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AN EXPERMENTAL INVESTIGATION OF GEO-POLYMER CONCRETE WITH MINERAL ADMIXTURES (FLY ASH AND METAKAOLIN)

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ABSTRACT:
Concrete is probably the most extensively used construction material in the world. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption by the use of supplementary materials. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. Metakaolin is a new mineral admixture, whose potential is not fully utilized. More over only limited studies have been carried out in India on the use of slag for the development of high strength concrete with addition of FlyashThe study focuses on the flexural strength performance of the geopolymer concrete replace with Metakaolin and fly ash as a partial replacement of OPC. The cement in concrete is replaced accordingly with the percentage of20%,30%,40%, 50%,100% by weight of fly ash and50%, 60%, 70% ,80%,100% by weight of metakolin.

INTRODUCTION

1.1GEOPOLYMER CONCRETE

The term "geopolymer" was first used by J. Davidovits in the late 1970s and nowadays identifies a family of amorphous alkali or alkali-silicate activated aluminosilicate binders of composition $M2O \cdot mAl2O3 \cdot nSiO2$, 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 poly condensation/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 SiO4 and AlO4 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 based materials. 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 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(AS3) 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.

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.

Table 1:Chemical and physical properties of Pozzolanic Material

Chemical composition	Fly ash (%)	GGBS(%)	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	-----	-----

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

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)	

1.3 Water

The locally available potable water, which is free from concentration of acid and organic substances, is used for mixing the concrete as well as preparing the alkaline solution

Table 3. Properties of water

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

1.4 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.**

1.5 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.

PREPARATION OF ALKALINE SOLUTION

For example, for preparation of 10M solution 400 g (molarity x molecular weight) of sodium hydroxide flakes dissolved in one litre of water to prepare sodium hydroxide solution of 10M. The mass of NaOH solids in a solution vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 310 g per kg of NaOH solution of 10M concentration. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the Geopolymer

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concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds as early as possible as the setting times are very low.

For 10M NaoH:

10M NaoH = 10 x 40 = 400 gm/lit.

Total NaoH to be mixed = 400/(sp.gravity of NaoH)

= 400/2.541

= 160 gm/lit

Assume sodium silicate / sodium hydroxide = 2.5

Na2Sio3 = 2.5 x NaoH

= 2.5 x 400

= 1000 gm/lit

Total Na2Sio3 = 1000/(sp.gravity of Na2Sio3)

= 1000/2.7

= 370.37 gm/lit

Finally for one litre of water mix:

NaoH = 160 gm/lit

Na2Sio3 = 370.3 gm/lit

CURING METHOD

AMBIENT CURING / OVEN CURING:

Water Curing is not required for these Geopolymer blocks. The heat gets liberated during the preparation of sodium hydroxide which should be kept undisturbed for one day. For the curing geo-polymer concrete cubes, two methods are used, one by placing the cubes in hot air oven and by placing the cubes in direct sun-light. For oven curing, the cubes are placed in an oven at 60 degrees centigrade for 24 hours. For the sun light curing, the cubes are demoulded after 1 day of casting and they are placed in the direct sun light for 3 and 7 days geopolymer concrete will gain it strength from 24 hours to 4 days only so 28 days testing will not play a vital role in knowing the strength of geopolymer concrete

Table 4. Compressive Strength Of Concrete Form30 Control Mix For 3,7, And 28 Days

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	

Table 5.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	1.24	3.26
2	100% White Mk	1.86	4.26
3	80%White Mk+20%Flyash	2.84	4.96
4	70%White Mk+30%Flyash	2.92	5.20
5	60%White Mk+40%Flyash	3.26	4.56
6	50%White Mk+50%Flyash	3.58	4.96

TABLE:6 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	1.24	4.56
2	100% White Mk	2.84	8.68
3	80%White Mk+20%Flyash	3.68	4.72
4	70%White Mk+30%Flyash	3.82	4.98
5	60%White Mk+40%Flyash	2.46	5.24
6	50%White Mk+50%Flyash	4.32	6.42

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

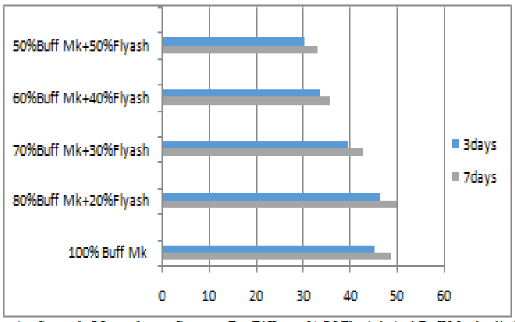
S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	1.26	2.58
2	10M	2.48	3.65
3	12M	3.82	4.28

TABLE:8 Compressive Strength of Concrete For 100 % buff Metakaolin For 3 And 7 Days At Air Dry Curing

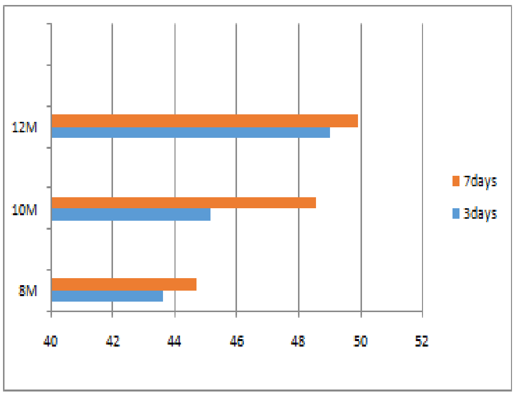
S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	43.59	44.67
2	10M	45.12	48.56
3	12M	48.97	49.89

TABLE:9 flexural Strength Of Concrete For 100 % buff Metakaolin For 3 And 7 Days At Air Dry Curing

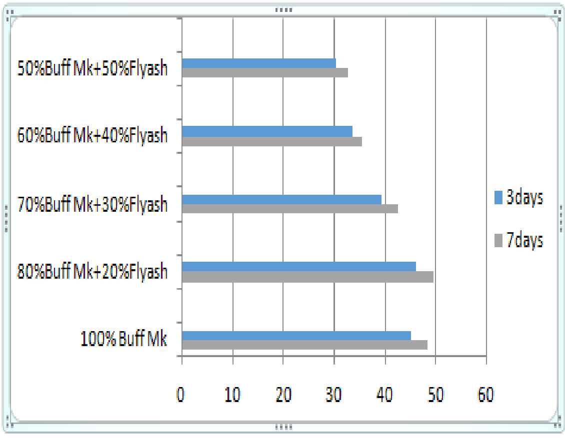
S.No	Molarity of solution	3days N/Mm2	7days N/Mm2
1	8M	0.02	0.10
2	10M	0.04	0.14
3	12M	0.07	0.24



Compressive Strength Ofgeopolymer Concrete For Different % Of Fly Ash And Buff Metakaolin W Solution For 3 And 7 Days At Air Dry Curing



Compressive Strength Of Concrete For 100 % buffMetakaolin with 8M, 10M and 12M For 3 And 7 Air Dry Curing



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 decreasing
- The compressive strength of geopolymerconcretewith 100% buff colored metakaoline is increasing with increasing in the molarity of the solution
- Combination of different percentages whitemetakaoline

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 fly ash up to 20% in the mixesin air dry curing, this is happening because if we use fly ash 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.

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