A STUDY ON FLYASH BASED GEOPOLYMER CONCRETE IN AMBIENT TEMPERATURE

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Abstract

The use of Portland cement in concrete construction is under critical review due to high amount of carbon dioxide gas released to the atmosphere during the production of cement. In recent years, attempts to increase the utilization of fly ash to partially replace the use of Portland cement in concrete are gathering momentum. Most of this by-product material is currently dumped in landfills, creating a threat to the environment.

Geopolymer concrete is a 'new' material that does not need the presence of Portland cement as abinder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and Aluminium(Al), are activated by alkaline liquids to produce the binder. Hence geopolymer concrete with no Portland cement.

This project reports the details of development of the process of making fly ash-based geopolymerconcrete in ambient temperature. Due to the lack of knowledge and know-how of making of fly ash based geopolymer concrete this study adopted a rigorous trial and error process to develop the technology of making, and to identify the salient parameters affecting the properties of fresh and hardened concrete. As far as possible, the technology that is currently in use to manufacture and testing of ordinary Portland cement concrete were used.

Fly ash was chosen as the basic material to be activated by the geopolimerization process to be the concrete binder, to totally replace the use of Portland cement. The binder is the only difference to the ordinary Portland cement concrete. To activate the Silicon and Aluminium content in fly ash, a combination of sodium hydroxide solution and sodium silicate solution was used.

Manufacturing process comprising material preparation, mixing, placing, compaction and curing is reported in the project. Roofplast SP 45 superplasticiser was found to be useful to improve the workability of fresh fly ash-based geopolymer concrete, as well as the addition of extra distilledwater. The main parameters affecting the compressive strength of hardened fly ash-based geopolymer concrete are the curing temperature and curing time, the molar H_2O-to-Na_2O ratio, and mixing time.

Keywords *– Geopolymer concrete, ambient temperature, geopolimerization, Roofplast SP 45, GGBS, Flyash.*

1 Introduction

After wood, concrete is the most often used material by the community. Concrete is conventionally produced by using the ordinary Portland cement (OPC) as the primary binder. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the amount of energy required to produce OPC is only next to steel and aluminium.

On the other side, the abundance and availability of fly ash worldwide create opportunity to utilize this by-product of burning coal, as partial replacement or as performance enhancer for OPC. Fly ash in itself does not possess the binding

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properties, except for the high calcium or ASTM Class C flyash. However, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. This pozzolanic action happens when fly ash is added to OPC as a partial replacement or as an admixture. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60-65% by mass (Malhotra 2002; Malhotra and Mehta 2002), can be regarded as a landmark in this attempt.

1.2 Flyash based Geopolymer

In this work, fly ash-based geopolymer and GGBS (Ground Granulated Blast Furnace Slag) is used as the binder, instead of Portland or any other hydraulic cement paste, to produce concrete. The flyash-based geopolymer and GGBS paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the conventional method.As in the OPC concrete, the aggregates occupy the largest volume, i.e. about 75-80 % by mass, in geopolymer concrete. The silicon and the aluminium in the low calcium (ASTM Class F) fly ash are activated by a combination of sodium hydroxide and sodium silicate solutions to form the geopolymer paste that binds the aggregates and other un-reacted materials.

2.MATERIAL PROPERTIES

2.1 Aggregates:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80 percent of volume of concrete. Aggregates are obtained either naturally or artificially. Aggregates can be classified on the basis of size as fine aggregate and coarse aggregate.

2.1.1Fine Aggregates (Sand)

For fine aggregate canal sand was used, comparable to IS383 -1970. To remove imported material, to use air dried sand, sieved, and earlier to mixing. The experiment was conducted as per IS: 2386-1963and the specific gravity value is2.67

2.1.2 Coarse aggregate:

The material whose particles are of size are retained on IS sieve of size4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS:383-1970 is considered as coarse aggregate. Aggregates should be of uniform quality with respect to shape and grading. The size of coarse aggregated depends up on the nature of the work. The coarse aggregate used in this experimental investigation is 20mm and 10mm size, crushed and angular in shape. The aggregates are free from dust before used in the concrete.

