

Effect of VFP (Vitrified Fine Powder) on GGBFS based Geo-Polymer Concrete

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Abstract

Geo-polymer concrete (GPC) is such a new class and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBFS (Ground granulated blast furnace slag), VFP (vitrified fine powder) and alkaline liquids are used for the binding of materials. It possesses the advantage of rapid strength gain, without water curing, good mechanical properties and durability properties and are eco-friendly and sustainable alternative to Portland based concrete. In the construction industry mainly the production of Portland cement causes the emission of air pollution which results in environment pollution. This paper presents the details of the studies carried out on development of strength for various grades of geopolymer concrete with varying replacement GGBFS and VFP. The alkaline liquids used in this study for the geopolymerization are sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Molarities of sodium hydroxide solution (14M) are taken to prepare different mixtures. The test specimens were 150 x 150 x 150 mm cubes, 150 x 300mm cylinders prepared with oven and ambient temperature curing conditions. The geopolymer concrete specimens are tested for their compressive strength at the age of 3, 7 and 28 days. GPC mix formulations with compressive strength ranging from 10 to 80 MPa have been developed. Experimental investigations have been carried out on workability, the various mechanical properties of GPC. The test results indicate that the combination of Vitrified fine powder (VFP) and ground granulated furnace slag (GGBFS) can be used for development of geopolymer concrete.

Keywords: Geopolymer concrete, sodium silicate, sodium hydroxide, VFP, slag (GGBFS)

I. INTRODUCTION

The geopolymer technology is proposed by Davidovits and gives considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission in to the atmosphere, caused by cement and aggregate industries about 80%. In this technology, the source material that is rich in silicon (Si) and Aluminium (Al) is reacted with a highly alkaline solution through the process of geopolymerization to produce the binding material. The term “geopolymer” describes a family of mineral binders that have a polymeric silicon-oxygen-aluminium framework structure, similar to that found in zeolites, but without the crystal structure. The polymerization process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Geopolymer binders might be a suitable alternative in the development of acid resistant concrete. Geopolymer concrete is emerging as a new environmentally friendly construction material for sustainable development, using fly ash and alkali in place of OPC as the binding agent. This attempt results in two benefits. i.e. reducing CO_2 releases from production of OPC and effective utilization of industrial waste by products such as fly ash, slag etc by decreasing the use of OPC.

A. Objective and Scope

To evaluate the different strength properties of geopolymer concrete mixture with G.G.B.F.S replaced in percentage to VFP. Making workable, high strength and durable geopolymer concrete containing G.G.B.F.S (Slag) and VFP without usage of ordinary Portland cement.

B. Significance

This paper aims to reduce the usage of ordinary Portland cement and to improve the usage of the other by product G.G.B.S (Slag) and VFP. This product helps in reducing the carbon emissions caused by the conventional concrete. This also produces high strength concretes with the use of nominal mixes when compared to conventional concrete.

II. LITERATURE SURVEY

A. Ganapati Naidu, P, A. S. S. N. Prasad , S.Adishes, P. V. V. Satayanarayana

In this paper an attempt is made to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages of 0,9,16.66,23.07,28.57. Author has found that Compressive strength of geopolymer concrete increases with replacement of fly ash with GGBS. Fly ash was replaced by GGBS up to 28.57%, beyond that fast setting was observed. 90% of compressive strength was achieved in 14 days.

B. V. Supraja, M. Kanta Rao

In this paper an attempt is made to produce the geopolymer concrete fully replaced with GGBS and alkaline liquids are used for the binding of materials. Different molarities of sodium hydroxide solution i.e. 3M, 5M, and 7M and 9M are taken to prepare different mixes. Two different curing are carried i.e. oven curing at 500c and curing directly by placing the specimens to direct sunlight. Author observed that the compressive strength is increased with the increase in the molarity of sodium hydroxide. Compared to hot air oven curing and curing by direct sun light, Oven cured specimens gives the higher compressive strength .In this paper author observed that sun light curing is convenient for practical conditions.

