

Performance Evaluation of Self Consolidating Geopolymer Concrete with Various Molarity and Alkaline Activator Ratio

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ABSTRACT: Geopolymer is considered as an inorganic member and it mainly aims in complete elimination of OPC which is used in concrete. It as a material for construction as a trend is acquiring its importance worldwide towards a sustainable development. This technology was first implemented by a French Professor by name Joseph Davidovits. It mainly uses alkaline solutions like silicates of sodium or potassium and hydroxides of sodium or potassium along with by-products of industries like GGBS, fly ash etc. The alkaline solution majorly undergoes geopolymerization and reacts with by-products of industries to produce a binding property and then binds the aggregates. In this study Flyash and GGBS are used as binder materials, alkaline like sodium hydroxide flakes and sodium silicate, M-sand as fine aggregates, 12.5mm down coarse aggregates, 6% dosage of PCE based water reducing admixture and fresh water were used to produce self consolidating geopolymer concrete(SCGC). In this work specimens were cured at ambient temperature. Test such as Fresh property, durability and hardened property were studied.

KEYWORDS: self consolidating geopolymer concrete(SCGC), Alkaline activator ratio(AAR), polymerization, Industrial by-products alkaline liquid solutions, Ambient curing.

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I. INTRODUCTION

The main requirement for any type of construction work is concrete. As per many literature survey conducted it is noted as second most used material on earth. It mainly uses Portland cement as its main ingredient. The demand for cement as construction material is increasing day to day. Cement producing industries emit greenhouse gas like carbon dioxide CO₂ which causes global warming. It causes 68% of global warming. Cement industries emit about 12% of greenhouse gas into the atmosphere. Therefore in order to eliminate various environmental ill effects, an alternate source of binding material should be used to make concrete. Various research studies have been done in partial replacement of cement, like incorporating industrial by-products as cementitious materials for binding like saw dust, metakaolin, rice husk ash, alccofine, ground granulated blast furnace slag (GGBS), fly ash, micro silica etc.

Geopolymers mainly use alkaline solution and industrial by-products. Geopolymers majorly undergo a polymeric reaction with alkaline solution and GGBS, Flyash. The chemical composition of geopolymer concrete is the same as zeolite but with an amorphous structure. The alumina and silica present in GGBS and Flyash react with alkaline solution

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and then produces a binding property. The combination of silicate and hydroxide of sodium is most commonly used activator as it is economical when compared to potassium based hydroxide and silicates.

II. SCOPE

1. The scope of this study is to evaluate the different characteristics of SCGC by varying the molarity and alkaline activator ratio.
2. The different materials used in this study are Flyash, GGBS, sodium hydroxide, sodium silicate and water. To improve properties and to cure the concrete under ambient fly ash is partially replaced by GGBS in the mix.

III. OBJECTIVES

1. To study the behavior of SCGC in its fresh and harden states.
2. To study durability properties of SCGC.
3. To find the optimum alkaline ratio.
4. To fix optimum molarity.
5. To make effective use of industrial waste by product like flyash and GGBS.
6. To produce a eco-friendly material for construction .

IV. MATERIAL USED AND THERE TESTING RESULTS

The different types of materials used for SCGC concrete are,

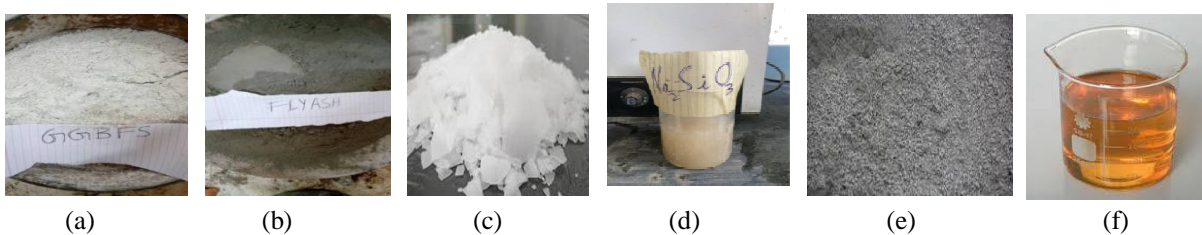


Fig.1. Material used (a) GGBFS (b) Flyash (c)Sodium hydroxide flakes (d) sodium silicate solution (e) M-sand (f) Superplasticizer

All the above materials required to produce SCGC where tested selected as per Indian standards.

