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Experimental studies on the Mechanical Properties of Geo Polymer Concrete

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Abstract-

Cement contributes 7% of the world's emission of Carbon-di-oxide .Geo polymer Concrete (GPC) is an eco friendly and an alternative of ordinary concrete.GPC is manufactured by using waste materials like flyash, GGBS etc. By using these waste materials there is minimization of green house gases and also reduces the cost of cement. An attempt has been made with flyash and GGBS instead of cement in this paper. The mechanical properties of Geo Polymer Concrete was studied. The specimens were casted and cured at ambient room temperature. Results show that (FA-50%,GGBS-50%) replacement performed well when compared to other replacement levels.

Key words: Geo polymer Concrete, flyash and GGBS

1. Introduction

The demand for cement production increases the demand for concrete in industries. Due to the emission of CO2 gases into the atmosphere by human beings, there arises a problem of global warming. One ton production of Portland cement emits approximately the same amount of CO_2 into the atmosphere. Hence there is a need to reduce the cement in construction industry. Several alternative materials like fly ash, GGBS, rice husk ash, metakaolin etc has been utilized to overcome the global warming issues of ordinary Portland cement. Geo polymer, the term coined by Davidojits, is a good alternative binder to Portland cement. The geo polymer technology reduces CO_2 emission and increases the properties of concrete. Fly ash can be used as an alternative material of cement in geo polymer concrete.

Later some new methods have been incorporated by using Ground Granulated Blast furnace Slag (GGBS) as a new approach. By using fly ash and Ground Granulated Blast furnace slag in geo polymer concrete the mechanical properties and durability has been increased. This paper focuses on geo polymer concrete by replacing cement by fly ash and GGBS in varying ratios. The results are compared with conventional concrete of M20 grade. Many works have been done across the globe in this area and some of them are presented in this paper.

2. Review of Literature

Hardigito. D [1] suggested that the compressive strength increases with longer curing time. Super plasticizers can be utilized to improve the workability of fresh geo polymer concrete. Salmabanu Luhar [2] concluded that geo polymer concrete reduces greenhouse footprints but also increases its strength and resistivity to harmful acids. Anuradha [3] has derived the guidelines for geo polymer concrete mix design using Indian Standard. Rajamane [4] concluded that geo polymer concrete resists acid attack better than conventional concrete. Madheswaran [5] concluded that the compressive strength increases with the concentration of NaOH and industrial wastes can be used as a binder in GPC.

3. Materials

3.1 Fly Ash

Fly ash used in the study was obtained from Mettur and the properties of fly ash was discussed in the following table.

3.2 Ground Granulated Blast Furnace Slag (Ggbs)

Addition of GGBS in Geo-Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible. GGBS was bought in Tirupur. The chemical composition of fly ash and GGBS is compared and discussed below.

Table 3.1 Properties of fly ash and GGBS

Constituents	Fly ash (%)	GGBS (%)
LOI	0.70	0.60
Silicon di Oxide	60.21	22.38
Aluminum Oxide	26.30	21.04
Fe_2O_3	7.82	0.98

3.3 Chemicals

In this project chemicals are very important constituents. Sodium Silicate and Sodium Hydroxide liquid are obtained commercially from local suppliers in Salem.

3.4 Sodium Hydroxide

The sodium hydroxide solids were of a laboratory grade in pellets form with 99% purity, obtained from local suppliers. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets in water.

3.5 Sodium Silicate

Sodium silicate solution (water glass) obtained from local suppliers was used. The chemical composition of the sodium silicate solution was Na_2O=8%, SiO_2=28%, and water 64% by mass. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

3.6 Super plasticizer

In this present investigation, a super plasticizer namely CONPLAST SP 430 has been used for obtaining workable concrete at low w/c ratio.

3.7 Aggregate

The aggregates are the main components of the concrete which greatly varies the strength, density and other properties of the concrete. Different types of aggregates used are discussed below.

3.8 Fine Aggregate

The fine aggregate used in the project was obtained from locally supplier and conformed to grading zone II as per IS: 383:1970

Table 3.2 properties of fine aggregate

S.No	Characteristics	Values
1	Type	Uncrushed (natural)
2	Specific gravity	2.623
3	Fineness modulus	5.80
4	Grading zone	Zone II

3.9 Coarse Aggregate

Locally available coarse aggregate having the maximum size of (10 - 20mm) were used.

