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Study on Compressive Strength of Geopolymer Concrete using Ultra-Fine GGBS for Ambient and Heat Curing

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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. Concrete is one of the most commonly used construction material in the world, which is normally produced by Ordinary Portland Cement. However, the production of OPC has created worries over the emission of CO_2. To create 1 ton of OPC 1 ton of CO_2 is emitted to the atmosphere. With a specific goal to minimise the utilization of OPC and emission of CO_2, the new concrete has been created and named as GEOPOLYMER CONCRETE. Latest research has shown that it is better 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 of ultra-fine slag and 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 (77.8 and 92.3 MPa).
Keywords: Ultra-Fine GGBS, Geopolymer Concrete, Fly Ash, GGBS, Sodium Hydroxide, Sodium Silicate.

I. INTRODUCTION

As a construction material, most commonly used material all over the world is concrete which is produced by Ordinary Portland cement and aggregates mixed with water. OPC is the most widely used binder material in concrete. The amount of OPC approximately present in concrete is 10% - 20% by mass of concrete. Production of OPC is creating the environmental problems over the decades. The production of Portland cement worldwide is increasing 9% annually. Portland cement produces almost 1.5 billion tonnes of greenhouse gas annually or about 7% of total greenhouse gas emissions to the earth's atmosphere. Approximately to produce 1 ton of OPC 1 ton of CO_2 is released to the environment. Due to this environmental issues, research on alternative binder material evolved.

A. Ingredients of Geopolymer Concrete (GPC)

Cementatious materials used in this Geopolymer concrete are

1) Ultra-fine GGBS
2) GGBS
3) Processed fly ash

Alkali activators are the combination of alkaline silicate solution and alkaline hydroxide solution. Sodium-based solutions were used in the present work because it is very less expensive compared to Potassium-based solutions.

a) Sodium Hydroxide (NaOH)
b) Sodium Silicate (Na_2SiO_3)

Superplasticizer is used to increase the workability of the Geopolymer concrete. Superplasticizer used in this project work was AURO MIX 400 Plus, which is a high range admixture. Amount of plasticizer added was 1.5% by mass of cementatious material.

II. EXPERIMENTAL PROGRAM

The experimental programtells the detailed step by step procedure that has been performed in this project work. Following are the steps that has been followed.

1) Material collection.
2) Mix Design of Geopolymer Concrete.
3) Casting and Curing of Specimens.
4) Testing of Specimens.

A. Binding Materials

Binding materials used in present work are Fly ash, GGBS and Ultra-fine GGBS. Chemical and Physical properties of these binding materials are shown in table 1 and 2 respectively.

Table 1 Chemical property of Binding materials

Property	Fly ash	GGBS	Ultra-fine GGBS
SiO_2	64.60	32.94	35.28
Al_2O_3	23.86	17.23	16.82
Fe_2O_3	5.12	1.11	1.48
CaO	1.30	37.98	35.90
MgO	0.87	9.93	8.08
Cl	0.011	0.02	0.008
Na_2O	0.32	0.48	0.34
K_2O	1.63	1.27	0.78

Table 2 Physical property of Binding materials

Property	Fly ash	GGBS	Ultra-fine GGBS
Specific gravity	2.33	2.87	2.85
Fineness(m^2/kg)	533	310	11500
Residue remain on 45µ wash	3.8%	4%	1.18%

B. Mix Design of Geopolymer Concrete

In normal conventional concrete, the main component for strength was cement. Cement is manufactured under controlled manner. Where as in geopolymer concrete there are mainly three parameters to be kept in controlled that is Binder materials (Fly ash, GGBS, Metakoline etc.), Alkaline activator solution (NaOH + Na_2SiO_3 or KOH and K_2SiO_3) and to some extent zone of aggregates. Keeping all the three parameters in controlled manner is very difficult and hence till date there is no standard Mix design for geopolymer concrete. Even in this paper we are assuming some of the data and worked out the mix design as shown below.

First and fore most assumption is unit weight of concrete. In the present case unit weight of concrete assumed is 2450 kg/m^3.