Table-1: Properties of GGBS.

Sl. No	Properties	Results
1	Colour	White
2	Specific gravity	2.73

Table-2: Properties of Flyash.

Sl. No	Properties	Results
1	Colour	Gray
2	Specific gravity	2.36

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Table-3: Sieve analysis for fine aggregates done as per IS 383 – 1970 and Sieve analysis for coarse aggregates (12.5 mm) as per Indian standards

Sieve size	Weight Retained in IS Sieve (gm)	Cumulative % retained in IS sieve	Cumulative % passing in IS sieve	Zones Different specifications as per IS 383 – 1970 for percentage passing in IS sieve			
				Zone 1	Zone 2	Zone 3	Zone 4
4.75 mm	0.00	0.00	100.00	90 – 100	90 – 100	90 – 100	95 - 100
2.36 mm	2.80	2.80	97.20	60 – 95	75 - 100	85 – 100	95 - 100
1.18 mm	13.50	16.30	83.70	30 - 70	55 - 90	75 - 100	90 - 100
600 μ	35.60	51.70	48.30	15 - 34	35 - 59	60 - 79	80 - 100
300 μ	18.20	83.70	16.30	5 – 20	8 – 30	12 - 40	15 - 50
150 μ	14.20	98.50	1.50	0 – 10	0 – 10	0 - 10	0 - 10
Pan	1.1	99.60	0.4	-	-	-	-

Sieve size (mm)	Weight retained in IS sieves (kg)	Percentage weight retained on each IS sieve	Cumulative percentage retained in IS sieves	Cumulative percentage passing in IS sieves
16	0.00	0.00	0.00	100.00
12.5	0.434	4.34	4.34	95.66
10	5.346	53.46	57.8	42.20
4.75	4.132	41.32	99.12	0.88
2.36	0.022	2.20	99.34	0.66
Pan	0.040	-	-	-

Mixing of alkaline activator solution.

Sodium hydroxide solution of 5M/10M is first prepared before 24 hours of casting the samples with sodium silicate and this should be used within 36 hours. Mixing was carried out in drum mixer, the dry materials like cementitious binder materials and aggregates were first dry mixed for 5 minutes. The alkaline solution was then poured to dry mix and this mix was mixed for 5 minutes. The SCGC in its fresh state is transferred to molds. Then this specimens were cured ambient temperature and after 24 hours this specimens were de-molded and once again subjected to ambient curing.

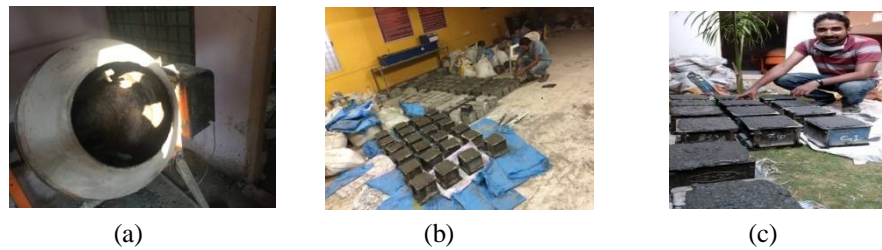


Fig.2- (a) Mixing of SCGC (b) ambient curing of SCGC (C) Mold used for casting specimens.

