International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.13 No.01, pp 117-122, 2020

Study on Setting & Strength Characteristic of GGBS based Geopolymer Concrete by Blending of Fly Ash and Metakaoline

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Abstract : Carbon dioxide is liberated in huge amounts by the manufacturing of Portland Pozzolana Cement. Normally, conventional concrete is manufactured with Portland cement, which acts as a binder. The production of cement emits CO_2 into the atmosphere, which is a green house gas and causes the environmental pollution. Considering this as a serious environmental problem, there is a need to develop sustainable alternatives to Portland cement utilizing the industrial byproducts such as fly ash, ground granulated blast furnace slag and Metakaoline which are pozzolonic in nature. It has been established that fly ash can replace cement partially. In this context, a new material was developed known as ”Geopolymer”.

In this study, the various parameters on the short term engineering properties of fresh and hardened properties of Geopolymer Mortar were studied. In the present investigation, cement is replaced by geopolymer source material and water is replaced by alkaline activator consisting of Sodium Silicate and Sodium Hydroxide of molarity (12M). The ratio of sodium silicate to sodium hydroxide adopted was 2.5. The test results showed that final setting time decreases as the GGBS content in the mix increases and also increase in compressive strength. Where as in the case of metakaoline, as the content increases, there is a decrease in compressive strength and setting times of the geopolymer concrete.

Keywords: Geopolymer Mortar, Normal Consistency, Normal Consistency, Setting Times, Fly Ash, GGBS, Metakaoline.

1.0 Introduction

Cement is one of the extensively used construction material. But the production of cement involves the emission of green house gases (GHG’s) into the atmosphere which results in huge amount of environmental pollution. The amount of green house gases emitted during the production of cement was estimated as 1 tonne for equivalent amount of cement produced. It was estimated that the cement industry contributes nearly 7% in the overall release of the carbon emissions into the atmosphere. The increasing demand and urge to construct the concrete structures for different purposes made the usage of cement concrete mandate in the construction

DOI= http://dx.doi.org/10.20902/IJCTR.2019.130114

industry. Regarding the environmental pollution with the use of cement concrete, there is a need to find the alternate material to the cement. Extensive research has been done in the area of replacement of cement with different cementititous materials up to certain limitations which reduces the CO_2 emissions to a considerable extent. Davidovits(1971) coined a term “Geopolymer Concrete” which has a sustainability to replace the cement content completely in the concrete with the use of source material which are rich in silica and alumina by using the chemicals like NaOH and Na_2SiO_3 as alkaline liquids. Rao G.M et al., (2015) concluded that the molarity concentration of NaOH did not shown considerable effect on the normal consistency of the geopolymer mortar and also with the increases in the content of GGBS, higher compressive strengths were reported. Kashyap et al(2018) reported that as the fly ash content increases, the initial and final setting times of the geopolymer concrete also decreases and also as the ground granulated blast furnace slag content increases, higher compressive strengths were attained by the geopolymer mortar.

2.0 Materials

The Ground granulated blast furnace slag was procured from the Vizag Steel Plant, which is a waste residue and the fly ash is obtained from the Vijayawada Thermal Power Station, Vijayawada which is of Class F and the Metakaoline is obtained from National Chemicals, Vijayawada and the alkaline solutions Sodium Silicate , Sodium Hydroxide were also produced from the same. The physical and chemical properties of the ground granulated blast furnace slag, fly ash and metakaoline are as follows:

Table 1 : Physical and Chemical Properties of GGBS, Fly Ash and Metakaoline

S.No	**Description**	**GGBS**	**Fly Ash**	**Metakaoline**
1.	Colour	Grey	Grey	Pink
2.	Specific Gravity	2.86	2.65	2.7
Chemical Composition				
1.	Silicon dioxide (SiO_2)	39.18	66.80	53
2.	Aluminum Oxide (Al_2O_3)	10.18	24.50	43
3.	Iron Oxide (Fe_2O_3)	2.02	4	1.2
4.	Calcium Oxide(CaO)	32.82	1.50	0.5
5.	Magnesium Oxide(MgO)	8.52	0.45	0.4
6.	Sodium Oxide(Na_2O)	1.14	0.40	-
7.	Potassium Oxide(K_2O)	0.30	0.22	-

Fine aggregate used in the present study is of Zone-III confirming to IS:383-1987 standards. The specific gravity was found to be 2.67.Coarse aggregate of sizes 20 mm, 12 mm and 6 mm were used. The 6 mm aggregate is used so as to fill the voids. The NaOH of 12 Molarity Solution is used in the present study. The Na_2SiO_3 to NaOH adopted in this study was 2.5.

