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A NOVEL EXPERIMENTAL STUDY ON QUICK SETTING GEOPOLYMER CONCRETE CURED AT AMBIENT TEMPERATURE

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Abstract — *Geopolymer concrete(GPC) is an innovative construction material, which utilize fly ash as a base material and alkaline solution as an activator. However conventional GPC recipe requires temperature curing which can be eliminated by introducing Ground granulated blast-furnace slag as a base material. This experimental investigation focuses on utilization of Ground Granulated Blast Furnace Slag (GGBFS) as a primary base material. It is observed that utilization of GGBFS in GPC develops minor surface cracks due to early setting of concrete, which can be eliminate by introducing Fly ash (FA) and Silica Fume (SF) as a binding material, which resulted in less surface cracking and even hardened mass. This paper represents strength aspect of GPC prepared with ternary blending system. Strength properties of GPC evaluated by performing Compressive strength test, Splitting Tensile strength test, Flexural strength test and dropping weight impact resistance test.*

Keywords-*GGBFS, Silica Fume, Flyash Alkaline liquid, Ambient Curing, compressive Strength, Split Tensile Strength, Flexural Strength.*

I. INTRODUCTION

Cementitious concrete is one of the energy intensive materials being the second major source of generation of carbon dioxide after automobile and needs an attention to get an alternative. Geopolymer concrete prepared with industrial wastes namely fly ash and alkaline activator has emerged as one such alternative to the cement based concrete in recent decades. After being first coined by Prof. Glukhovsky in the former Soviet Union in the middle of 20th century, later in 1970s Prof. J. Davidovits [1-2] researched on a chemistry of geopolymer binder and its application as a construction material. Usage of pozzolanic materials viz. fly ash, red mud and alkaline activators makes GPC an environment friendly and less energy intensive construction material.

Noticeable work has been carried out by many researchers on the usage of GGBFS as a base material. A. Rajarajeswari, G. Dhinakaran [3] mentioned thatCompressive strength were significantly improved when 100% slag were replaced, besides early strength gain was observed. Muhammad N.S. Hadi and their fellow [4] mentioned that Inclusion of fly ash in GGBFS based mix found to be suitable for in situ construction work along with precast construction work. Replacement of the GGBFS with fly ash, Metakeolin, and Silica Fume increases the initial and final setting time of the geopolymer paste. PradipNath&Prabir Kumar Sarker[5] concluded that incorporation of GGBFS in Fly ash based GPC accelerated setting time along with improvement in strength, however workability and handling time was remarkably reduced. SumanSaha, C. Rajasekaran[6] concluded that Incorporation of GGBFS increases Initial and final setting time of geopolymer paste. Due to High amount of CaO content in GGBFS improves C–S–H gel formation along with the 3D stable silico-aluminate structure by the geopolymeric reaction at the early duration. Therefore, setting time was reduced appreciably with higher dosage of GGBFS in the geopolymer paste mixes. After referring past research work it has been observed that Conventionally, geopolymer binders require heat curing, high pH and also have difficulty in field handling. Therefore, efforts are needed to develop a room temperature cured one component geopolymer system using solid activators instead of alkaline solutions in view of its wider acceptance in the field. Many authors worked on this issues and overcome with notable solution, however need of explicit data was felt for GPC cured at ambient temperature.

The objective of this experimental study was to cure Geopolymer concrete at ambient temperature by utilizing ground granulated blast furnace slag, Fly ash &silica fume and to come up with effective proportion of each binder. For this experimental work strength of GPC was evaluated by performing Compressive strength test, Splitting Tensile strength test, Flexural test and dropping weight impact resistance test.

