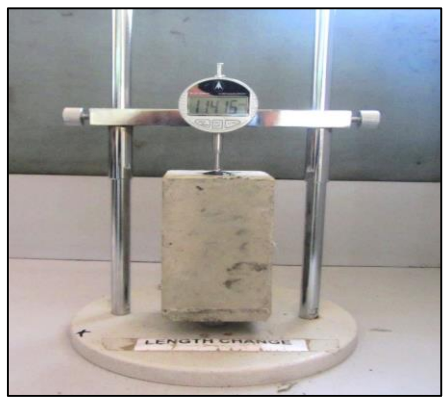

Fig. 8: Drying Shrinkage test setup

D. Abrasion Resistance

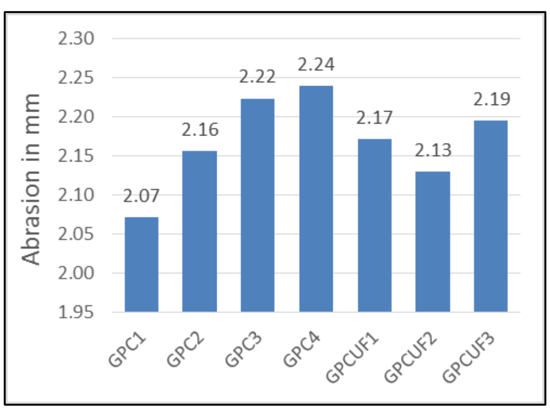

Fig. 9: Abrasion Resistance test results

Fig. 10: Abrasion Resistance test setup

Abrasion resistance is the ability of a material to resist surface wear caused by flat rubbing contact with another material. The sample is prepared of size 7.06 x 7.06 cm and place in oven for 24 hours at 110oC, and initial weight and thickness is measured.

Then sample is tested for abrasion and loss of weight is noted. The abrasion value for residential building is 3.5mm and for heavy duty commercial building is 2.5mm. The abrasion value which we have got was within 2.5mm range and hence we can conclude that Geopolymer Concrete is very good in abrasion resistance.

E. Sorptivity

Sorptivity is the measure of capacity of medium to absorb the water from one surface. Samples of size 100mm dia and 50mm thick is casted. Leaving casting surface all other surface is covered as shown below and samples are kept in water to the depth of 5-10mm. Weight gained at certain intervals are noted and calculation has been done. We observed that Ultra-fine GGBS of 20% replacement has very low observation capacity compared to all other ratios.

Fig. 11: Sorptivity Test Specimens

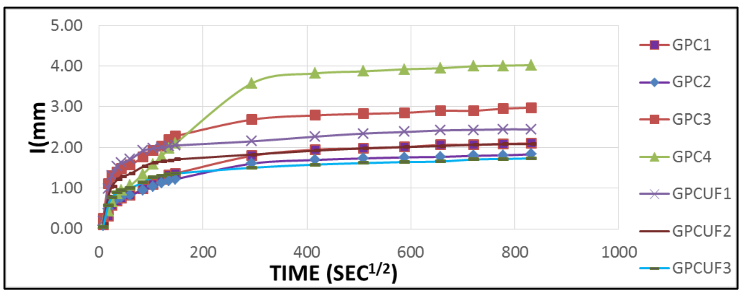

Fig. 12: Sorptivity Test Result Comparison

F. Acid and Sulphate Attack

Samples of cube size 75x75mm are casted for both acid and Sulphate attack. Dry weight of the samples are noted. Samples are immersed in the solutions of 5% concentration. For Acid attack samples are immersed in H2SO4 and for Sulphate attack samples are immersed in Sodium Sulphate. Then samples are oven dried and weight of each sample is noted and compressive strength is done.

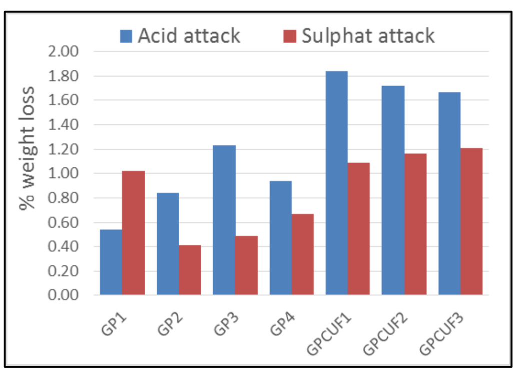

Fig. 13: Acid and Sulphate attack results comparison

Fig. 14: Acid and Sulphate attack specimens

G. Water Absorption

Cube size of 75x75mm is prepared and dry weight is noted. These samples are placed in water for 24 hours and wet weight is also noted. Since cubes are cured at ambient temperature water absorption will be high for Geopolymer concrete. Ultra-fine GGBS plays an important role, as we increase the ultra-fine material voids in the GPC gets reduced and hence water absorption also decreases.

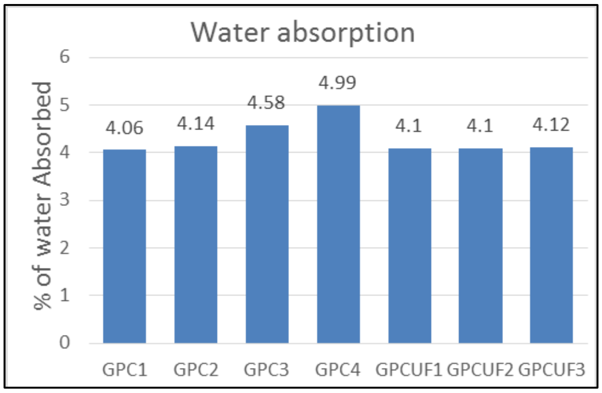

Fig. 15: Water Absorption test results comparison

V. Conclusion

- Geopolymer concrete with Ultra-fine GGBS gives high compressive strength compared to ordinary GGBS.
- GPC achieves 75 to 80% of strength in 3 Days, therefore de-shuttering can be done earlier than conventional concrete work.
- High strength of 91.1MPa is achieved for 20% replacement of Ultra-fine GGBS in oven curing.
- As the ultra-fine GGBS is increased, percentage of voids in the GPC decreases and hence durability properties such as permeability and water absorption gives better results than Ordinary Portland Cement.
- GPC offers better resistance against Abrasion than conventional concrete. GPC's abrasion value is not exceeding the specified abrasion value as per IS 1237-1980.

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