ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

An Experimental Study on Geo-Polymer Concrete with Fly Ash and Metakaolin as Source Materials

Chunchu Bala Rama Krishna
Post Graduate Student,
Sunflower College of Engineering and Technology,
Lankapalli, Krishna District A.P.

Mr.M.Rama KRishna, M.E
Associate Professor, HoD,
Sunflower College of Engineering and Technology,
Lankapalli, Krishna District A.P.

Abstract:

Concrete is the most abundant used man made material in the world. One of the main ingredients of concrete mixture is Ordinary Portland Cement (OPC) which is the second most utilized material after water. The amount of the CO2 released during the manufacturing of OPC is nearly one ton for every ton of OPC produced and is responsible for approximately 7% of the world's carbon dioxide emissions. In order to create a more sustainable world, innovators are developing and using a greener building material, one of them is geopolymer Concrete.

This paper discusses various combinations of Metakoline and Fly Ash, as source material, to produce geopolymer concrete at room temperature. It has been generally accepted that heat treatment is required for producing geopolymer concrete which is considered a drawback affecting its applications. In this paper variation of source material i.e. various combination of Fly ash and Metakaoline and at various molarities like 8M, 10M and 12M is done to achieve compressive strength and flexural strength for medium grade of concrete of M-30.Air dry curing is done. It is found that geopolymer concrete with Metakoline and Fly ash as decrease its strength and on other hand shows good strength with increase in the molarity of the alkaline solutions.

Keywords: ***Geopolymer Concrete, Fly Ash, Metakaolin, A53 Solution, NaoH Solution, Curing, Compressive Strength, Flexural Strength***

INTRODUCTION

1.1 GEOPOLYMER CONCRETE

The term "geopolymer" was first used by J. Davidovits in the late 1970sand nowadays identifies a family of amorphous alkali or alkali-silicate activated aluminosilicate binders of composition $M_2O{\bullet}mAl_2O_3{\bullet}nSiO_2$, 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 geopolymer, 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

Moreover supersaturated aluminosilicate solution (SAS) is created and the time for the SAS to form a continuous gel varies considerably with: raw materials, solution composition, processing and synthesis conditions.The synthesis of geopolymers takes place starting from reactive precursors such as metakaolin (kaolinite calcined at 600–700 °C) or many other natural and artificial silico-aluminates, which are mixed with alkali metal (Na or K) hydroxide and/or silicate solutions.

When in contact with a high pH alkaline solution, aluminosilicate reactive materials release free SiO_4 and AlO_4 tetrahedral units which afterwards condensate to form a rigid network. Geopolymer based materials are attractive because excellent mechanical properties, high early strength, freeze-thaw resistance, low chloride diffusion rate, abrasion resistance, thermal stability and fire resistance, can be achieved. Due to their lower calcium content, they are more resistant to acid attack than Portland cement based materials. In addition, geopolymer based materials are of great interest because of the reduced energy requirement for their manufacture.

In fact, the reaction pathway requires either metakaolin or raw silico-aluminates so that greenhouse gas emissions can be reduced up to 80% in comparison to traditional cement basedmaterials. In fact, even if natural aggregates are substituted by sustainable artificial ones,manufactured by using industrial wastes, the emissions of CO2 in concrete industry is mainly linked to the use of ordinary Portland cement as a binder. Geopolymer can be made from fly ash, slag or calcined kaolin (metakaolin). Geopolymers have received considerable attention from scientists worldwide, because of their low cost, excellent mechanical and physical properties, low energy consumption and reduced “greenhouse emissions” at the elaboration process. Geopolymer can be used as a binder instead of Portland cement paste, to produce concrete. Concretes based on fly ash and metakaolinegeopolymers have been synthesizedand characterized however, limited research can be found in current literature regarding concrete based on fly ash and metakaolingeopolymer.

1.2 OBJECTIVE

The main objective of using this Metakaolin and Fly ash is to reduce environmental pollutions like water pollution, air pollution and disposal problems on agricultural lands.

- To overcome all the above effects we are using the Metakaolin and Fly ash as a cement replacement material in different proportions for the preparation of concrete, by this we can reduce the usage of natural resources and emission of carbondioxide in the atmosphere.
- With the use of metakaoline we can attain early strength

2.0 MATERIALS

2.1 MATERIALS USED IN THE PROJECT

The materials used in the project are as follows:

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- Metakaolin
- Fly Ash
- Alkaline solution

2.1.1 Cement

Ordinary PortlandCement 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.

2.1.2 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.

2.1.3 Coarse aggregate

Machine crushed angular Basalt metal used as coarse aggregate. The coarse aggregate is free from clayey matter, silt and organic impurities etc. The coarse aggregate is also tested for specific gravity and it is 2.68. Fineness modulus of coarse aggregate is 4.20. Aggregate of nominal size 20mm and 10mm is used in the experimental work, which is acceptable according to IS: 383-1970.

2.1.4 Water

The locally available potable water, which is free from concentration of acid and organic substances, is used

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

for mixing the concrete as well as preparing the alkaline solution

S. NO	PARAMETER	RESULTS	PERMISSIBLE LIMITS AS PER IS 456-2000
1	Organic	46 mg/lit	200 mg/lit
2	In organic	386 mg/lit	3000 mg/lit
3	Sulphates	40.32 mg/lit	400 mg/lit
4	Chloride	51.77 mg/lit	2000 mg/lit Fire concrete not containing R.C.C For R.C.C 500mg/lit
5	Suspended matter	183 mg/lit	2000 mg/lit

Table1: Properties of water

2.1.5Metakaolin

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:2 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 2: Chemical composition of Metakaolin

Figure1.Buff colored Metakaolin

Figure2.white colored metakoline

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

2.1.6 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 (SiO_2) (both amorphous and crystalline) and calcium oxide(CaO), both being endemic ingredients in many coal-bearing rock strata

2.1.7 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).