3.0 Mix Design

Mix Design for normal grade M30 concrete was done according to the standards of IS:10262:2009 code of practice and the mix design is as follows:

S.No	**Constituents**	**M30 grade Quantity(kg/m^3)**
1.	Binder content(GGBS+Fly ash)& (GGBS+MK)	405
2.	Fine aggregate	683.13
3.	Coarse aggregate	1268.66
4.	Sodium Silicate solution	70.8
5.	Sodium Hydroxide solution	28.3
6.	Admixture (1.5%)	6.075
7.	Extra water (10%)	40.5

4.0 Concrete Preparation

Geopolymer Concrete is prepared using the traditional techniques as used in the preparation of Cement Concrete. The sources materials, i.e., GGBS,FA,MK with different proportions by weight are mixed together in the dry condition in a pan mixer. Later, the alkaline solution which has the solutions of NaOH and Na_2SiO_3 of desired molarity i.e., 12 M which is prepared prior 1 day to casting, is added to the binding material until a homogeneous mix is achieved and the mixture is placed in the cube, cylinder and beam specimens to predict the mechanical properties of the geopolymer concrete. The specimens are demolded after 24 hr of ambient curing. During this process, the fresh properties of the geopolymer mix will be determined. The normal consistency, initial and final setting times of geopolymer mortar mix was done satisfying the requirements of IS: 4031 (Part IV-1988).

5.0 Test Results

The fresh and hardened properties of the blended geopolymer concrete as are as follows

Table 1: Fresh Properties of the blended geo polymer concrete

S.No	Mix Designation	Percentage of alkaline activator required to produce geopolymer paste (P)	Final Setting Time (mins)	Slump Values (mm)
1.	M1- FA 100%	27	235	95
2.	M2 - GGBS 100%	39	50	80
3.	M3-(GGBS+FA)(50%+50%)	33	100	90
4.	M4-(GGBS+MK)(50%+50%)	34	585	90

From table 1, it is evident that the percentage of alkaline activator required to produce geopolymer paste was less for fly ash and more for ground granulated blast furnace slag and also the combination of GGBS+FA requires 33% and for GGBS+MK requires 34%. The final setting time for GGBS is less and the mix M4 where the Metakaoline is used the final setting time is observed at 585 minutes. It can be concluded that with the use of metakaoline in geopolymer concrete, the setting time enhances drastically.

Table 2 : Mechanical properties of M30 grade geopolymer concrete with different combinations of mineral admixtures in ambient curing condition

S.No	Mix Designation	Compressive Strength after 28 days of ambient curing (MPa)	Split tensile Strength after 28 days of ambient curing (MPa)	Flexural Strength after 28 days of ambient curing (MPa)
1.	M1- FA 100%	36.88	3.98	2.56
2.	M2 - GGBS 100%	39.55	4.12	5.78
3.	M3-(GGBS+FA)(50%+50%)	39.00	4.82	5.83
4.	M4-(GGBS+MK)(50%+50%)	20.44	1.98	2.20

