iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** XI **Month of publication:** November 2018

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

An Experimental Study on Geopolymer Concrete with Flyash and Metakaolin Source Materials

Padala Hemanth Reddy[1], Kolagani Srinivasa Rao[2]
[1, 2]Universal College of Engineering and Technology

Abstract:** The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and Metakaolin and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na2Sio3). 10Molar Sodium hydroxide is taken for the preparation of different mixes by varying the percentages of GGBS (Ground granulated blast furnace slag) and Metakaolin. The cube specimens are taken of size 150mm x 150mm x 150mm for compression test. The curing was done directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength at the age of 3, 7 and 28days and compared with conventional concrete. For this study M30 concrete mix was used for experimental work. The result shows that there is an increase in the strength of Geopolymer concrete up to 40%GGBS content and then it is decreasing. Therefore it is preferable to use 40%GGBS with metakaolin to get high strength. Metakaolin and GGBS can be used as a replacement material for cement gives an excellent result in strength aspect and quality aspect since it is better than the control concrete.

I. INTRODUCTION

A. Geopolymer Concrete

The term "geo polymer" was first used by J. Davidovits in the late 1970sand nowadays identifies a family of amorphous alkali or alkali-silicate activated alumino silicate binders of composition M2O·*m*Al2O3·*n*SiO2, usually with $m \approx 1$ and $2 \leq n \leq 6$ (M usually is Na or K) This is a broadly termed "inorganic polymer". In the synthesis of geo polymer, the chemical reaction may consist of the following steps:

1) Dissolution of Si and Al atoms from the source material through the action of hydroxide ions,
2) Transportation, orientation or condensation of precursor ions into monomers,
3) Setting or polycondensation/polymerisation of monomers into polymeric structures

B. Metakaolin-Flyash Based Geopoymer

In this work, Metakaolin-Fly ash based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The Metakaolin-Fly ash based Geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.

As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in Geopolymer concrete. The silicon and the aluminum in the Metakaolin-Fly Ash react with an alkaline liquid that is a combination of sodium silicate(A53) and sodium hydroxide solutions of different molarities like 8M to 16M can be used but in our project we have used 8M, 10M and 12M only to form the Geopolymer paste that binds the aggregates and other un-reacted materials.

II. REVIEW ON GEOPOLYMER CONCRETE

1) *Joseph Davidovits* found that Flyash reacted with alkaline solution and formed a binding material.
2) *Hardijito & Rangan* observed that higher concentration of sodium hydroxide (molar) resulted higher compressive strength and higher the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass, showed higher compressive strength of geopolymer concrete. They also found that the increased in curing temperature in the range of 30 to 90 °C increased the compressive strength of geopolymer concrete and longer curing time also increased the compressive strength. They handled the

geopolymer concrete up to120 minutes without any sign of setting and without any degradation in the compressive strength, resulted very little drying shrinkage and low creep.

3) *Suresh Thokchom etal* reported that the Geopolymer mortar specimens manufactured from fly ash with alkaline activators were structurally intact and did not show any recognizable change in colour after 18 weeks exposure in 10% sulfuric acid solution and the Geopolymer Concrete was high resistance against sulfuric acid.
4) *D. Bondar etal* indicated that the strength of geopolymer concrete decreased as the ratio of water to geopolymer solids by mass increased. Anuar etal revealed that the concentration (in term of molarity) of NaOH influenced the strength characteristic of geopolymer concrete.
5) *S. Vaidya etal* examined that uniform temperature was developed throughout the mass and Elastic Modulus and Poission's ratio were within the acceptable limits.
6) *Raijiwala etal* noticed that the Compressive strength of GPC increased over controlled concrete by 1.5 times (M-25 achieves M-45), Split Tensile Strength of GPC increased over controlled concrete by 1.45 times and Flexural Strength of GPC increased over controlled concrete by 1.6 times.
7) *Muhd An Fadhil Nuruddin etal* recommended thatcast in-situ application in Geopoymer concrete is a viable one.
8) *Douglas etal* successfully used Geopolymer Concrete in waste stabilization.Geopolymer Concrete immobilized chemical toxins and reduced leachate level concentrations.

III. THE MOST COMMONLY USED POZZOLANIC MATERIALS

A. Metakaolin

Metakaolin is a calcined product of the clay mineral kaolinite. The Particle size of Metakaolin is smaller than cement particles, but not as fine as silica fume. When kaolinite, a layered silicate mineral with a distance of 7,13 A between the layers of Sio_2 and Al_2O_3 is heated, the water contained between the layers is evaporated and the kaolinite is activated for reaction with cement.

