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COST ANALYSIS OF GEOPOLYMER CONCRETE OVER CONVENTIONAL CONCRETE

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ABSTRACT

Now a days concrete is one of the widely used constructuction materials in construction industry.Portland cement is the main constituent for making concrete. Geopolymer can be consider as the key factor which does not utilize Portland cement, nor releases greenhouse gases.the geopolymer technology proposed by Davidovits(1978) shows considerable promise for application in concrete industry as an alternative binder to the Portland cement.He proposed that binders could be proposed by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geopolymer origin or by-product materials such as Fly Ash,Ground Granulated blast furnace slag ,Rice-Husk Ash etc.He termed these binder as geopolymers. Among the waste or by-product materials,Fly Ash and Slag are the most potential source of geopolymers.

The objective of this project is to study the effect of class Fly Ash (FA) and Ground Granulated Blast Furnace Slag (GGBS) on the micro properties of geopolymer concrete (GPC) at different replacement levels (FA0-GGBS100, FA25-GGBS75, FA50-GGBS50, FA75-GGBS25, FA100-GGBS0)). Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution will be used as alkaline activators. The molar ratio of hydroxide solution considered in the investigation is 10M. The result shows that the mechanical decrease with increase in FA content in the mix irrespective of different curing periods like 7, 28, 56 and 90 days at ambient room temperature.

Key words: - Geopolymer concrete, sodium silicate, sodium hydroxide, fly ash, granulated blast furnace slag, compressive strength.

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1. INTRODUCTION

The geopolymer technology is proposed by Davidovits (1978) gives considerable promise for application in concrete industry as an alternative binder to the Portland cement [1,2].In terms of reducing global warming, the geopolymer technology could reduce the co_2 emission into the atmosphere, caused by cement and aggregate industries about 80%[8].In this technology ,the source material that is FA and GGBS [Fly Ash and Ground Granulated Blast Furnace slag] in silicon (si) and aluminum (Al) is reacts with a highly alkaline solution through the process of geopolymerisation to produce the binding material[4] . Geopolymer concrete is a new material which does not need presence of Portland cement as a binder [6].

2. LITERATURE REVIEW

Ganapathi Naidu (2011),parthiban et al (1988),Krishna Rao (2013),Hardjtio et al (2005),Supraja and Kantha Rao (2008),Madheswara and Ganasundgar (2013) etc have worked in the area of geopolymer concrete. Most of the researchers have replaced cement by the by-product materials such as Fly Ash and Ground Granulated Blast Furnance Slag (GGBS) and have concentrated on the compressive strength of Geopolymer Concrete at different replacement levels.

3. MATERIALS

Although geopolymer concrete can be made using various source materials, the present study used Class F fly ash and GGBS. Also, as in the case of OPC, the aggregates occupied 75-80 % of the total mass of concrete. The following sections discuss constituent materials used for manufacturing GPC. Chemical and physical properties of the constituent materials are presented in this section.

3.1. FLY ASH

According to ASTM C 618 (2003), Class F fly ash produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P. was used.

3.2. GROUND GRANULATED BLAST FURNACE SLAG

In the present investigation, GGBS produced from the Vizag steel plant was used in the manufacturing of GPC.

3.3. FINE AGGREGATE

Natural river sand was used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) were 2.62 and 1% respectively.

3.4. COURSE AGGREGATE

Crushed granite stones of size 20 mm and 10 mm were used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm and 10mm as per IS 2386 (Part III, 1963) were 2.58 and 0.30% respectively.

3.5. ALKALINE LIQUIDE

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium silicate solution (Na_2O= 13.7%, SiO_2=29.4%, and water=55.9% by mass) was purchased from a local supplier. The sodium hydroxide (NaOH) in flakes or pellets from with 97%-98% purity was also purchased from a local supplier. The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. The mass of NaOH solids in a solution diverse depending on the concentration of the solution which is expressed in terms of molar, M. For instance, NaOH solution with a concentration of 10M consisted of 10x40 = 400 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH.

4. MIX DESIGN

Based on the limited past research on GPC (Hardjito & Rangan, 2005), the following proportions were selected for the constituents of the mixtures.

- The combined mass of coarse and fine aggregates has taken as 77% of the mass of concrete.
- Ratio of activator solution-to-fly ash and GGBS, by mass, in the range of 0.3 and 0.4. This ratio was fixed at 0.35.
- Class F fly ash and GGBS (FA100-GGBS0; FA25-GGBS75; FA50-GGBS50; FA75-GGBS25; FA0-GGBS100).
- Ratio of sodium silicate solution-to-sodium hydroxide solution, by mass, of 0.4 to 2.5. This ratio was fixed at 2.5 for most of the mixtures, because the sodium silicate solution is considerably cheaper than the sodium hydroxide solution.
- Molarity of sodium hydroxide (NaOH) solution was kept at 10M.
- Calculate water-to-geopolymer solids.
- Extra water, when added, in mass.
- M_{45} grade of conventional concrete (CC) has been designed (refer Appendix (B) as per **IS 10262 (2009)** and **IS 456 (2000)** for comparative study.