3.0 EXPERIMENTAL PROGRAMME

3.1 INTRODUCTION

An experimental study is conducted on “Metakaolin and Fly Ash” as a full replacement of cement concrete. Normal strength grade concrete of M30 Design mix with various percentages of Metakaolin and Fly Ash replacing cement has been made use in the investigation.an investigation is also done with 100% Metakoline with 8M,10M and 12M solutions. The test program consists of carrying out compressive strength test on cubes and Flexural strength of Beams. Experimental study is carried out to investigate the compressive and flexural strengths of concrete.

Firstly conventional concrete mix was done for M30 grade concrete with cement inorder to compare the values with the Geopolymer concrete mixes. The M30 mix was done confining to IS: 10262-1984

3.2 TESTS ON CEMENT:

Checking of materials is an essential part of civil engineering as the life of structure is dependent on the quality of material used.

Following are the tests to be conducted to judge the quality of cement.

1.Fineness

2.Consistency

3.Initial And Final Setting Time

4.Soundness

5.Specific gravity

3.3 TESTS ON AGGREGATE

There are many tests which are conducted to check the quality of aggregates. Aggregates are very important components of concrete, so the quality really matters when it comes to aggregates.

Various tests which are done on aggregates are listed below.

1. Sieve analysis for fine aggregate
2. Sieve analysis for Coarse Aggregate
3. Aggregate impact Value
4. Aggregate crushing value
5. Specific gravity and water absorption of Aggregate

3.4 TESTS ON FRESH CONCRETE

The basic tests to be conducted in the field as well as in the lab based on its state of concrete are given below.

1. Tests on Fresh concrete
2. Tests on Hardened concrete

Tests to be conducted on site as well as lab for quality control are

A. Slump Test

B. Compaction Factor Test

4.0 RESULTS AND DISCUSSIONS

4.1physical Tests results of Bharathi opccement

The following tabular column shows the physical Tests results of Bharathi opc cement

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 3: physical Tests results of Bharathi opccement

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

4.2Tests on aggregate:

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 4: Tests Results of aggregate

4.3 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	

Table5: 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

Table6: 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

Table7: 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

Table:8 Compressive Strength Of Concrete For Different % Of Fly Ash And Buff Metakaolin With 12m Solution For 3 And 7 Days At Air Dry Curing

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

S.No	Percentage Of Metakaolin And Fly Ash In Mixture	3days N/Mm 2	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

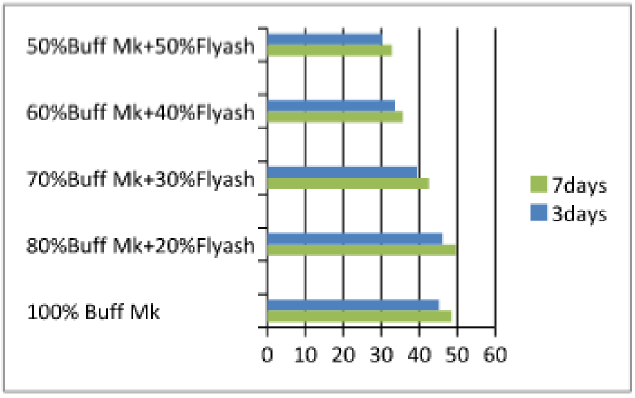
Table 9: Flexural Strength Of Concrete For Different % Of Fly Ash And Buff Metakaolin With 12m Solution For 3 And 7 Days At Air Dry Curing

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

Table 10: 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/Mm 2
1	8M	Fail	Fail
2	10M	Fail	Fail
3	12M	Fail	Fail

Table:11 flexural Strength Of Concrete For 100 % white Metakaolin For 3 And 7 Days At Air Dry Curing



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

Table12: Compressive Strength Of Concrete For 100 % buff Metakaolin For 3 And 7 Days At Air Dry Curing

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

Table:13flexural Strength Of Concrete For 100 % buff Metakaolin For 3 And 7 Days At Air Dry Curing

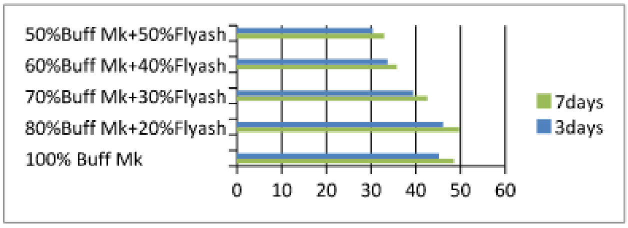


Fig .3 Compressive Strength Ofgeopolymer Concrete For Different % Of Fly Ash And Buff Metakaolin With 12m Solution For 3 And 7 Days At Air Dry Curing

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

5.0 CONCLUSIONS

- 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
- The alkaline solutions with 8M, 10M and 12M also not showing positive results on geopolymer concrete with 100% white metakaoline
- 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
- 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
- The compressive strength of geopolymer concretewith 100% buff colored metakaoline is increasing with increasing in the molarity of the solution
- Combination of different percentages white metakaoline and flyash, buff metakaoline and flyash are failed in flexural strength point
- Both white and buff colored metakaoline with 8M, 10M and 12M are very week in flexural strength
- 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
- 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.
- By using the Metakaolin and flyash as a filler or replacement in cement will reduce environmental pollution.

6.0 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.

Author Details

Chunchu Bala Rama Krishna
Post Graduate Student,
Sunflower College of Engineering and Technology,
Lankapalli, Krishna District A.P.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Mr.M.Rama KRishna, M.E
Associate Professor, HoD,
Sunflower College of Engineering and Technology,
Lankapalli, Krishna District A.P.