Based on experience, mass of aggregates should be assumed to be 75% to 80% of mass of concrete. In the present work 77% mass of concrete is assumed to be mass of aggregates. Hence weight of aggregates is 2450 x 0.77 = 1886.5 kg/m^3.

Mass of aggregates contains both coarse and fine aggregates. From the experience and observation made by researchers 70% by mass of aggregates is filled with coarse aggregates and 30% is finned with fine aggregates. Hence,

Mass of coarse aggregates = 1886.5 x 0.7 = 1320.55 kg/m^3

Mass of fine aggregates = 1886.5 x 0.3 = 565.95 kg/m^3

Mass of Binder and Alkaline liquid = 2450 – 1886.5 = 563.5 kg/m^3

Ratio of Alkaline liquid to Binder can be assumed to be 0.35 to 1.5.

Here in the present project assumed ratio of Alkaline liquid to Binder is 1.

Mass of Binder = 563.5/2 = 281.8 kg/m^3

Mass of Alkaline liquid = 563.5/2 = 281.8 kg/m^3

From the literature, ratio of sodium silicate to sodium hydroxide can be assumed from 1 to 3.5. In present project work 2.5 is the assumed ratio of sodium silicate to sodium hydroxide. Therefore,

Mass of NaOH = 281.88/3.5 = 80.5 kg/m^3

Mass of Sodium silicate = 281.88 – 80.5 = 201.38 kg/m^3

Molarity of NaOH assumed = 10M

C. Casting and Curing of Specimens

Before casting of specimens, we need to fix the percentage variation of binding material such as Fly ash, GGBS and Ultra-fine GGBS. First we have casted only for Fly ash and GGBS. From the previous optimum percentage GGBS is replaced by Ultra-fine GGBS by 7.5, 12 and 20%. Optimum percentage obtained for Fly ash and GGBS is 25 and 75% respectively. Percentage variation of binder is shown in below table 3

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Table 3 Percentage of Binding material

	Percentage of 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

Compressive strength of geopolymer cubes are obtained for both ambient curing and oven curing. The above figure 3.8 shows the oven curing of cubes. Specimens are kept in oven for 24 hours at a temperature of 60^{o}C later specimens are removed from the oven and cured under room temperature.

Figure 1 Oven curing of cubes

III. TESTING OF SPECIMENS

A. Compressive Strength

Compressive strength is tested on CTM of 2000KN capacity load. Compressive strength is tested on 3, 7 and 28 days.

Figure 2 Compressive testing machines

IV. RESULTS AND DISCUSSION

Compressive strength is done for ambient curing at 3, 7 and 28 days for GPC1, GPC2, GPC3, GPC4, GPCUF1, GPCUF2 and GPCUF3 and results are tabulated in table 4. And results for oven curing at 3, 7 and 28 days for the same mixes are given in table 5.

Table 4 Strength for Ambient curing in MPa

MIX	3rd day	7th day	28th day
GPC1	36.0	41.7	50.4
GPC2	43.5	54.5	70.5
GPC3	30.3	42.3	50.6
GPC4	24.4	37.8	40.5
GPCUF1	52.1	66.1	70.3
GPCUF2	54.5	67.8	74.5
GPCUF3	58.0	71.5	77.8

Table 5 Strength for Oven curing in MPa

MIX	3rd day	7th day	28th day
GPC1	50.4	58.6	64.3
GPC2	55.9	68.2	82.5
GPC3	49.4	54.6	62.7
GPC4	34.6	56.5	61.3
GPCUF1	70.3	75.3	84.8
GPCUF2	73.5	77.2	87.3
GPCUF3	77.4	80.5	92.3

V. CONCLUSION

Based on the results the following conclusion was made

A. High compressive strength of 92.3MPa was achieved for 28 days for GPCUF3 mix i.e. Ultra-fine GGBS of 20%, GGBS of 55% and Fly ash of 25%.
B. Compressive strength for oven curing was observed to be 20% more than the ambient curing.
C. With irrespective of trial mixes, the compressive strength of geopolymer concrete has increased with respect to number of days of curing.
D. Significant increase in strength was observed when the samples are cured in oven for 24 hours with irrespective of mix and number of days.
E. For normal GGBS and Fly ash, with ratio of 75:25 respectively gave the highest strength.
F. Increase in strength was observed by increasing the Ultra-fine GGBS. As we increase the Ultra-fine GGBS content, voids in the concrete gets reduced and bonding in the concrete is increased.