III. CONSTITUTE MATERIAL

A. VFP

Due to faster urbanization in the developing country like “India” There is much demand for the tiles production, which will make problem by its waste dumped in any manner to the valuable lands. The application of such concrete with VFP waste is increased now a days as it is environment friendly cost reduction and energy conserving implication. VFP material is hard, rigid. It is estimated that 20 to 30% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill. Chemical properties of VFP waste is as per table 1.

Table 1:

Met-chem Laboratories, Vadodara

CONTENTS	Mass %
SiO ₂	68.67
Al ₂ O ₃	28.62
CaO	0.46
Fe ₂ O ₃	0.23

B. Slag (GGBFS)

Ground granulated blast furnace slag is obtained from Ambuja cements (alccofine-1206) are presented in table 2:

Table 2:

Properties of Ground granulated blast furnace slag

Chemical Analysis	Mass %
CaO	30-34
Al ₂ O ₃	18-25
Fe ₂ O ₃	0.8-3.0
SO ₃	0.1-0.4
MgO	6-10
SiO ₂	30-36

C. Coarse Aggregate

The coarse aggregate used in the investigation is crushed stone aggregate passing through 20mm and 10mm sieve. The aggregate occupy 70%-80% of the total volume normal concrete. Coarse aggregate shall comply with the requirement of IS 383.

D. Fine Aggregate

The fine aggregate used in the investigation is clean river sand and conforming to zone II. The sand was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. Fine aggregates shall conform to the required of IS 383.

E. Sodium hydroxide

Sodium hydroxide is commonly available in Flakes or pellets form is Sodium hydroxide (NaOH) in flakes form with 98% purity is purchased from local supplier has been used. The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water.

F. Sodium Silicate

sodium silicate solution (Na₂O = 14.7%, SiO₂= 29.4% and water = 55.9% by mass) is a liquid form available local industrial.

G. Admixtures

The most important admixtures are the super plasticizers DAFS GLENIUM 8784 used with workability greater than 20%.

H. Mixing Water

Water conforming to Standards should be used in convectional mixes. Where recycled water, recovered from processes in the concrete industry, is used but should conform the specifications.

IV. MIX DESIGNE OF GEOPOLYMER CONCRETE

A. Mix Design of Geopolymer Concrete

In the design of geopolymer concrete mix, total aggregates (fine and coarse) taken as 75% of entire concrete mix by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire concrete mix by mass. Fine aggregate was taken as 35% of the total aggregates. From the available literature, it is observed that the average density of GGBFS-based geopolymer concrete is similar to that of OPC concrete (2400 kg/m³). Knowing the density of concrete, the combined mass of alkaline liquid and GGBFS, VFP can be arrived at. By assuming the ratios of alkaline liquid to GGBFS and VFP as 0.4, mass of GGBFS, VFP and mass of alkaline liquid was found out. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5. In the present investigation, concentration of NaOH solution is taken as 14 M.

B. Preparation of Geopolymer Concrete

560 g (molarity x molecular weight) of sodium hydroxide flakes dissolved in one litre of water to prepare sodium hydroxide solution of 14M. The mass of NaOH solids in a solution vary depending on the concentration of the solution expressed in terms of molar, M. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds as early as possible as the setting times are very low.

C. Mixing and Casting

It was found that the fresh geopolymer masonry mix was grey in colour and was cohesive. The amount of water in the mix played an important role on the behaviour of fresh mix. Davidovits (2002) suggested that it is preferable to mix the sodium silicate solution and the sodium hydroxide solution together at least one day before adding the liquid to the solid constituents. The author suggested that the sodium silicate solution obtained from the market usually is in the form of a dimmer or a trimmer, instead of a monomer, and mixing it together with the sodium hydroxide solution assists the polymerization process. The effects of water content in the mix and the mixing time were identified as test parameters in the detailed study. From the preliminary work; it was decided to observe the following standard process of mixing in all further studies. Mix sodium hydroxide solution and sodium silicate solution together at least one day prior to adding the liquid to the dry materials. Mix all dry materials in the pan mixer for about three minutes. Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes. Compaction of fresh concrete in the cube moulds was achieved by compacting on a vibration table for ten seconds. After casting, the specimens were left undisturbed for 24 hours. Two different mixes were developed in this study, for each mix 9 cubes of 150mm, 3 cylinders of diameter of 150mm x height 300mm and 3 beams of 100mm x 100mm x 500 mm were cast to study compressive, split and flexural strengths of each mix.