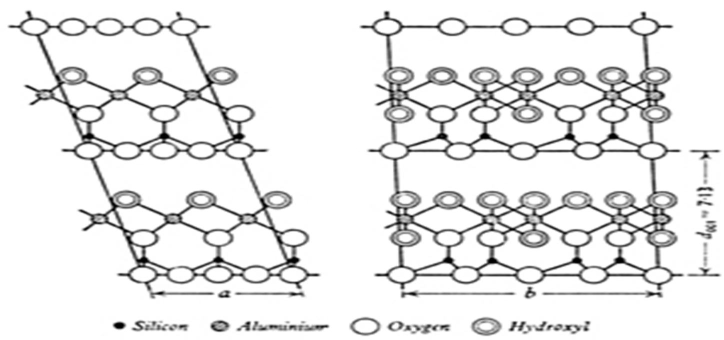


Figure1. Metakaolin structure

B. Chemical And Physical Properties Of Pozzolanic Materials

The following table gives the chemical properties of the above Materials. However, the values given here are only to appreciate the range and percentage of each of the elements contained in them.

Chemical composition	Fly Ash (%)	GGBFS (%)	Silica Fume (%)
SiO2	35.8-42.83	32.6	90.11
Al2O3	18.0-26.9	12.8	1.63
Fe2O3	6.5-8.2	1.3	1.98
MgO	3.5-4.1	7.2	0.78
SO3	2.2-3.5	0.03	--
Na2O+K2O	--	--	1.97
P2O5	--	0.05	1.18
CaO	18.8-19.8	41.0	--
Moisture(H2O)	0.2-1.9	--	--

Table 1:Chemical and physical properties of Pozzolanic Materials

Physical property	Silica Fume	Fly Ash	Cement
SiO_2 Content	85-97	35-48	20-25
Surface Area m^2/kg	17,000-30,000	400-700	300-500
Pozzolanic activity(with cement%)	120-210	85-110	n/a
Pozzolanic activity(with lime%)	1,200-1,660	800-1,000	n/a
(MPa)	(8.3-11.4)	(5.5-6.9)	

Table 2:Comparison of Chemical and Physical Characteristics - Silica Fume, Fly Ash and Cement.

IV. MATERIALS

A. Cement
Ordinary Portland Cement of "BHARATHI" brand 53 GRADE confirming to Indian standards is used in the present investigation. The cement is tested for its various properties as per IS: 4031-1988 and found to be confirming to the requirements as per IS: 8122-1989.

B. Fine Aggregate
The sand obtained from Krishna River near Vijayawada is used as fine aggregate in this project investigation. The sand is free from clayey matter, silt and organic impurities etc. The sand is tested for specific gravity, in accordance with IS: 2386-1963 and it is 2.719, where as its fineness modulus is 2.31. The sieve analysis results are presented in table. The sand confirms to zone-II.

C. Metakaolin
Metakaolin is obtained from the Kaomine industries PVT LTD at Vadodara on Gujarat state. The specific gravity of Metakaolin is 2.6 and the size of particle is less than 90 microns. The colour of metakaolin is pink.
Chemical formula of Metakaolin is Al2O3·2SiO2·2H2O.
Table:5 shows the Chemical compositions of Metakaolin. The chemical composition of Metakaolin is similar to Portland Cement.

Chemicals	Percentage (%)
SiO_2	62.62
Al_2O_3	28.63
Fe_2O_3	1.07
MgO	0.15
CaO	0.06
Na_2O	1.57
K_2O	3.46
TiO_2	0.36
LOI	2.00

Table 5: Chemical composition of Metakaolin

Figure1.Buff colored Metakaolin

CERTIFICATE OF ANALYSIS

METAKAOLIN

+/- 300 MESH W/W	3.0 % MAX
-2 MICRON W/W	50. 0% MIN.
MOISTURE W/W	0. 5 – 1.0%% (MAX.)
METAKAOLIN CONTENT	97.0 % MIN.
REACTIVE WITH LIME (MgCa(OH)2/gm)	1000

TYPICAL ANALYSIS:	
PHYSICAL:	
APPEARANCE	OFF – WHITE
PH (10% SOLIDS)	4.5 – 5. 5
BULK DENSITY (Kg/Lit0	0. 4 – 0. 5
SPECIFIC SURFACE AREA m2/g (BET)	19 – 20
SPECIFIC GRAVITY	2. 6