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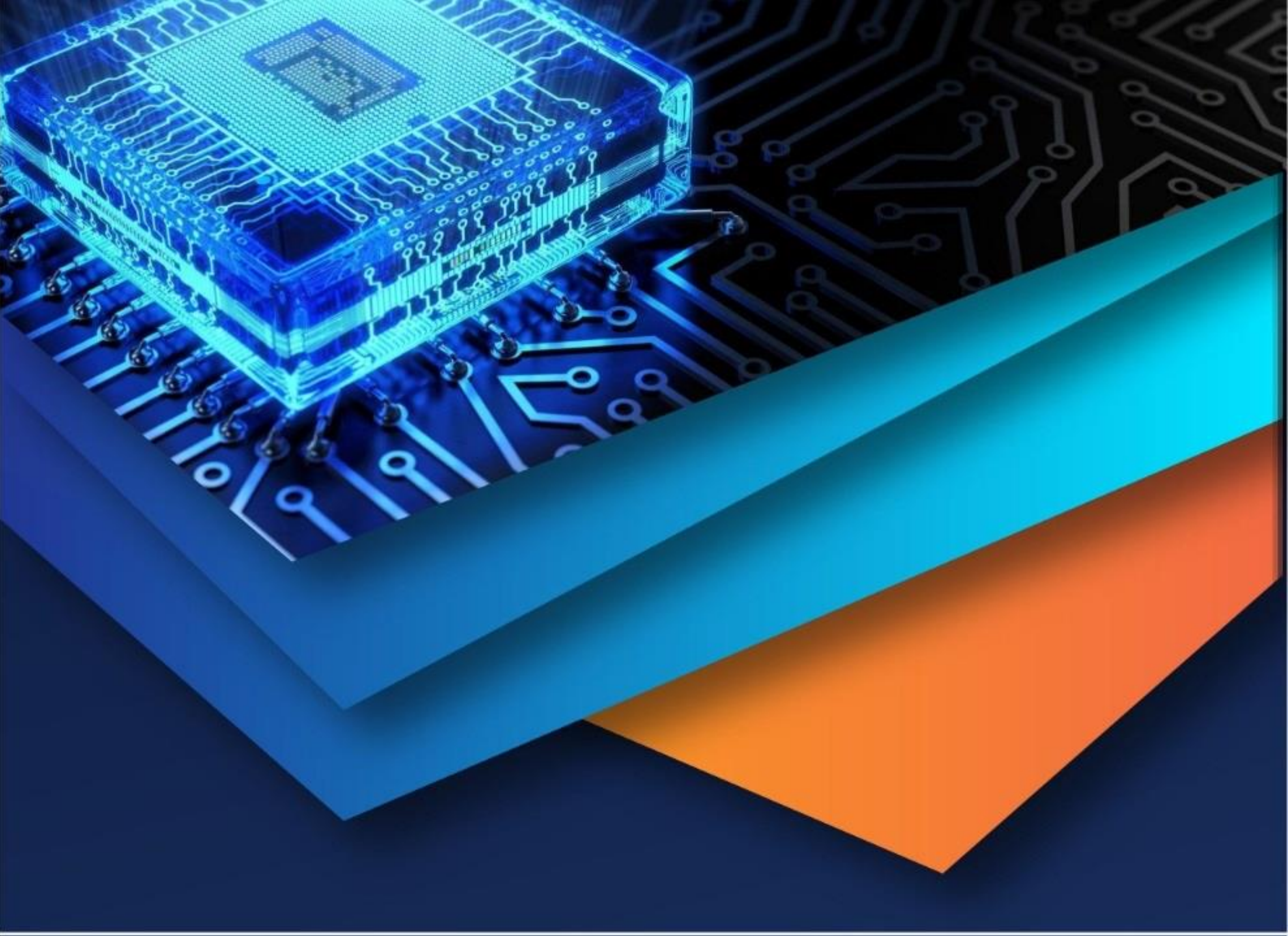

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