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The specific gravity of the coarse aggregate is 2.80

2.1. Super Plasticizer

To improve the workability of the fresh geopolymer concrete, a Roof plast sp45 super plasticizer in liquid form, manufactured by Armstrong chemicals in Hyderabad, was used.

2.1.4 Fly Ash

In this experimental work Fly ash which has grade of low calcium or ASTM class F has taken but usually two types of grades available high calcium i.e. ASTM class C and low calcium i.e.ASTM calss F but from previous experiments and results, we have taken low calcium fly ash (ASTM class F).

2.1.5 GGBS

GGBS was obtained from Simhadri iron industry at Guntur in AndhraPradesh.The properties of GGBS are given below table, due to unavailability of XRF, we have taken the values directly from international journals .

3. EXPERIMENTAL PROGRAM

3.1 Mixing & Casting

There were 5 mixture proportions which comprised $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$, $F_{60}G_{40}$, $F_{50}G_{50}$.The coarse aggregates, fine aggregates, flyash, GGBS mixed together uniformly about 2minutes and then freshly prepared sodium hydroxide which has morality of 14M added to sodium silicate solution further this solution mixed with the dry material about 2minutes .Finally distilled water and super plasticizer added to improve the workability .This entire mixture mixed about 3minutes for proper bonding all material. After the mixing is done, cubes are casted by giving proper compaction in three layers.

It was found that the fresh fly ash-based geopolymer concrete was dark in colour (due to the dark colour of the fly ash), and was cohesive. The amount of water in the mixture played an important role on the behavior of fresh concrete. The workability of the fresh concrete was measured by means of the conventional slump test.

The material for all mixtures has taken same but fly ash and GGBS proportions were different .The following table gives complete weight of all the materials.

Table No.3.1Material for one cube for different mixture proportions

Mixture Proportion	Materials weighed in grams (For making of one cube)

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	Coarse aggregates	**Sand**	**Fly Ash**	**GGBS**	**Na_2SiO_3**	**NaoH**	**Distilled water**	**Roof plast SP45**
F90G10	4000	2100	1305	145	500	200	145	70
F80G20	4000	2100	1160	290	500	200	145	70
F70G30	4000	2100	1015	435	500	200	145	70
F60G40	4000	2100	870	580	500	200	145	70
F50G50	4000	2100	725	725	500	200	145	70

3.2Curing

Previous works researches revealed that Geopolymer concrete gains high strength if the cube placed in hot oven or steam chambers but here we are curing under sun light but this is not feasible in some cases where the temperature is very low. However with the addition of GGBS there was an immediate increased strength for one day and also the strength of F60G40 gained high among other mixture proportions. We also cured the one day cubes with water and hot air oven.

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Figure 3.1 curing F60G40 cube at 90^{o}c in one day

3.3 Testing

Fly ash based geopolymer concrete cube tests were performed in a 2500 KN universal testing machine.

Figure 3.2 Testing compressive strength of cube

4. RESULTS

4.1 EFFECT OF SALIENT PARAMETERS

4.1.1 Age of concrete

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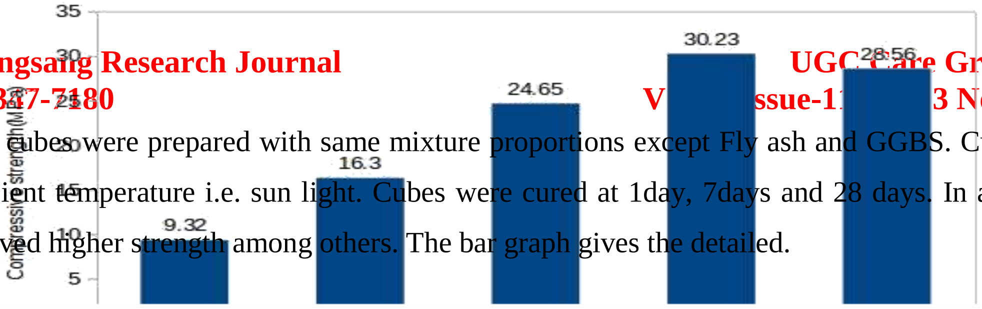

Totally 20 cubes were prepared with same mixture proportions except Fly ash and GGBS. Cubes were cured under ambient temperature i.e. sun light. Cubes were cured at 1day, 7days and 28 days. In all cases F60G40 cube achieved higher strength among others. The bar graph gives the detailed.

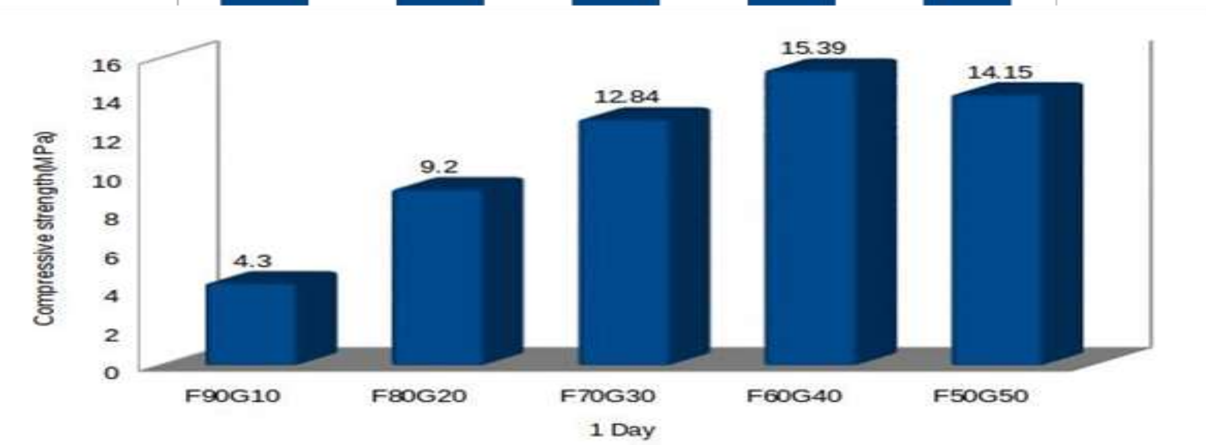

Figure4.1 compressive strength for 1 day cubes

Figure 4.2 Compressive strength for 7days cubes

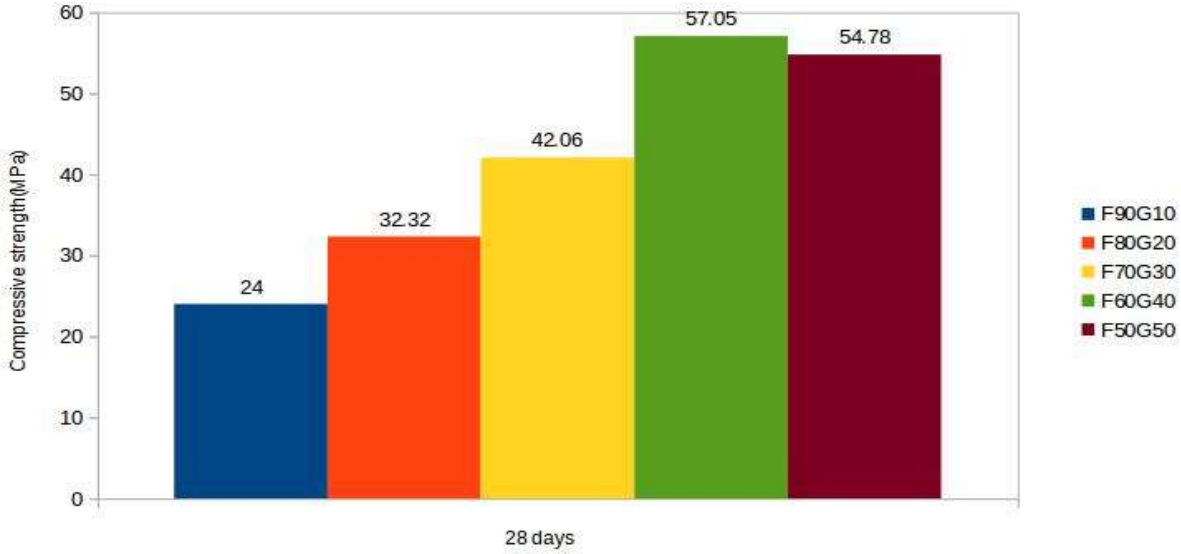

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Figure 4.3 Compressive strength for 28 day cubes

4.1.2Ambient temperature curing v_s water curing

There is a wide difference between the strength which were cured with water and ambient temperature. Both the cubes were cured at one day, but in water curing the strength of cubes come high where as in ambient temperature the compressive strength come very less. The following graph gives detailed information.

4.1.3 Ambient temperature curing v_s oven curing

F60G40 cube achieved high strength among others so, we have taken this mixture proportion and prepared two cubes. One for oven curing at 90^{o}c another in ambient temperature.After testing its compressive strength, the one which cured under hot oven gives very high strength but in ambient temperature the strength was came very less compared to oven curing cube. The cubes were cured at 24 hours.

The summary of present study, the major conclusions, and some recommendations for future research. With the generic information available on geopolymers, a rigorous trial-and-error method was adopted to develop a process of manufacturing fly ash-based geopolymer concrete. After some failures in the beginning, the trail-and-error method yielded successful results with regard to manufacture of low-calcium (ASTM Class F) fly ash-based geopolymer concrete.

Compressive strength of various mixture proportions are:

Table 4.1 Compressive strength table for ambient curing

Mixture proportions	**Compressive strength (MPa)**		