II. MATERIAL AND METHOD

Ground granulated blast furnace slag was used as a primary binder. The 100% utilization of GGBFS resulted in quick setting of concrete however it resulted in developed of micro surface cracks due to early setting. This drawback was resolved by incorporation of Flyash and Silicafume. The silica fume and Flyash was added as a partial replacement of GGBFS in variation of 0%, 5%, 10% and 15% by mass of total binder. The chemical composition of all three binders is mentioned in table 1. The specific gravity of GGBFS, FA and SF was 2.26, 2.4 and 2.22 respectively.Proportions of binders are mentioned in Table 2. A combination of sodium silicate (Na_2SiO_3) solution and sodium hydroxide (NaOH) solution was used as the alkaline binder. It is proposed that the alkaline binder need to be rendered by combining both of the solutions together at least one-day advance to use. The NaOH were dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in from 8 to 16 molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution; for example, NaOH solution with a concentration of 16 molar consists of 16 × 40 = 640 g of NaOH solids per liter of the solution, where 40 is the molecular weight of NaOH. It was observed that mechanical strength of Geopolymer concrete is depends upon Molarity of the alkaline solution. Higher the molar content, higher the strength. For this experimental work 14 Molar solutions were used. Concrete mix was then placed in a mould and vibrated on a table vibrator in order to remove residue and air bubbles. All specimens were cured at ambient temperature. Table 3 shows mix proportion that was used to cast concrete specimen. Hardened mass then tested for Compressive strength test, Splitting tensile strength test, Flexural resistance test and impact resistance test.

Table 1: Chemical Composition of GGBFS, FA and SF

Oxide	**GGBFS**	**FA**	**SF**
	Percentage(%)	**Percentage (%)**	**Percentage (%)**
Silica (SiO_2)	34.01	63.53	88
Alumina (Al_2O_3)	16.62	27.40	0.6
Ferric Oxide (Fe_2O_3)	1.71	3.67	0.3
Calcium Oxide (CaO)	34.85	1.26	0.95
Magnesium Oxide (MgO)	9.11	0.35	0.95
Potassium Oxide(K_2O)	0.46	0.85	0.7
Sodium Oxide (Na_2O)	0.48	0.19	0.7
Titanium Dioxide (TiO_2)	0.69	1.84	-

Table 2: Binder Proportions

Mix	**GGBFS**	**FA**	**SF**
	Percentage(%)	**Percentage (%)**	**Percentage (%)**
A0	100	0	0
A1	95	0	5
A2	90	0	10
A3	85	0	15
A4	60	30	10
A5	50	40	10

Table 3: Mix design and curing detail

Constituent	Value	Unit
Binder	368	kg/m^3
Sand	554.4	kg/m^3
10 mm aggregate	443.52	kg/m^3
20 mm aggregate	850.08	kg/m^3
NaOH solution	46	kg/m^3
Na2sio3	138	kg/m^3
Extra water	29.44	kg/m^3
NaOH Molarity	14	Molar
Type of curing	Ambient curing	

III. TEST RESULTS

A. Compressive strength test

The mechanical strength of Geopolymer concrete was measured by conducting compression strength test. This test was performed on 150 mm concrete cubes (three for each mix) at the age of 7 days. Figure 2 shows test results of compressive strength of GPC containing different types of silica fume and fly ash at the age of 7 days respectively.

Figure 1: Compressive strength test

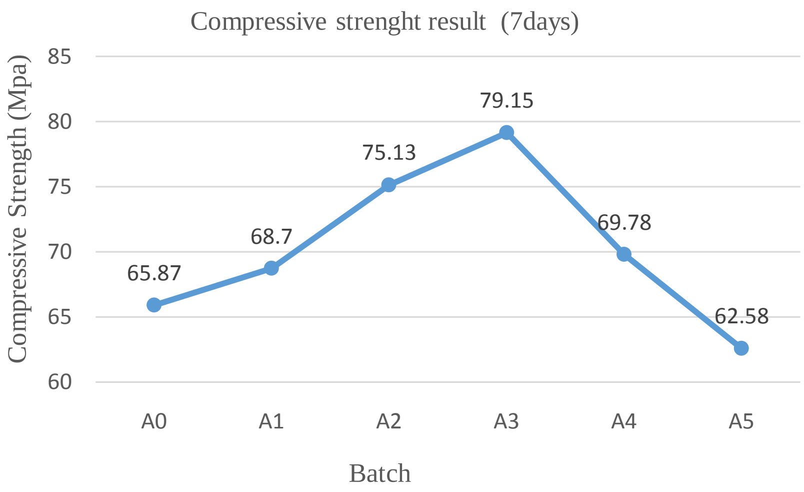

Figure 2: Compressive strength of GPC at the age of 7 days

B. Splitting tensile strength test

Split tensile strength test was conducted to evaluate the strength development of concrete containing various percentage of silica fume contents at the age of 7 days. Figure 4 shows test results of splitting tensile strength of GPC containing at various percentage of silica fume and fly ash contents at the age of 7 days.