CHEMICAL (MASS%)	
SiO2	52. 0
Al2O3	46. 0
Fe2O3	0. 60 (MAX.)
TiO2	0. 65 (MAX.)
CaO	0. 09 (MAX.)
MgO	0. 03 (MAX.)
Na2O	0. 10 (MAX.)
K2O	0. 03 (MAX.
LOSS ON IGNITION	1. 00

Table 6:Properties of White Metakaoline obtained from the astrra chemicals, MOORES ROAD, THOUSAND LIGHTS, CHENNAI - 600 006

D. Fly Ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash that does not rise is called bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide(CaO), both being endemic ingredients in many coal-bearing rock strata.

Content of the component, %							
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	$K_2O + Na_2O$	LOI
60.5	30.8	3.6	1.4	0.91	0.14	1.1	0.8

LOI – Loss of ignition

Table 7:Properties of the fly ash obtained from Vijayawada Thermal Power Station

E. Alkaline Solution

The most common alkaline liquid used in geopolymerisation is a combination of

1) sodium hydroxide (NaOH) and
2) sodium silicate (Na_2SiO_3).

The following tabular column shows the physical Tests results of Bharathi opccement

S.NO	PHYSICAL TESTS	OBTAINED RESULTS	REQUIREMENTS AS PER IS CODES
1	Fineness	2.6%	Not>10% as per IS 4031 part 1
2	Standard Consistency	27.5%	IS 4031 part 4
2	Initial Setting time	47min11sec	Not less than 30 minds as per IS 4031 part 5
3	Final setting time	498 min	Not more than 600 minutes as per IS 4031 part 5
4	Soundness	5mm	Not>10mm as per IS 4031 part 3
5	Specific gravity	3.01	IS 2720 part 3(3.15isgeneral value)

Table 11: physical Tests results of Bharathi opc cement

The following tabular column shows the physical Tests of Aggregates which were used in Geopolymer concrete.

Sl. No	Physical Tests	Obtained results	Requirements as per IS 383
1	Crushing Test	38%	Not more than 45% (other than wearing surfaces)
2	Impact Test	32.95%	Not more than 45% (other than wearing surfaces)
3	Los Angeles Abrasion Test	28.5%	Not more than 50% (other than wearing surfaces)
4	Flakiness Index	20.12%	Not > 35% as per MORTH
5	Specific gravity		
	a) Coarse Aggregates	2.8	
	b) Fine Aggregates	2.6	
6	Water absorption		Not>2%as per IS:2386-Part 3
	a) Coarse Aggregates	0.2%	
	b) Fine Aggregates	0.5%	

Table 12: Tests Results of aggregate

F. Compressive Strength For Conventional And Geopolymer Concrete Mixes

The following are the various results obtained for concrete and the values are tabulated as below.

S. No	Time(Days)	Compressive Load Kn	Compressive Strength N/Mm2	Average Strength N/Mm2
1	3	345	15.1	15.11
		350	15.2	
		355	15.26	
2	7	470	20.81	20.87
		480	21.11	
		475	21.1	
3	28	870	38.28	38.28
		870	38.28	
		860	38.22	

Table15: Compressive Strength Of Concrete Form30 Control Mix For 3,7,And 28 Days

S.No	Percentage Of Metakaolin And Flyash In Mixture	3days N/Mm2	7days N/Mm2
1	100% Fly Ash	Fail	Fail
2	100% White Mk	Fail	Fail
3	80%White Mk+20%Flyash	Fail	Fail
4	70%White Mk+30%Flyash	Fail	Fail
5	60%White Mk+40%Flyash	Fail	Fail
6	50%White Mk+50%Flyash	Fail	Fail

Table16: Compressive Strength Of Concrete For Different % Of Fly Ash And White Metakaolin For 3 And 7 Days At Air Dry Curing

S.No	Percentage Of Metakaolin And Flyash In Mixture	3days N/Mm2	7days N/Mm2
1	100% Fly Ash	Fail	Fail
2	100% White Mk	Fail	Fail
3	80%White Mk+20%Flyash	Fail	Fail
4	70%White Mk+30%Flyash	Fail	Fail
5	60%White Mk+40%Flyash	Fail	Fail
6	50%White Mk+50%Flyash	Fail	Fail