Results of tests carried out :

Table-4: Workability test and compressive strength results

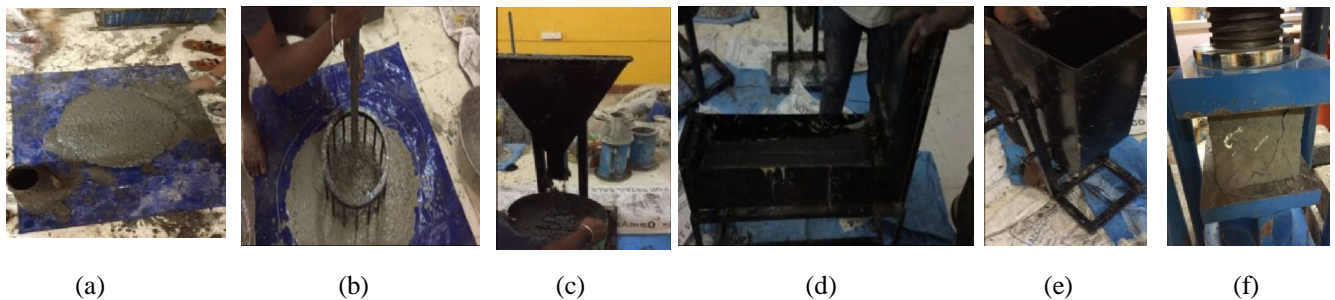


Fig.3- (a) Flow test (b) J-Ring test(c) V-Funnel test(d) L-Box test(e) U-Box test (f) Compressive strength measurement.

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	MIX NO.	AAR	Molarity	Flow (mm)	T50 (secs)	J Ring (mm)	V-Funnel (secs)	V-Funnel T5 mins (secs)	L Box	U Box (mm)	Compressive strength(mpa)	
											7 days	28 days
80%FLYASH 30%GGBS	G1	2	5	763	3	5	10	12	1.0	24	36.17	41.00
	G2		10	752	3	7	10	12	0.9	27	40.00	45.83
	G3	4	5	778	3	4	8	6	0.8	20	33.33	38.00
	G4		10	755	3	6	9	9	0.8	22	39.00	43.67
70%FLYASH 30%GGBS	G5	2	5	719	3	6	11	12	0.7	24	43.00	51.83
	G6		10	702	4	9	12	12	0.9	28	49.17	53.33
	G7	4	5	753	2	4	4	7	0.8	27	42.17	47.13
	G8		10	736	3	6	7	9	0.8	28	42.67	50.00

Table-5: Non destructive test results: Rebound hammer and Ultra sonic pulse velocity test results:



Fig.4- (a) Rebound hammer (b) Ultra sonic pulse velocity.

	MIX NO.	AAR	Molarity	Compressive strength(mpa)		Rebound hammer values		Ultra sonic pulse velocity values m/s , (28days)	Quality grading for UPV (As per IS-13311 PART1)
				7 days	28 days	7 days	28 days		
80%FLYASH 30%GGBS	G1	2	5	36.17	41.00	33.50	37.00	3.08	Medium(3.0 to 3.5)
	G2		10	40.00	45.83	36.50	41.00	3.23	Medium(3.0 to 3.5)
	G3	4	5	33.33	38	30.00	36.00	2.85	Doubtful(Below 3.0)
	G4		10	39.00	43.67	35.50	39.50	3.01	Medium(3.0 to 3.5)
70%FLYASH 30%GGBS	G5	2	5	43.00	51.83	39.00	48.50	3.89	Good(3.5 to 4.5)
	G6		10	49.17	53.33	43.00	50.00	4.08	Good(3.5 to 4.5)
	G7	4	5	42.17	47.13	38.50	42.00	3.56	Good(3.5 to 4.5)
	G8		10	42.67	50.00	38.50	46.50	3.61	Good(3.5 to 4.5)

Table-6 : Drying shrinkage test values for all mix.

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Fig.5- Drying shrinkage apparatus .

	Mix no.	Alkaline activator ratio	Molarity	Initial length(wet) (mm) (a)	Final length(dry measurement) (mm) (b)	Dry length (original length)mm (c)	Drying shrinkage(%) (d)=((a)-(b))/c x 100
GPC1	G1	2	5	2.543	2.449	162.50	0.06
	G2	2	10	2.153	2.056	162.53	0.06
GPC2	G3	4	5	2.189	2.051	162.59	0.08
	G4	4	10	1.986	1.863	162.63	0.08
GPC3	G5	2	5	1.756	1.740	162.63	0.01
	G6	2	10	2.156	2.099	162.60	0.04
GPC4	G7	4	5	1.165	1.101	162.47	0.04
	G8	4	10	2.453	2.379	162.89	0.05

Table-6 : Water Absorption Test Results.