D. Curing

Curing is not required for these geopolymer blocks. But slightly heat provided for polymerization oven curing 60°C can also sunlight curing is used. The heat gets liberated during the preparation of sodium hydroxide which should be kept undisturbed for one day.

Table 4.1:
Mix Designe for GPC

Materials (replacement of VFP with GGBFS)	Mix 1 (kg/m ³) (0%)	Mix 2 (kg/m ³) (10%)	Mix 3 (kg/m ³) (20%)	Mix 4 (kg/m ³) (30%)	Mix 5 (kg/m ³) (40%)	Mix 6 (kg/m ³) (50%)	Mix 7 (kg/m ³) (60%)	Mix 8 (kg/m ³) (70%)	Mix 9 (kg/m ³) (80%)	Mix 10 (kg/m ³) (90%)	Mix 11 (kg/m ³) (100%)
Course aggregate	20mm	702	702	702	702	702	702	702	702	702	702
	10mm	468	468	468	468	468	468	468	468	468	468
Fine aggregate		630	630	630	630	630	630	630	630	630	630
VFP		428.57	385.71	342.85	300	257.14	214.285	171.43	128.57	85.72	42.86
GGBFS		0	42.86	85.72	128.57	171.43	214.285	257.14	300	342.86	385.71
Sodium hydroxide		48.98	48.98	48.98	48.98	48.98	48.98	48.98	48.98	48.98	48.98
Sodium silicate		122.45	122.45	122.45	122.45	122.45	122.45	122.45	122.45	122.45	122.45
Extra added water		42.86	42.86	42.86	42.86	42.86	42.86	42.86	42.86	42.86	42.86
Super plasticizer		4.29	4.29	4.29	4.29	4.29	4.29	4.29	4.29	4.29	4.29

Oven Curing (24 hours)	60°C	60°C	60°C	60°C	60°C	60°C	60°C	60°C	60°C	60°C	60°C
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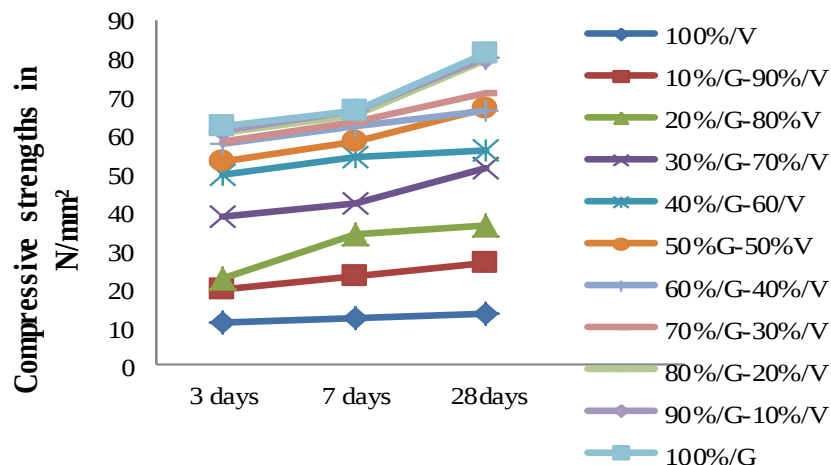
V. RESULTS AND DISCUSSIONS