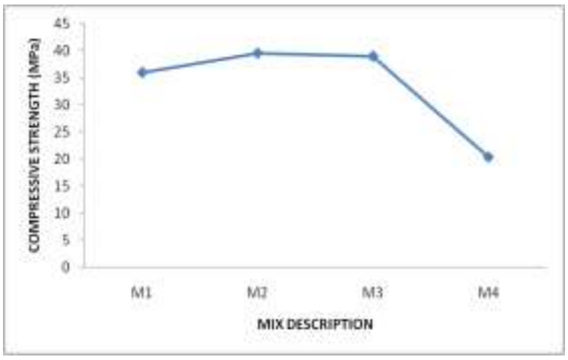

Fig.1 Variation in compressive strength mineral admixtures after 28 days

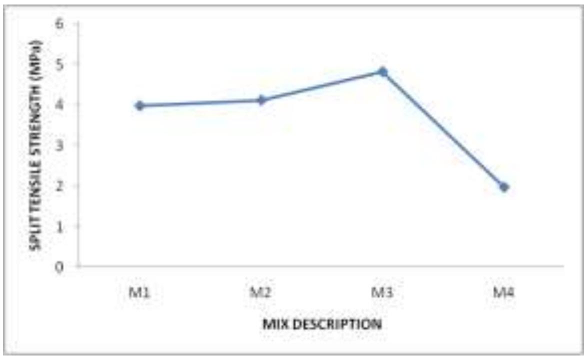

Fig.2 Variation in split tensile strength with different different mineral admixtures after 28 days

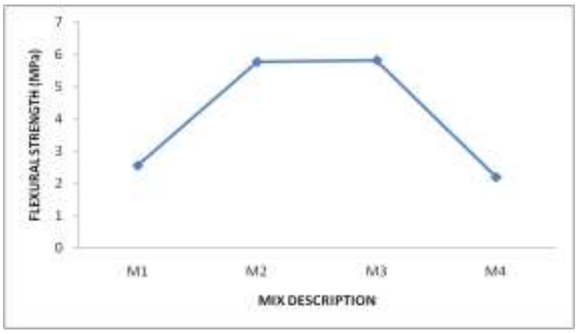

Fig.3 Variation in flexural strength with different mineral admixtures after 28 days

From table 2, fig.1,2,3 it is evident that use of fly ash and ggbs in the geopolymer concrete gives satisfactory results in complete replacement individually or by blending too. The compressive strength of fly ash 100% was found to be 36.88 MPa and for ggbs 100% was found to be 39.55 and the blending of ggbs with fly ash achieved a compressive strength of 39.00 MPa and the blending of ggbs with metakaolineachieved a compressive strength of 20.44 Mpa and it can be concluded that the use of metakaoline in the preparation of geopolymer concrete is not feasible.