Table 3.3 properties of coarse aggregate

S.No	Characteristics	Values
1	Type	crushed
2	Specific gravity	2.670
3	Fineness modulus	2.320
4	Maximum size	20mm

3.10 Water

Water free from oils, chemicals and other forms of impurities available in our college campus was used for mixing of concrete and is tested.

4. Experimental Investigation

4.1 Geo polymer concrete mix design procedure

Coarse aggregate + Fine aggregate =75% to 80% by mass
Take 77% in design of geo polymer concrete
Fine aggregate = 30% of total aggregate
Average density of GPC = 2400 kg/m^3
Fly ash + GGBS = 0.4
Na_2SiO_3 / NaOH = 2.5
NaOH = 10 x 40 = 400 gram

10 molarity:

Alkaline liquid / fly ash + GGBS = 0.4

Trial mix:

In Na_2SiO_3 water is = 0.559×113 = 63 kg
In Na_2SiO_3 Solids is = 113-63 = 50 kg
In NaOH solution solids is = 0.4 × 45 = 18 kg
In NaOH solution water is = 45-18 = 27 kg
Total water = 63 + 27 = 90 lit/m^3
Mass of Fly ash +GGBS = 394 kg/m^3
Mass geo polymer solid = 394 + 50 + 18 = 462 kg
Water / geo polymer solid = 90 / 462 = 0.19

Table 4.1 Mix Design Proportions

Materials (kg/m^3)	Fly ash=0% GGBS=100%	Fly ash=25% GGBS=75%	Fly ash=50% GGBS=50%	Fly ash=75% GGBS=25%	Fly ash=100% GGBS=0%
Coarse aggregate 20 mm	776.4	776.4	776.4	776.4	776.4
Coarse aggregate 10 mm	517.6	517.6	517.6	517.6	517.6
Fine aggregate	554	554	554	554	554
Fly ash	394	295.5	197	98.5	0
GGBS	0	98.5	197	295.5	394
Na_2SiO_3	113	113	113	113	113
NaOH	45	45	45	45	45
Water	90	90	90	90	90
Super plasticizers	11.82	11.82	11.82	11.82	11.82

4.2 General

The experimental programme involved in this project is to study the compressive strength, tensile strength and flexural strength on the specimen for the following ratios. Concrete cubes of size150X150X150 mm was subjected to axial compressive strength test loading .The specimens were cured at ambient temperature. Axial compressive strength test was done after 7, 14 and 28 days. In split tensile test the cylinder specimens of size 150mm x 300mm are placed diagonally in the standard compression testing machine. The load is applied gradually till the specimens fail. The ultimate load value was recorded. Similarly split tensile test and Flexural tests were carried out for 7,14 and 28 days .

Table 4.2 Compressive strength Test (N/mm²)

Specifications	7 days	14 days	28 days
Conventional concrete (M20)	11.42	21.65	28.22
100% GGBS	21.43	28.16	35.56
75% GGBS + 25% Fly Ash	24.3	33.05	37.92
50% GGBS + 50% Fly Ash	28.23	36.76	41.78
25% GGBS + 75% Fly Ash	19.16	26.23	32.44
100 % Fly Ash	12.71	24.74	30.47

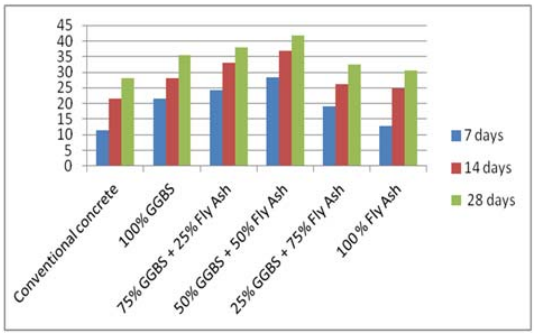

Fig. 4.1 Compressive strength

Table 4.3 Split tensile test (N/mm²)