The CC and geopolymer concrete mixture proportions are given as follows:

Table 1. GPC mix proportions

Materials		**Mass (kg/m³)**					
		M_{45}	FA0-GGBS100	FA25-GGBS75	FA50-GGBS50	FA75-GGBS25	FA100-GGBS0
Coarse aggregate	20mm	606	776	776	776	776	776
	10mm	404	517	517	517	517	517
Fine aggregate		625	554	554	554	554	554
Cement		533	0	0	0	0	0
Fly ash (Class F)		0	0	102.2	204.5	306.7	409
GGBS		0	409	306.7	204.5	102.2	0
Sodiu silicate solution		0	102	102	102	102	102
Sodium hydroxide solution		0	41 (10M)	41(10M)	41 (10M)	41 (10M)	41(10M)
Extra water		0	55	55	55	55	55

Alkaline solution/ (FA+GGBS) (by weight)	0	0.35	0.35	0.35	0.35	0.35
Water/ geopolymer solids (by weight)	0	0.29	0.29	0.29	0.29	0.29

Fly Ash

Ground Granulated Blast Furnance Slag(GGBS)

10mm Coarse Aggregate

20mm coarse aggregate

Fine aggregate

Sodium hydroxide

Sodium silicate

5. RESULTS AND DISCUSSION

5.1. Compressive strength on geopolymer concrete: -

Compressive strength test was conducted on the cubical specimens for all the mixes after 7, 28, 56 and 90 days of curing as per IS 516 (1991). Three cubical specimens of size 150 mm x 150 mm x 150 mm were cast and tested for each age and each mix. The compressive strength (f'_c) of the specimen was calculated by dividing the maximum load applied to the specimen by the cross-sectional area of the specimen.

The compressive strength values of GPC mixes were measured after 7, 28, 56 and 90 days of curing. These compressive strength properties were then compared to that of M_{45} grade of conventional concrete (CC).

The compressive strength of CC (M_{45}) and GPC mixes (FA100-GGBS0; FA25-GGBS75; FA50-GGBS50; FA75-GGBS25; FA0-GGBS100) at different curing periods.

Table 2. Compressive strength of CC and GPC

Mechanical property	Age	Mix type					
		M45	FA0-GGBS100	FA25-GGBS75	FA50-GGBS50	FA75-GGBS25	FA100-GGBS0
Compressive strength p_c (MPA)	7	26.12	54.29	51.11	35.30	13.30	10.51
	28	51.39	60.23	58.12	46.32	15.55	12.11
	56	54.23	63.11	59.02	48.33	28.22	18.68
	90	56.34	65.23	62.32	51.78	33.02	22.03

6. COST ANALYSIS OF GEOPOLYMER CONCRETE OVER CONVENTIONAL CONCRETE

This section mainly focused on the cost analysis of GPC (FA39-GGBS69) and M_{45} grade of CC. Time, cost and quality are the three important factors which assume significance in construction due to their impact on the industry as a whole. Any development which has positive impact on these factors is always in the interest of civil engineering.

The compressive strength test can be relatively easily conducted. Hence, the most frequently conducted test on concrete is the compressive strength test. The compressive strength at 28 days after casting is taken as a criterion for specifying the quality of concrete which is called grade of concrete. The concrete develops strength with continued hydration. The rate of gain of strength is earlier to start with and the rate gets reduced with age. It is customary to assume the 28 days strength as the full strength of concrete.

The 28 days compressive strength of M_{45} grade CC is 51.39Mpa. In order to achieve the same strength in case of GPC, the proportion of FA: GGBS is 39: 61. Hence, in this chapter the cost of one cubic meter of GPC for the above proportion is worked out and is compared with the cost of one cubic meter of M_{45} grade of CC.

Calculations of quantities of dry ingredients of CC and GPC for the cost analysis are presented in Table 3 and 4 respectively.

Table 3 Calculation of quantities of dry ingredients of CC

Quantity calculation of M_{45} grade of CC						
Dry co-efficient of concrete : 1.52 (a)						
Material	Weight (Kg/m^3) (b)	Specific gravity (c)	Volume (m^3) (d)=(b)/(c)	Volume Proportions (e)=(d)/(f)	Quantity per cubic meter of concrete (m^3) (h)=(e)*(a)/(g)	Remarks
Cement	533	3.06	174.18 (f)	1.00	0.33	Let 1 cement bag of 50 kg = 0.0347 m^3 volume
Sand	625	2.62	238.55	1.37	0.45	
CA 20	606.4	2.58	235.04	1.35	0.44	
CA 10	404.3	2.658	156.71	0.90	0.30	
Total volume of proportions				4.62 (g)	Total: 1.52	