Table17: Flexural Strength Of Concrete For Different % Of Fly Ash And White Metakaolin

For 3 And 7 Days At Air Dry Curing

S.No	Percentage Of Metakaolin And Flyash In Mixture	3days N/Mm2	7days N/Mm2
1	100% Fly Ash	Fail	Fail
2	100% Buff Mk	45.12	48.56
3	80%Buff Mk+20%Flyash	46.12	49.67
4	70%Buff Mk+30%Flyash	39.37	42.56
5	60%Buff Mk+40%Flyash	33.65	35.72
6	50%Buff Mk+50%Flyash	30.37	32.86

Table18: Compressive Strength Of Concrete For Different % Of Fly Ash And Buff

Metakaolin With 12m Solution For 3 And 7 Days At Air Dry Curing

S.No	Percentage Of Metakaolin And Fly Ash In Mixture	3days N/Mm2	7days N/Mm2
1	100% Fly Ash	Fail	Fail
2	100% Buff Mk	Fail	Fail
3	80%Buff Mk+20%Flyash	Fail	Fail
4	70%Buff Mk+30%Flyash	Fail	Fail
5	60%Buff Mk+40%Flyash	Fail	Fail
6	50%Buff Mk+50%Flyash	Fail	Fail

Table19: Flexural Strength Of Concrete For Different % Of Fly Ash And Buff Metakaolin

With 12m Solution For 3 And 7 Days At Air Dry Curing

S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	Fail	Fail
2	10M	Fail	Fail
3	12M	Fail	Fail

Table 20: Compressive Strength Of Concrete For 100 % white Metakaolin For 3 And 7 Days

At Air Dry Curing

S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	Fail	Fail
2	10M	Fail	Fail
3	12M	Fail	Fail

Table:21 Compressive Strength Of Concrete For 100 % white Metakaolin For 3 And 7 Days

At Air Dry Curing

S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	Fail	Fail
2	10M	Fail	Fail
3	12M	Fail	Fail

Table:22 flexural Strength Of Concrete For 100 % white Metakaolin For 3 And 7 Days At Air

Dry Curing

S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	43.59	44.67
2	10M	45.12	48.56
3	12M	48.97	49.89

Table:23 Compressive Strength Of Concrete For 100 % buff Metakaolin For 3 And 7 Days

At Air Dry Curing

S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	Fail	Fail
2	10M	Fail	Fail
3	12M	Fail	Fail

Table:24 flexural Strength Of Concrete For 100 % buff Metakaolin For 3 And 7 Days At Air Dry Curing