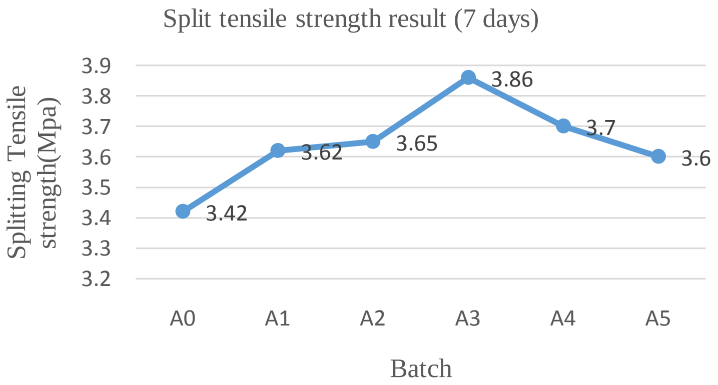

Figure 3 Splitting tensile strength of GPC at the age of 7 days

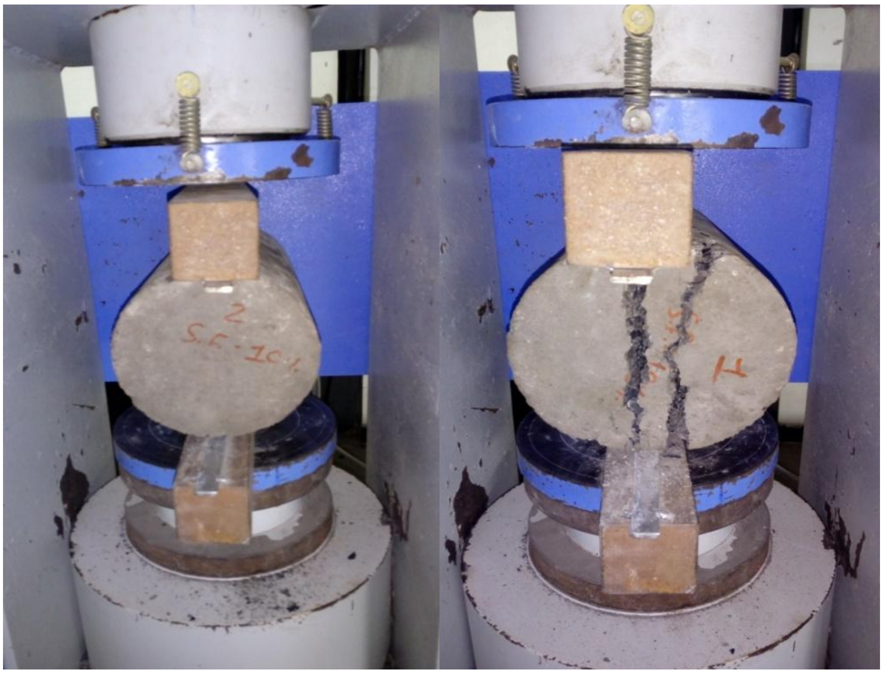

Figure 4 Splitting tensile strength test

C. Flexural strength test

Flexural strength test was conducted to evaluate the flexural strength of concrete containing various percentage of silica fume and fly ash contents at the age of 7 days. Figure 6 shows test results of flexural strength at the age of 7 days.