Table 4 Calculation of quantities of dry ingredients of GPC

Quantity calculation of M_{45} grade of GPC						
Material	Weight (Kg/m^3) (b)	Specific gravity (c)	Volume (m^3) (d)=(b)/(c)	Volume Proportions (e)=(d)/(f)	Quantity per cubic meter of concrete (m^3) (h)=(e)*(a)/(g)	Remarks
GGBS	249.49	2.9	86.03 (f)	1.00	0.14	
Fly ash	159.51	2.12	72.17	0.87	0.12	
Sand	554	2.62	211.45	2.50	0.37	
CA 20	776	2.58	300.78	3.49	0.52	
CA 10	517	2.58	200.39	2.32	0.34	
Total volume of proportions				10.18 (g)	Total: 1.49	

Table 5 Cost analysis of M_{45} grade of CC and GPC

Material	Unit	Rate (Rs)	Control concrete (M_{45})		GPC (FA39-GGBS61)	
			Quantity	Amount (Rs)	Quantity	Amount (Rs)
Cement	Bags	250	9.51	2377.50	0	0.00
GGBS	m^3	70	0	0	0.14	9.8
Fly ash	m^3	65	0	0	0.12	7.8
CA 20	m^3	1076	0.44	473.44	0.54	559.52
CA 10	m^3	788	0.30	236.40	0.34	267.92
Sand	m^3	375	0.45	168.75	0.37	138.75
Sodium silicate solution	Litre	24	0	0	102	2448.00
NaOH pellets	Kg	55	0	0	16	880.00
Total				3256.09		4311.79
Cost over CC(%)						32.42

Cost analysis of M_{45} grade of CC and GPC is made as per standard schedule of rates **(SSR (2013))** and is presented in Table 3. From the Table 3, it is found that the initial material cost of GPC (FA0-GGBS100) was about 32% higher than that of CC (M_{45}). Obviously, the higher material cost of GPC over CC gives a feeling that GPC is much costlier than CC for the same strength.

But having realized the other components of GPC such as savings in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties (mechanical and durable), it is inferred that these components would offset the initial material cost of GPC. Though lot of research work needs to be done on cost-effective GPC, it can be recommended as an innovative construction material for the use of constructions.

7. CONCLUSIONS

Based on the results reported in this investigation, the following conclusions are drawn

1. The compressive strength of Geopolymer concrete decrease with increase in FA content in the mix irrespective of curing period.

2. For a given proportion of mix, the compressive strength increase with age.

3. The compressive strength of Geopolymer concrete is maximum, when the mix proportion FA: GGBS: 0:100 irrespective of curing period.

4. The initial material cost of GPC (FA39-GGBS61) is about 32% higher than that of CC (M_{45}) at 28 days' compressive strength.

REFERENCES

[1] J. Davidovits, “Geopolymers: Man-Made Geosynthesis andthe Resulting Development of Very Early High StrengthCement”, J. Materials Education Vol. 16 (2&3), 1994, pp. 91-139.

[2] P. Nath and P.K. Sarker, “Effect of GGBS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition”, Construction Building Materials Vol. 66, 2014, pp. 163-171

[3] P.K. Sarker, S. Kelly and Z. Yao, “Effect of exposure on cracking, spalling and residual strength of fly ash geopolymer concrete”, Materials and Design Vol. 63, 2014, pp. 584-592.

[4] P.S. Deb, P. Nath and P.K. Sarker, “The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature”, Materials and Design Vol. 62, 2014, pp. 32-39.

[5] J. Davidovits, “Geopolymer: Inorganic Polymeric New Materials”, Journal of Thermal Analysis Vol. 37, 1991, pp.1633-1656.

[6] J. Davidovits, “Global Warming Impact on the Cement and Aggregate Industries”, World Resource review, Vol. 6, no. 2, 1994, pp. 263-278.

[7] Palomo, A.; Grutzeck, M.W.; Blanco, M.T. (1999). Alkali-activated fly ashes – A cement for the future. Cement and Concrete Research, 29(8), 1323-1329.

[8] IS 2386 (1963). Methods of test for aggregates for concrete. Part III - Specific gravity, Density, Voids, Absorption and Bulking. Bureau of Indian Standards, New Delhi.

[9] IS 383 (1970). Specification for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi.

[10] Hardjito, D., & Rangan, B. V. (2005). Development and Properties of Low-Calcium Fly Ash-Based Geopolymer Concrete. Research Report GC1, Perth, Australia: Faculty of Engineering, Curtin University of Technology.

[11] IS 10262 (2009). Concrete Mix Proportioning-Guidelines. Bureau of Indian Standards, New Delhi.

[12] IS 456 (2000). Plain and reinforced concrete code for practice. Bureau of Indian Standards, New Delhi.