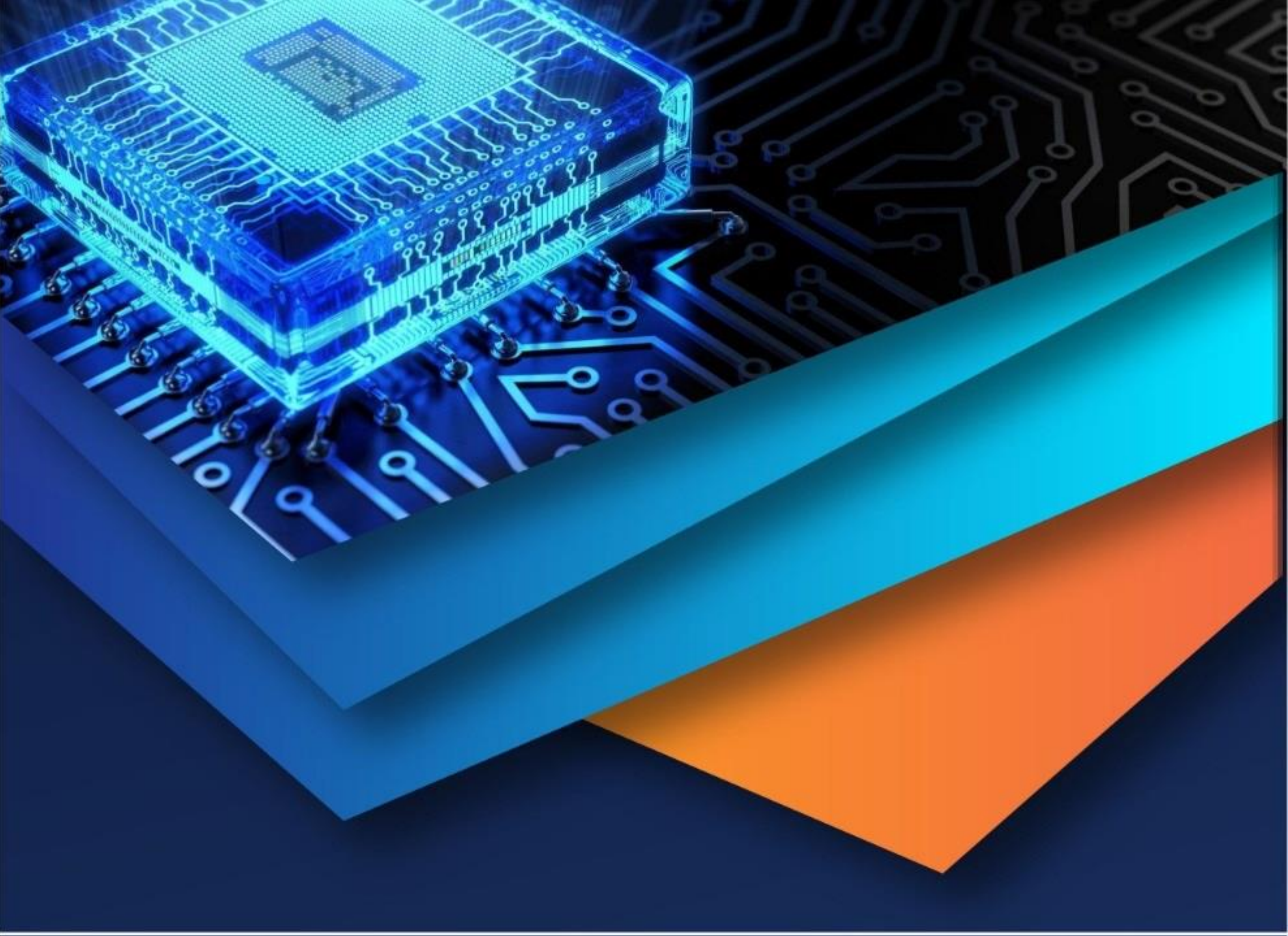
V. CONCLUSIONS

A. From the above results it is appearent that the alkaline solution is not showing any positive results on Geopolymer concrete based on flyash and white metakaoline
B. The alkaline solutions with 8M, 10M and 12M also not showing positive results on geopolymer concrete with 100% white metakaoline
C. Buff colored metakaoline was activily participating in the formation of polymerization when it is used as a binding material with alkaline solution and fly ash in the preparation of geopolymer concrete
D. The compressive strength of the geopolymer concrete with metakaoline and fly ash is good when the percentage of fly ash is upto 20% beyond that the strength is decresing
E. The compressive strength of geopolymer concretewith 100% buff colored metakaoline is increasing with increasing in the molarity of the solution
F. Combination of different percentages white metakaoline and flyash, buff metakaoline and flyash are failed in flexural strength point
G. Both white and buff colored metakaoline with 8M, 10M and 12M are very week in flexural strength
H. The strength of the Geopolymer concrete is increasing with the increase in fly ash content upto 20% and then reduces, so it is preferable to use flyash upto 20% in the mixesin air dry curing, this is happening because if we use flyash we should go for oven or steam curing
I. The strength of the Geopolymer concrete increases with 2%-4% from 7 to 28 days that means there is no much increase in the strength after 4 days.
J. By using the Metakaolin and flyash as a filler or replacement in cement will reduce environmental pollution.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