Figure 5: Flexural strength test

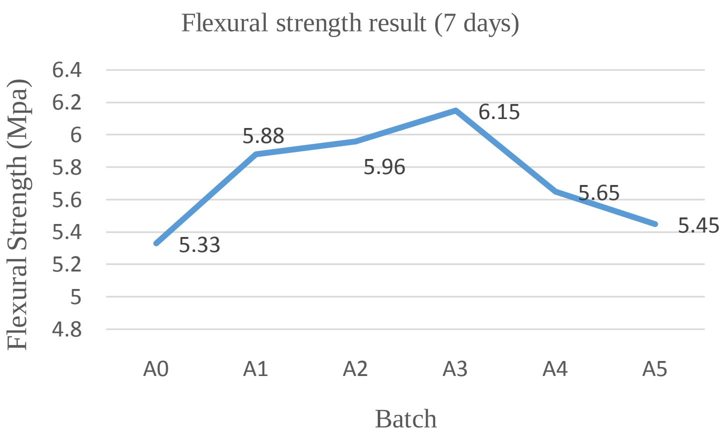

Figure 6: Flexural strength of GPC at age of 7 days

D. Dropping weight impact resistance test

For this experimental work specimen was prepared as per the standard mention in ACI 544.2R-89. Circular specimen having height = 63.5mm diameter = 100mm was prepared. Dropping weight impact test was used to determine the impact resistance of a GPC. Test was conducted as per the standard mentioned in the ACI 544.2R-89. Figure 7 shows typical setup of a dropping weight impact strength assembly; Figure 8 shows undisturbed sample. Figure 9 shows the test result of dropping weight impact resistance at age of 7 days.

Figure 7: Drop weight impact apparatus & Tested Specimen

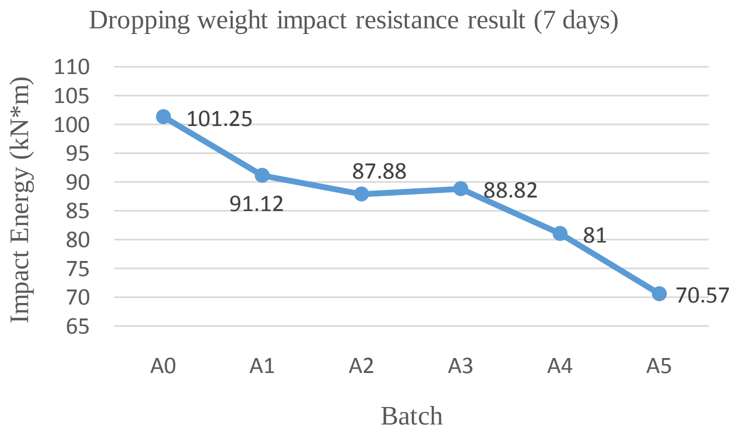

Figure 8: Dropping weight impact resistances result of GPC at age of 7 days

IV. DISCUSSION

A. Discussion on Compressive strength

Compressive strength of all the mix batch gave better result compare to OPC based concrete in ambient curing conditions. Test result shows that addition of SF in GGBFS based GPC resulted in improvement in compressive strength up to 20.16% at 15% replacement of GGBFS with SF. However, replacement with FA in concrete resulted in less development of surface cracks. Mix Batch A4 proves better in terms of compressive strength while managed to less generation of surface cracks. Over all mix proportion A4 is convenient option as it resulted in less surface cracks generation and gave sufficient amount of compressive strength at the age of 7 days at ambient curing condition.

B. Discussion on Splitting Tensile strength

Splitting tensile strength of slag based GPC proves better compare to OPC based concrete. Test results reveals that addition of SF in GGBFS based GPC significantly improve Splitting tensile strength up to 13% at 15% replacement of GGBFS with SF. Addition of FA in concrete gave sufficient results.

C. Discussion on Flexural Strength

Flexural Strength tends to increase when GGBFS replaced by SF up to 15%. Mix Proportion A3 resulted in 15% improvement in Flexural strength. However, GPC along with FA resulted in 6% improved strength.

D. Discussion on Impcat Resistance

Impact resistance strength tend to decrease in addition of FA and SF. Blending of different binders resulted in decrement in impact resisting capacity of hardened mass, however impact resistance of GPC is better than OPC based concrete.

V. CONCLUSION

- Conventional GPC required thermal curing for the polymerisation process, recent studies support that it could be eliminated by using GGBFS as a binding material, which extends its scope to in situ construction work, however it resulted in micro surface cracks due to quick setting of concrete.
- Addition of SF in GGBFS based GPC resulted in significant improvement in strength of concrete, however addition of FA resulted in sufficient strength of concrete.
- Blending of all three ingredients resulted in less generation of micro surface cracks without compromising strength of the concrete.

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