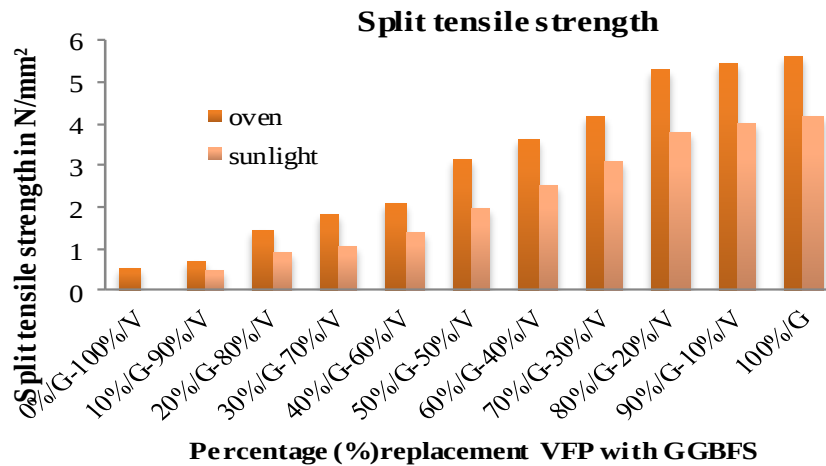
In this investigation, to study the strength properties of geopolymer concrete, 11 different mixes were prepared by replacing of VFP with slag and the 11 different mixes were presented in Table 5.1.

Table 5.1:
Mix Design Results

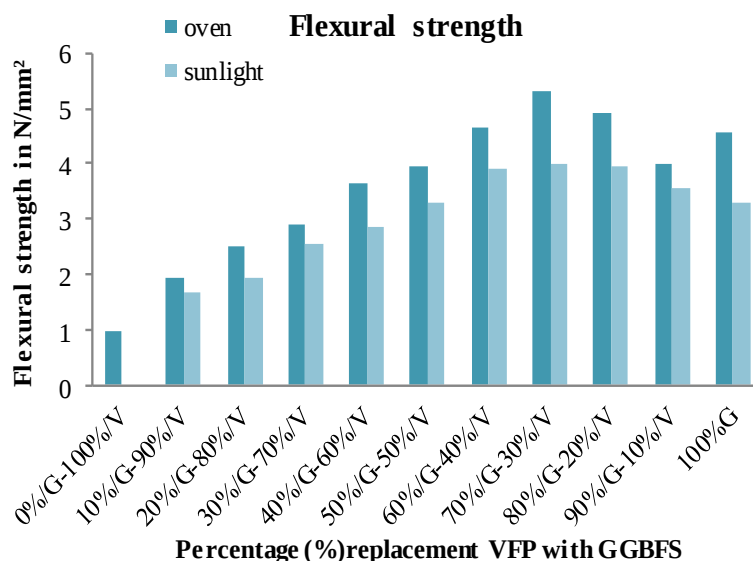
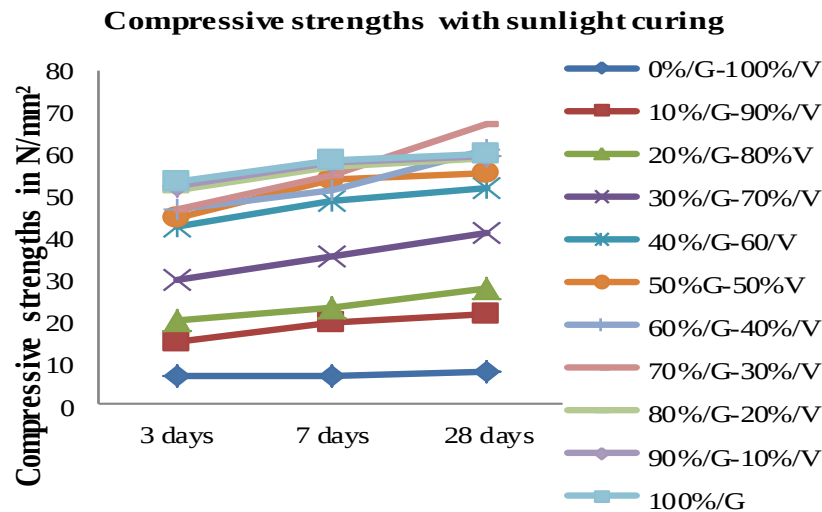
Materials (replacement of VFP with GGBFS)	Mix 1 (kg/m ³) (0%)	Mix 2 (kg/m ³) (10%)	Mix 3 (kg/m ³) (20%)	Mix 4 (kg/m ³) (30%)	Mix 5 (kg/m ³) (40%)	Mix 6 (kg/m ³) (50%)	Mix 7 (kg/m ³) (60%)	Mix 8 (kg/m ³) (70%)	Mix 9 (kg/m ³) (80%)	Mix 10 (kg/m ³) (90%)	Mix 11 (kg/m ³) (100%)
Slum	50	45	40	47	35	30	33	30	27	25	23
C.F.	0.90	0.89	0.89	0.86	0.87	0.85	0.85	0.80	0.77	0.76	0.76
Density	2472	2470	2454	2438	2458	2460	2415	2458	2440	2434	2470
After 3day C.S. in oven	10.67	19.85	22.37	38.52	49.48	53.04	57.63	58.07	60.74	61.04	62.07
After 7day C.S. in oven	12.3	23.11	34.07	42.22	53.93	58.37	62.52	63.56	65.19	66.07	66.52
After 28day C.S. oven	13.48	26.67	36.3	51.41	56.15	66.96	66.52	70.67	79.7	80.3	81.19
After 3day C.S. in sunlight	6.96	14.81	19.85	29.93	42.52	44.44	46.37	46.81	50.96	52.14	53.19
After 7day C.S. in sunlight	6.82	19.7	22.96	35.41	48.74	53.78	51.41	54.52	56.59	57.63	58.22
After 28day C.S. in sunlight	7.56	21.63	27.7	40.74	51.56	55.41	60.89	66.96	58.82	59.26	59.85
Flexural strength in oven	0.973	1.92	2.51	2.91	3.67	3.95	4.64	5.30	4.933	4	4.56
Flexural strength in sunlight	0	1.693	1.95	2.56	2.88	3.28	3.93	4	3.95	3.58	3.28
Split tension strength in oven	1.60	2.36	3.23	3.70	4.57	5.38	5.94	6.25	6.10	5.38	5.94
Split tension strength in sunlight	0	1.13	1.65	2.59	3.35	4.06	4.20	4.55	4.06	3.96	3.59
Durability (H ₂ SO ₄)	11.89	24.87	35.39	49.51	54.25	64.97	65.52	69.68	80.1	79.38	78.29
Durability (HCl)	7.48	22.67	34.32	47.41	53.75	61.46	64.90	71.67	78.23	76.30	79.76