REFERENCES

[1] Davidovits, J. 1984. "Pyramids of Egypt Made of Man- Made Stone, Myth or Fact?" Symposium on Archaeometry 1984. Smithsonian Institution, Washington, DC.
[2] Davidovits, J. 2008. Geopolymer Chemistry and Applications. Institut Géopolymère, Saint-Quentin, France.
[3] Geopolymer Institute. 2010. What Is a Geopolymer? Introduction. Institut Géopolymère, SaintQuentin, France. Accessed on January 29, 2010, at http://www.geopolymer.org/science/introduction.
[4] Hardjito, D., S. Wallah, D. M. J. Sumajouw, and B. V. Rangan. 2004. "On the Development of Fly Ash– Based Geopolymer Concrete." ACI Materials Journal, vol. 101, no. 6.
[5] Rangan, B. V.. "Low-Calcium, Fly-Ash-Based Geopolymer Concrete." Concrete Construction Engineering Handbook. Taylor and Francis Group, Boca Raton, FL, 2008.
[6] Lloyd, N., and V. Rangan. 2009. "Geopolymer Concrete—Sustainable Cementless Concrete." ACI Special Publication SP-261, 10th ACI International Conference on Recent Advances in Concrete Technology and Sustainability Issues. American Concrete Institute, Farmington Hills, MI.
[7] Recent Research Geopolymer Concrete- Nguyen Van Chanh Bui Dang Trung, Dang Van Tuan during the 3rd ACF International Conference-ACF/VCA 2008.
[8] Suresh Thokchom, Partha Ghosh and Somnath Ghos – Resistance of Fly Ash based Geopolymer Mortars in Sulfuric Acid- ARPN Journal of Engineering and Applied SciencesVOL. 4, NO. 1, FEBRUARY 2009.
[9] D. Bondar(a), C. J. Lynsdale(b), N. B. Milestone(c), N. Hassani(d), and A. A. Ramezanianpour - Engineering Properties of Alkali Activated Natural Pozzolan Concrete –Second International Conference, University of Wisconsin,June2010.
[10] Anuar K.A, Ridzuan A.R.M., Ismail S., Universiti Teknologi MARA 40450 Shah Alam, Selangor, Malaysia, Strength Characteristic of Geopolymer Concrete - International Journal of Civil & Environmental Engineering, Vol: 11 No: 01 February2011.
[11] S. Vaidya and etal- Experimental evaluation of Self cure Geopolymer concrete for mass pour application – World Coal Ash Conference,2011.
[12] Raijiwala D.B.1 Patil H. S – Geopolymer Concrete- a Concrete of next decade, Journal of Engineering Research and Studies., March 2011.
[13] Muhd Fadhil Nuruddin, Andri Kusbiantoro, Sobia Qazi, Nasir Shafiq- Compressive Strength and Interfacial Transition Zone Characteristic of Geopolymer Concrete with Different Cast In-Situ Curing Conditions, World Academy of Science, Engineering and Technology, 2011.
[14] Douglas C. Comrie, John H. Paterson & Douglas J. Ritcey, D. Code Consulting Ltd, Boulevard East, Mississauga, Ontario - Applications of geopolymer technology to waste stabilization.
[15] A Study On Strength Properties Of Geopolymer Concrete With Addition Of G.G.B.S, Ganapati Naidu. P, A.S.S.N.Prasad,International Journal of Engineering Research and Development eISSN : 2278-067X, pISSN : 2278-800X,Volume 2, Issue 4 (July 2012), PP. 19-28
[16] Strength, Economic And Sustainability Characteristics Of Coal Ash –Ggbs Based Geopolymer Concrete. Mr. Bennet Jose Mathew, Mr. M Sudhakar, International Journal Of Computational Engineering Research (ijceronline.com) Vol. 3 Issue.1 ,2012
[17] A Review On Use Of Metakaolin In Concrete, Aiswarya S, Prince Arulraj G, IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498,Vol.3, No.3, June 2013
[18] Mechanical Properties Of Geopolymer Concrete With Fly Ash And Ggbs As Source Materials, B. Rajini1, A.V. Narasimha Rao, International Journal of Innovative Research in Science, Engineering and Technology'Vol. 3, Issue 9, September 2014
[19] A Review on Use of Metakaolin in Cement Mortar and Concrete, Dr.K.Srinivasu, M.L.N.Krishna Sai, Venkata Sairam Kumar.N, International Journal of Innovative Research in Science, Engineering and Technology'Vol. 3, Issue 7, September 2014
[20] Effect of Metakaolin Content on the Properties of High StrengthConcrete, P. Dinakar*, Pradosh K. Sahoo, and G. Sriram, International Journal of Concrete Structures and Materials,Vol.7, No.3, pp.215–223, September 2013
[21] A review: The comparison between alkali-activated slag (Si+Ca) and metakaolin (Si+Al) cements,Chao Li a,*, Henghu Sun a,b, Longtu Li, Cement and Concrete Research 40 (2010) 1341–1349,elsvier journal.
[22] Experimental study on Geo-Polymer concrete incorporating GGBS,V. Supraja, M. Kanta Rao, International Journal of Electronics, Communication & Soft Computing Science and Engineering ,ISSN: 2277-9477, Volume 2, Issue 2



doi crossref
10.22214/IJRASET

INDEX COPERNICUS
45.98

ISRA JIF
IMPACT FACTOR:
7.129

SJIFactor
TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY