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Effect Of GGBS To Fly Ash Ratio And Molarities Of Alkaline Activator On The Compressive Strength Of Geopolymer Concrete

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The use of Geopolymer concrete (GPC) is being seen as an alternate to the conventional Portland concrete from the point of sustainability. The requirement of heat curing of fly ash based GPC is hindering its application in large scale utilisation. In the present experimental investigation a study has been made on the combined use of GGBS and Fly ash in producing the GPC. The presence of GGBS has eliminated the requirement of heat

curing in order to activate the polymerisation in GPC. Also the compressive strength of GPC has increased with increase in GGBS to Fly ash ratio and also with higher molarity of alkaline activator.

Introduction

The growth in infrastructure development and boom in the housing sector has put a lot of demand on cement. Due to environmental concerns of cement industry, there arises a strong need to make use of alternate sustainable technology. The development of alkali activated binders with promising engineering properties and longer durability has emerged as an alternative to OPC. Geopolymer (Inorganic polymer concrete) is an emerging class of cementitious material and could be the next generation concrete for civil infrastructure applications. This innovative technology provides a new platform for sustainable growth of urban society in the decades to come. These materials can be replaced to the binder in concrete as a major construction material.

(Davidovits, 1970) [4] reported the use of waste material like fly ash (FA) and ground granulated blast furnace slag (GGBS) as and high alkaline solution as activators. The commonly used combination of alkaline solution is NaOH and Na^2SiO^3. This solution binds the loose aggregates in mixture to form geopolymer concrete (GPC) which has high strength, durability and low creep. The curing conditions especially, temperature significantly impacts the polymerization process Wang [6]. Hardjito et al [2] concluded that a combination of sodium hydroxide and sodium silicate solutions can be a good application for activators and higher concentration of sodium hydroxide solution and curing temperature enable the concrete compressive strength to be higher. Various authors studied the importance of molar ratio of Na_2SiO_3/NaOH and suggested as 2.5 for maximum compressive strength at constant binder content B.V.Rangan [5], Anuradha [1] carried out research on fly ash based geopolymer concrete considering different mix proportions and developed a mix design process by varying the water to geopolymer solids ratio with two different molarities of NaOH i.e. 8M and 12M.

Keeping in view of the past work done on GPC, the present investigation is aimed at studying the compressive strength of GGBS and Fly ash based GPC which can be called as ‘Binary blended GPC’. The parameters varied include GGBS to FA ratio, Molarty of alkaline activator. The ratio of sodium silicate to sodium hydroxide is kept at 2.5.

Experimental Program

The experimental Program consisted of determining the compressive strength of GGBS and FA based geopolymer concrete by casting and testing of cubes of size 150mmx150mmx150mm.

Table 1: Chemical Composition of Fly Ash and GGBS (% by mass)

	SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	MgO	Na_2O	LOI
Fly ash	60.12	26.63	4.22	0.32	4.10	1.21	0.20	0.85
GGBS	34.16	20.10	0.81	0.88	32.8	7.69	--	--

Table 2: Materials used in Preparing NaOH Solution

Molarity(M)	SH Pellts (gm)	Water (gm)
6	200	800
8	255	745
10	306	694
12	354	646

Table 3: Materials used in GPC

SNo			Materials (Kgs)					
	FA : GGBS	GGBS/ FA ratio	Coarse Agg.	Robo Sand	Fly Ash	GGBS	NAOH Solution	Sodium Silicate
1	80 : 20	0.25	18.00	13.20	7.85	2.00	1.80	4.50
2	70 : 30	0.43	18.00	13.20	6.90	2.95	1.80	4.50
3	60 : 40	0.67	18.00	13.20	5.91	3.94	1.80	4.50
4	50 : 50	1.00	18.00	13.20	4.93	4.92	1.80	4.50
5	40 : 60	1.50	18.00	13.20	3.94	5.91	1.80	4.50
6	30 : 70	2.30	18.00	13.20	2.95	6.90	1.80	4.50

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Table.4. The Compression Strength of GPC (kg/sq.cm)

SNo	GGBS/FA	6M			8M			10M			12M			% increase in strength as molarty changes from 6 to 12	
		7D	28D	7D/28D	7D	28D	7D/28D	7D	28D	7D/28D	7D	28D	7D/28D	7D	28D
1	0.25	120	163	0.736	124	189	0.656	138	221	0.624	191	274	0.697	59	68
2	0.43	128	178	0.719	134	230	0.583	148	255	0.58	223	295	0.756	74	66
3	0.67	209	245	0.853	220	296	0.743	237	367	0.646	265	389	0.681	27	59
4	1.00	293	371	0.79	294	378	0.778	297	388	0.765	302	403	0.749	3.1	8.6
5	1.50	349	409	0.853	370	419	0.883	396	430	0.921	402	439	0.916	15	7.3
6	2.30	421	448	0.94	461	484	0.952	488	529	0.922	505	569	0.888	20	27
	% increase in strength as GGBS/FA increases from 0.25 to 2.3	251	175	--	272	156	--	253	139	--	164	107	--		

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Materials Used

Fly ash and GGBS are used as binders in this research work. GGBS is obtained from Toshali Cements Pvt ltd, Bayyavaram, India and Fly ash from National thermal power plant, Ramagundam, India. Specific gravity of GGBS and Fly ash are 2.90 and 2.17 respectively. Chemical Composition details are shown in Table 1.

Fine Aggregate: The Robo sand (RS) also called as manufactured sand made out of stone crushing was used as fine aggregate instead of normal river sand. The RS used conforming to Zone-2 according to IS: 383 and has specific gravity and bulk density as 2.65 and 1.45 gram/c.c. respectively.

Coarse Aggregate: Crushed granite of 20 mm nominal size obtained from a local crushing unit is used as coarse aggregate and the aggregate is well graded aggregate according to IS: 383[11]. The specific gravity and bulk density are 2.80 and 1.5 gram/c.c.

Water: Potable water was used in the experimental work for preparation of alkaline Solution.

Alkaline Solution: The molarity of Sodium Hydroxide Solution used varies from 6M to 12M. The sodium hydroxide pellts used in preparing NaOH solution is given in Table.2. The ratio of Sodium Silicate Solution to Sodium Hydroxide Solution is considered as 2.5 and the mixed solution is stored for 24 hours at room temperature (25±2°C) and relative humidity of 65% before it is used for casting.

Mix Proportions: After certain trail mixes and testing of cast specimens, a final mix proportion shown in Table 3 was adopted to carryout mechanical properties.

Casting of GPC Specimens

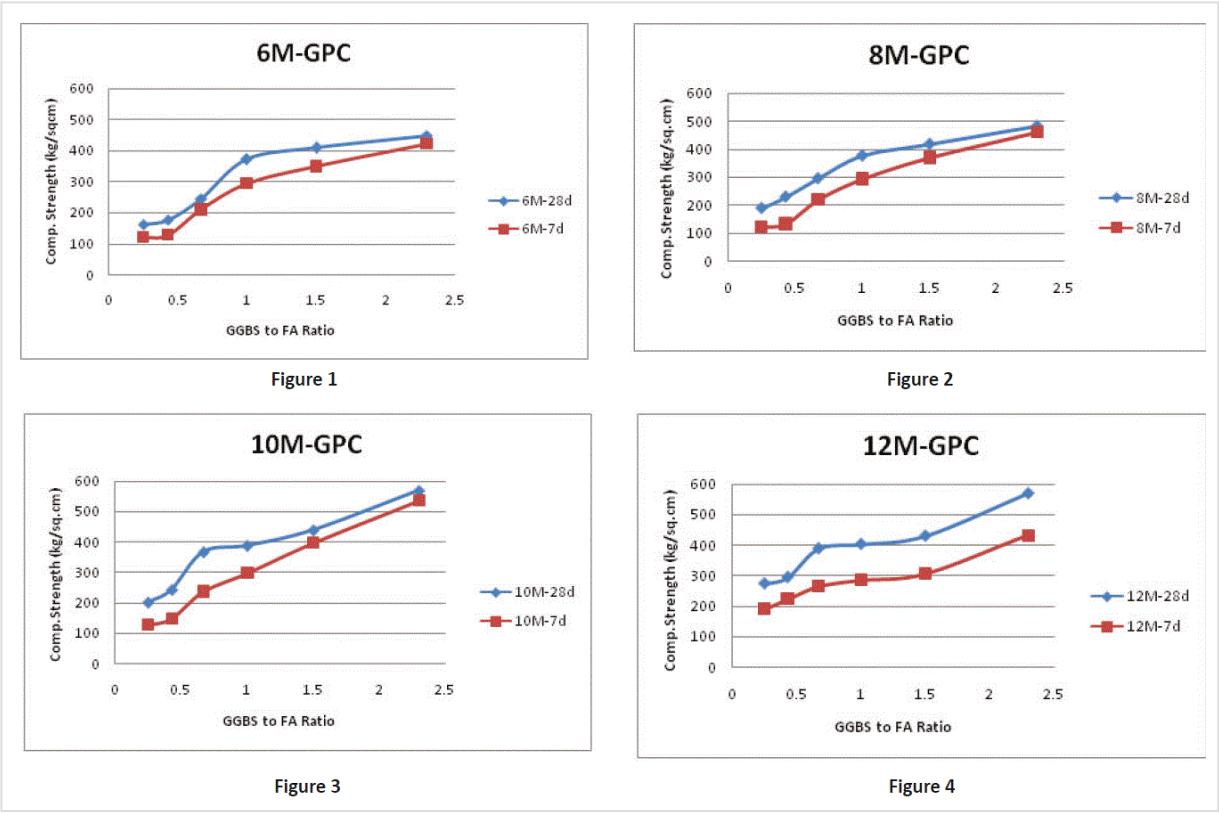
The individual dry material weighed were mixed using a rotating drum type 100 kg capacity pan mixer and the alkaline liquid and super plasticizer of optimum dosage were added. Proper homogenous mixing was obtained by continuous mixing for about 5 minutes. The fresh mixes prepared were cohesive and segregation resistant. Immediately after mixing, the fresh GPC was transferred into cube moulds followed by table vibration. After compaction the top surface was levelled with a trowel.

Curing of GPC Specimens

The specimens were demoulded after 24 hours of casting and cured in outdoor. For outdoor curing, specimens were left out air dried for a period of 28 days. The room temperature and relative humidity measured were 35±2°C and 75% respectively.

Testing for Compressive Strength

The cube specimens are tested on compression testing machine of capacity 2000kN. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on the specimen is recorded. The testing was done as per IS 516 [3]. The testing of specimens was carried out at the end of 7days (7D) and
28 days (28D) of outdoor curing. The compression strength of GPC for different GGBS to fly ash ratio and for different molarity of alkaline activator are given in Table.4.



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Results and Discussion

3.1. Effect of GGBS to Fly Ash Ratio on Compressive Strength of GPC

The effect of GGBS to Fly ash ratio on Compressive strength of GPC for a particular molarity of alkaline activator is shown in Fig.1 -4. From these figures it can be observed that the compression strength of GPC has increased with increase in GGBS to FA ratio. However the rate of increase of compressive strength is more for GGBS to FA ratios less than 1.0 as evidenced by the per cent increase in strength values with change in molarity presented in Table.4.

3.2. Effect of Molarity of Alkaline Activator on Compressive Strength of GPC

The effect of molarity of alkaline activator for different GGBS to FA ratios, on 28 day compressive strength of GPC is shown in Fig.5. In general as the molarity increases the 28 day compressive strength of GPC also has increased. However the increase in strength is not in proportion to the increase in molarity. As the GGBS to FA ratio increased from 0.25 to 2.3 the 28 day compressive strength of GPC has increased by 175%, 156%, 139% and 107% for molarity of alkaline activator of 6M, 8M, 10M and 12M respectively.

3.3. Comparison of 7-Days Strength to 28-Days Strength Ratio of GPC

The variation of the ratio of 7 day strength to 28 day strength of GPC for different GGBS to FA ratio and for different molarity of alkaline activators is shown in Fig.6. This variation indicates that the 7D to 28D strength ratio has no particular trend. However it can be observed in general the 7D to 28D strength ratio has increased approximately in linear way

with increase in GGBS to FA ratio. The following linear equation can be used to relate 7D to 28D strength ratio with that of GGBS to FA ratio of GPC, irrespective of molarity. The correlation coefficient of the equation is 0.73.

7D to 28D compressive strength ratio of GPC = 0.63 + 0.14 (GGBS to FA ratio)

From the above observations it can be concluded that the GGBS can be used for the partial replacement of Fly ash. The GGBS, which normally contains a substantial amount of Calcium compared to that of fly ash, imparts heat of hydration required for the polymerization process. Thus geopolymer concrete with fly ash and GGBS combination reveal encouraging results without the need of heat curing.

Conclusions

The following conclusion can be made from the experimental investigation presented.

The compression strength of GPC has increased with increase in GGBS to FA ratio for a particular molarity of activator used.

The rate of increase of compressive strength is more for GGBS to FA ratios less than 1.0

As the molarity of activator increases the 28 day compressive strength of GPC also has increased. However the increase in strength is not in proportion to the increase in molarity.

The 7D to 28D compressive strength ratio of GPC has increased with increase in GGBS to FA ratio and the increase may be approximated by a linear relation.

Fly ash and GGBS combination can be used in producing GPC without the need of heat curing.

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