	Mix no.	AAR	Molarity	24 HOUR Water (H ₂ O) Absorption			
				Dry weight of specimen(kg)	Density(kg/m ³)	wet weight of specimen(kg)	water absorption percentage(%)
80%FLYASH 30%GGBS	G1	2	5	8.022	2376.89	8.064	0.523
	G2	2	10	7.750	2296.30	7.789	0.503
70%FLYASH 30%GGBS	G3	4	5	8.101	2400.30	8.116	0.185
	G4	4	10	8.147	2413.93	8.166	0.233
80%FLYASH 30%GGBS	G5	2	5	8.084	2395.26	8.093	0.111
	G6	2	10	7.981	2364.74	7.911	0.125
70%FLYASH 30%GGBS	G7	4	5	8.059	2387.85	8.07	0.136
	G8	4	10	7.909	2343.41	7.924	0.190

Table-7 : Sorptivity And Permeability Test Results :

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Fig.6- (a) Preparation of concrete cubes for sorptivity test (b) Concrete specimens kept in 5mm of water level for Sorptivity test (c) Permeability test setup.

	Mix no.	A A R	Molarity	Water (H ₂ O) Absorbed						PEREMEABILITY TEST-Average depth of penetration of water(mm) [DIN-1048]
				15 mins	30 mins	1 hour	24 hour	48 hour	72 hour	
80% FLYASH 30% GGBS	G1	2	5	0.00009	0.00026	0.00028	0.00036	0.00047	0.00056	138.9
	G2	2	10	0.00009	0.00024	0.00029	0.00034	0.00043	0.00054	129.8
70% FLYASH 30% GGBS	G3	4	5	0.00006	0.00023	0.00025	0.00032	0.00041	0.00055	160.7
	G4	4	10	0.00007	0.00022	0.00023	0.00032	0.00043	0.00053	157.6
80% FLYASH 30% GGBS	G5	2	5	0.00003	0.00019	0.00021	0.00029	0.00039	0.00051	86.7
	G6	2	10	0.00004	0.00019	0.00020	0.00026	0.00037	0.00052	83.9
70% FLYASH 30% GGBS	G7	4	5	0.00002	0.00017	0.00019	0.00026	0.00034	0.00051	90.6
	G8	4	10	0.00003	0.00019	0.00020	0.00024	0.00034	0.00051	89.8

Table-9 : Rapid Chloride Penetration Test(RCPT) results:



Fig.7- RCPT setup .

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	Mix no.	AAR	Molarity	RCPT Values for different percentages in coulombs
80% FLYASH 30% GGBS	G1	2	5	5564.8
	G2	2	10	5532.9
70% FLYASH 30% GGBS	G3	4	5	5601.5
	G4	4	10	5593.7
80% FLYASH 30% GGBS	G5	2	5	5586.9
	G6	2	10	5575.5
70% FLYASH 30% GGBS	G7	4	5	5559.6
	G8	4	10	5549.8

V. CONCLUSIONS

- SCGC completely reduces greenhouse gas like carbon dioxide emission in atmosphere
- The waste industrial by – product was used effectively to produce SCGC.
- For any SCC geo polymer concrete mix the workability improves with increase in flyash percentage and alkaline activator ratio.
- Increase in molarity of NaOH and GGBS percentage reduces workability and increases compressive strength.
- As the alkaline activator ratio increase it was noticed that the surface hardness and quality of concrete reduces as per Non-destructive test conducted i.e both rebound hammer and ultra sonic pulse velocity test.
- The water absorption percentage, permeability, sorptivity, drying shrinkage and RCPT is low for mix having higher GGBS percentage.
- The optimum mix and design for SCC geopolymer is obtained when molarity is 5M and activator liquid ratio is 2.
- The test results of compressive strength at 7 days was found to be 80-95% of its 28 days compressive strength.

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