	1day	**7 day**	**28 day**
F90G10	4.3	9.32	24
F80G20	9.2	16.3	32.32
F70G30	12.84	24.65	42.06
F60G40	15.39	30.23	57.05
F50G50	14.15	28.56	54.78

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Table 5.2 Compressive strength table for 1 days cubes

Mixture proportions	Compressive strength(MPa)	
	Curing in ambient temperature at 24 hours	Curing in water at 24 hours
F90G10	4.3	17.28
F80G20	9.2	20.64
F70G30	12.84	21.03
F60G40	15.39	22.50
F50G50	14.5	20.54

Table 4.3 Compressive strength table for $F_{60}G_{40}$

Mixture proportion	Compressive strength (MPa)	
	Curing in ambient temperature at 24hrs	Curing in water at 24 hrs.
$F_{60}G_{40}$	15.39	22.50

5.Conclusion

Based on the experimental work reported in this study, the following conclusions are drawn:

- Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of fly ash-based geopolymer concrete but from previous research work we prepared 14M to achieve high strength.
- Higher the ratio of sodium silicate-to-sodium hydroxide ratio by mass, higher is the compressive strength of fly ash-based geopolymer concrete but we maintained 2.5 ratio.
- Longer curing time, in the range of 1day,7days and 28 days produces higher compressive strength of fly ash-based geopolymer concrete.
- The addition of Roofplast SP45 -based super plasticiser up to approximately 4.8% of fly ash and GGBS by mass, improves the workability of the fresh flyash based geopolymer concrete.
- The slump value of the fresh fly-ash-based geopolymer concrete decreases with the increase of GGBS proportion added to the mixture.

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- Higher strength achieved if the cubes placed in water curing.
- The strength of Geopolymer concrete achieved high in oven curing than water and ambient temperature. However oven curing economically not feasible.
- F60G40 cube achieved high strength in ambient temperature.
- The average density of fly ash-based geopolymer concrete is similar to OPC concrete.

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