Specifications	7 days	14 days	28 days
Conventional concrete(M20)	1.97	2.36	2.92
100% GGBS	3.16	3.68	4.02
75% GGBS + 25% Fly Ash	3.71	4.13	4.52
50% GGBS + 50% Fly Ash	4.85	5.11	5.42
25% GGBS + 75% Fly Ash	2.37	3.29	3.98
100 % Fly Ash	2.12	2.82	3.23

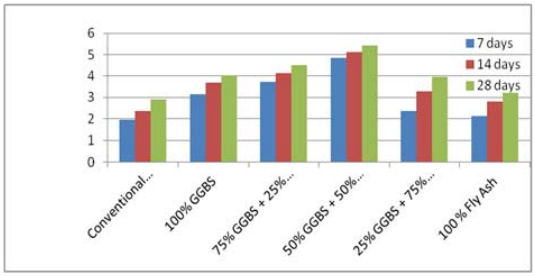

Fig. 4.2 Split tensile strength

Table 4.4 Flexural strength test (N/mm²)

Specifications	7 days	14 days	28 days
Conventional concrete(M20)	3.02	3.22	3.65
100% GGBS	4.26	4.68	4.76
75% GGBS + 25% Fly Ash	4.39	4.46	4.89
50% GGBS + 50% Fly Ash	4.61	4.74	5.11
25% GGBS + 75% Fly Ash	4.54	4.67	4.85
100 % Fly Ash	4.46	4.63	4.75

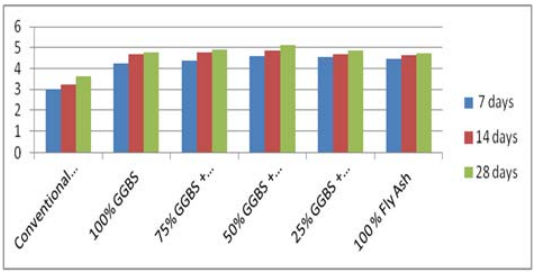

Fig. 4.3 Flexural strength

5. Resuts And Discussion

Compression Testing machine was used for testing the concrete cubes 150 mm x 150 mm x150 mm of size which are cured at ambient temperature. Due to the substantially fast polymerization process the compressive strength does not vary with the ages (as per literature).

This is contrast to OPC concrete which gains strength as time increase due to hydration process compressive strength increases which improves the polymerization process. Similarly split tensile test and Flexural test were conducted. In all the test GPC performs better than conventional concrete.

Based on the experimental programme conducted on geo polymer concrete the following points were drawn: Compressive strength test was conducted as per IS 516-1956 with uniform rate of load application for both conventional concrete and geo polymer concrete mixes.

It has been observed that the strength development of geo polymer concrete is very slow under ambient curing when compared to heat curing based on literature. The compressive strength of geo polymer concrete reaches its maximum value for equal replacement of fly ash and GGBS. Both plays the role in polymerisation and results in the increase of strength.

The results of conventional concrete and geo polymer concrete is almost similar and this work can be extended to study the increase in strength and durability up to 90 days also. The alkaline liquid to fly ash ratio and molar concentration also plays a role in the compressive strength.

Regarding workability, although proper compaction has been given still geo polymer concrete has stiff consistency. Based on literature naphthalene based super plasticizer improves the workability. So it was added. The value of slump gets increased as the super plasticizer is also increased. Addition of more than 2% of super plasticizer reduces the compressive strength as per literature studies.

6. CONCLUSION

Based on the above test results, the following conclusions were drawn:

1. GGBS blended with Fly ash attains the enhanced strength at ambient curing itself without oven curing.

2. It is an eco friendly material because the embodied energy and embodied CO_2 release is less when compared to conventional concrete.

3. From the test results it has shown that 50% replacement of GGBS and 50% replacement of fly ash for OPC gives the maximum strength when compared to other replacement.

4. By using Geo polymer concrete the consumption of cement was reduced and emission of carbon di -oxide and greenhouse effects are reduced.
5. GPC seems to be costlier due to the higher cost of alkaline activator solution, but it has the advantages of good earlier strength.

6. Increase in the molarity of sodium hydroxide solution results in the increase of compressive strength.

7. The addition of naphthalene based super plasticizer increases the workability up to 2%.After this addition the compressive strength decreases.

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