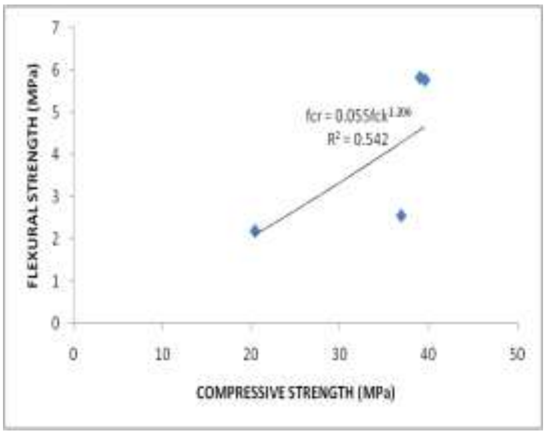

Fig.4 Relationship between compressive Strength and flexural strength of GPC

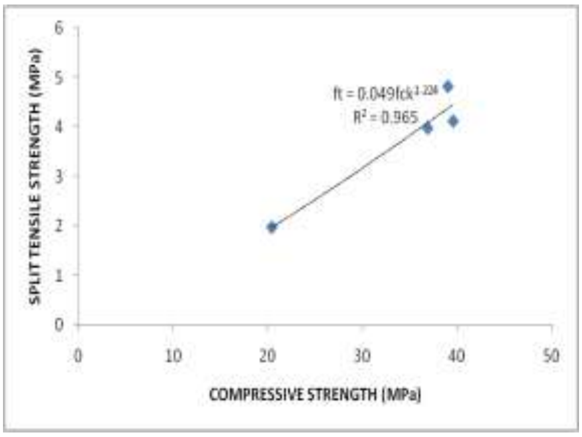

Fig.5 Relationship between compressive and split tensile strength of GPC

Table 3 : Various relationship equations proposed

Code	Country	Relationship
IS: 456-2000	INDIA	$f_{cr}=0.7\sqrt{fck}$
ACI	USA	$f_{cr}=0.62\sqrt{f^{1}_{ck}}$
NZS-3101	NEWZEALAND	$f_{cr} = 0.60\sqrt{f_{ck}}$
EC-02	EUROPE	$f_{cr} = 0.201\sqrt{f^{1}_{ck}}$
BS-8110	BRITIAN	$f_{cr}= 0.60\sqrt{f_{ck}}$
ACI Committee 318 (1999)	USA	$fsp = 0:56\sqrt{f_{ck}}$
Carneiro and Barcellos (1953)	-	$fsp= 0:34fc^{0:735}$
Carino and Lew (1982)	-	$fsp = 0:272fck^{0.71}$
Oluokun et al. (1991)	-	$fsp= 0:294fck^{0:69}$
Selim (2008)	-	$fsp= 0:106fc^{0:948}$

where f_r = modulus of rupture (flexural strength) at 28 days in N/mm^2.

f_c = cube compressive strength at 28 days in N/mm^2, and

fc' = cylinder compressive strength at 28 days in N/mm^2.

f_{sp}= Splitting tensile strength at 28 days in N/mm^2

The relationship between the compressive strength and flexural strength of M30 grade geopolymer concrete proposed in this study is

$f_{cr}= 0.055f_{ck}^{1.206}$; $R^2= 0.542$ ------------------(1)

The relationship between the compressive strength and split tensile strength of M30 grade geopolymer concrete proposed in this study is

$f_t= 0.049f_{ck}^{1.244}$; $R^2 = 0.965$ ------------------(2)

The experimental results are correlated with the theoretical results and a good agreement was found between them.

6.0 Conclusions

1. The blending of ground granulated blast furnace slag with fly ash shows better results than the blending with metakaoline.
2. Target Strengths were not achieved when metakaoline is used as blending material for ground granulated blast furnace slag.
3. A good agreement was attained between the theoretical and experimental results.

7.0 References

1. Kashyap A.M.N, Rao.T.C.,Rao N.V.R., "Prediction Of Setting And Strength Characteristic Of Binary Blended Geopolymer Matrix", i-manager publications, Volume 6. No. 4, December 2017 - February 2018, ISSN : 2278-7887.
2. Rao.G.M., Rao.T.D.G (2015),"Final Setting Time and Compressive Strength of Fly Ash and GGBS-Based Geopolymer Paste and Mortar", Arabian Journal for Science and Engineering, ISSN 1319-8025, Arab J SciEng, DOI 10.1007/s13369-015-1757-z.
3. Davidovits, J.: Properties of geopolymer cements. In: First International Conference on Alkaline Cements and Concretes. SRIBM, Kiev State Technical University, Kiev, Ukraine, pp. 131–149(1994).
4. Daniel, K., Sanjayan, J., Sagoe-Crentsil, K.: The behaviour of geopolymer paste and concrete at elevated temperatures. In: International Conference on Pozzolan, Concrete and Geopolymer, KhonKaen, Thailand, pp. 105–118 (2006)
5. Davidovits, J.; Comrie, D.C.; Paterson, J.H.; Ritcey, D.J.: Geopolymeric concretes for environmental protection. ACI Concr.Int.J. 12(7), 30–40 (1990).

6. van Jaarsveld, J.G.S.; van Deventer, J.S.J.; Lukey, G.C.: The effectof composition and temperature on the properties of fly ash and kaolinite-based geopolymers. Chem. Eng. J. 89, 63–73 (2002).
7. Douglas, E.; Bilodeau, A.; Brandstetr, J.: Alkali activated groundgranulated blast-furnace slag concrete: preliminary investigation. Cem.Concr.Res. 21, 101–108 (1991).
8. 8.IS: 383, Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian standards, New Delhi (1970).
9. IS: 4031–1988 (PART 4). Method of Physical Test for Hydraulic Cement—Determination of Standard Consistency of Cement Paste.Bureau of Indian Standards, New Delhi (1988).
10. 10.Hardjito, D.; Wallah, S.E.; Sumajouw, D.M.J.; Rangan, B.V.: On the development of fly ash-based geopolymer concrete. ACI Mater. J. 101(M52), 467–472 (2004)

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