Compressive strengths for with oven curing





The result are compression strength of geo polymeric concrete increase in extra water amount and it decreases with increase in extra water amount. The workability of mix is count to be 3 were found to be good and also given required target strength (oven-cured-36.3, sun-light-cured-27.7) on both curing process oven as well as sun-light.



In this part of this test compressive strength, flexural strength and split tensile test is calculated at the age of 28 days. Above this figure shows different mix given optimization values in Mix-3.

VI. CONCLUSIONS

Based on the experimental work the following conclusions are drawn:

- Higher concentrations of G.G.B.F.S (Slag) result in higher compressive strength of geopolymer concrete. Mixing of more G.G.B.F.S was tested that immediate setting was observed.
- Compressive strength of geopolymer concrete increases with increase in percentage of replacement of GGBFS with VFP.
- The average density of geopolymer concrete was equal to that of OPC concrete.
- The test result of durability demonstrates that geopolymer concrete has an excellent resistance.
- By increasing the water content VFP and GGBFS based Geo-polymer concrete compressive strength is decrease.
- With the elimination of the use of Portland Cement, the emission of CO₂ has been greatly reduced which results in the reduction of Environmental pollution.

ACKNOWLEDGEMENTS

I would like to thank to Internal guide Faculty Guide Prof. Y.V.Akbari for providing a vision about the dissertation. I have been greatly benefited from the regular critical reviews and inspiration throughout my work.

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