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PERFORMANCE EVALUATION OF METAKAOLIN AND FLYASH BASED GEO-POLYMER CONCRETE

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ABSRACT: This paper presents the report on the use of metakaolin-based Geo Polymer Concrete (GPC) containing different proportions of Alkaline activator and its effects on mechanical properties of GPC. Two different concrete mixes containing different combinations with flyash and metakaolin content varying between 0% and 100% were prepared. Sodium Hydroxide (NaOH) and sodium silicate (Na2SiO3) were used to prepare alkaline activators with two different molarities of 8M and 10M. All the specimens were cured in hot air oven for 24hours at 85°c and thereafter cured at ambient temperature before testing.
Keywords: Geopolymer, fly ash , metakaolin, alkali activator

I. INTRODUCTION

Recently, with drastic increase in exhaustion of CO_2, researchers have been concerned with the need for development of cement less concrete. In the year 1978, French researcher Davidov its established concept of geopoly merisation by using kaolinite ($Al_2Si_2O_5(OH)$) and alkaline activators. Geopolymer concrete could be generally termed as "inorganic polymers". Geopolymer binders and cements are usually fashioned by reaction of aluminosilicate powder (such as metakaolin or fly ash) with alkaline solution. The chemical reaction method responsible for geopolymer formation, best known as geopoly merization, involves the dissolution of aluminum and silicon atoms from the supply material, reorientation of precursor ions in alkaline solution, associates in condensation reactions to form an inorganic chemical compound (geopolymer). They contain tetrahedral aluminium (Al)and silicon(Si) with charge balancing of the Al tetrahedra achieved by sodium or potassium ions. Since geopolymer production reduces the necessity for high temperature calcination processes compared with Portland cement clinker manufacture, geopolymers have high potential for use in 'green' concretes with less environmental impact than concretes primarily based on Ordinary Portland Cement (OPC). In the current study, flyash and metakaolin is used for preparation of geopolymer concrete. Flyash which is a waste byproduct in thermal power stations is used as a binder and metakaolin used in geopolymerisation is derived from kaolin sources by thermal processing of alumino silicates at a relatively low temperature (600°C to 800°C). Alkali activator solutions play a vital role within the dissolution of Si and Al oxides. Hence geopolymer is synthesized by mixing the foremost common chemicals. Alkaline activators like sodium hydroxide (NaOH) sodium silicate(Na_2SiO_3) or potassium hydroxide(KOH),potassium silicate(K_2SiO_3) are used. The molarity concentration of alkaline activator used in geopolymer concrete has a significant effect on compressive strength. As the molarity concentration of the solution increases the compressive strength of the geopolymer concrete also increase and when molarity of the solution decreases compressive strength also decreases. However curing temperature and age also affect the compressive strength of geopolymer.

II. MATERIAL AND EXPERIMENTAL DETAILS

A. Materials

In this study Low calcium class-F flyash from Rayalaseema thermal power plant in kadapa district, Andhra Pradesh is used. This flyash contains huge quantities of aluminium oxide(Al2O3) and silcon dioxide(SiO2) which helps in geopolymerization reaction with alkaline solution. Metakaolin is obtained from Astrra chemicals in Chennai which is prepared by calcining purified kaolinite within 650-700°C.The chemical composition of metakaolin and flyash are given in Table 1.

TABLE1. Chemical Composition Of Metakaolin And Flyash

chemical	**Metakaolin(wt%)**	**Fly ash(wt%)**
Al_2O_3	37.2	27.0
SiO_2	55.9	48.8
CaO	0.11	6.2
Fe_2O_3	1.7	10.2
K_2O	0.18	0.85
MgO	0.24	1.4
Na_2O	0.27	0.37
P_2O_5	0.17	1.2
TiO_2	2.4	1.3
BaO	0.05	0.19
MnO	-	0.15
SrO	0.03	0.16
SO_3	0.02	0.22
ZrO_2	-	-
Loss On ignition	0.8	1.7

B. Super plasticizer

Super plasticizer Conplast sp430, 3% by mass of binders were added to enhance the workability of fresh geopolymer concrete.

C. Mix Design

Totally two mixes of different molarities(8M & 10M) were prepared each mix containing five different combinations. Each mix was prepared with varying flyash and metakaolin contents. The ratio of activator solution to flyash is maintained at 0.45.The details of various mix proportions are as shown in Table 2.

D. Geopolymer preparation

The choice of chemicals used to make geopolymer mainly depends upon the reactivity of the activator and economic cost of activator. Recent studies indicate that sodium silicate and sodium hydroxide reacts better than potassium hydroxide. So two different molarities(M) of NaOH (8M & 10M)concentrations were prepared and ratio of sodium silicate to NaOH by mass of 2.5 was used which is kept constant throughout the mixes. The ratio of Activator solution to fly-ash is taken as 0.45.

TABLE2. Mix Proportions Of Geopolymer

MIX ID	8M(MOLARITY)	10M(MOLARITY)
Fly Ash(kg/m3)	426	426
Coarse Aggregate(kg/m3)	1158	1158
Fine Aggregate(kg/m3)	613	613
Sodium Silicate(l/m3)	296.29	370.3
Sodium Hydroxide(l/m3)	125.93	157.4
Activator Solution/Fly-ash	0.45	0.45
Superplasticiser(l/m3)	6	6

E. Preparation of specimens and mixing procedure

To study the compressive strength of GPC cubical moulds of size 100mmx100mmx100mm were casted. For split tensile test of GPC cylindrical moulds of size 100mmx200mm were used. Prism moulds of size 100mmx100mmx500mm were used for flexural strength test.

Flyash(FA), metakaolin(MK) and aggregates were mixed in a concrete mixer nearly for 2 minutes. Then the alkaline solution of sodium hydroxide and sodium silicate which is prepared 24 hours prior to casting along with the super plasticizer were added into the blend and is mixed about 3minutes.

F. Testing Of Specimens

To study the workability of fresh concrete, slump cone test is used. In accordance with ASTM C1437-07 flow of fresh geopolymer concrete are conducted immediately after mixing. Using Vicat needle apparatus in accordance with ASTM C 191-01 standard the initial and final setting time of geopolymer slurries were found. Compressive strength test was conducted on 3,7,28 days in accordance with IS:516-1959 using compressive testing machine with capacity of 2000kN.Similarly split tensile and Flexural strength of concrete were also known.

III. RESULTS AND DISCUSSIONS

A. Compressive Strength

The results of two different mixes of molarities (8M& 10M) are obtained shown in Table 3&4. From Fig 1 and 2 GPC mix of GCC2(8M) gives better compressive strength of 34.8 Mpa and GPC mix of GCD2(10M) gives better compressive strength of 37.5 Mpa when compared with other concrete mixes. This is due to the fact that increase in molarity of alkaline activator increases the Na2O content which is necessary for geo-polymerisation and better bonding between aggregates and binder. After 3 days of curing average compressive strength increases by 22% at normal room temperature which gave better compression strength.

TABLE3. Compressive Strength Of 8M GPC

Mix	3days(mpa)	7days(mpa)	28days(mpa)
GCC0(100% FA)	12.02	16.65	18.5
GCC1(75%FA,25% MK)	20.66	28.89	32.1
GCC2(50%FA,50% MK)	22.62	31.32	34.8
GCC3(25%FA,75% MK)	17.35	24.0	26.7
GCC4(100%MK)	16.57	22.95	25.5

FIG1. Compressive Strength of 8M GPC

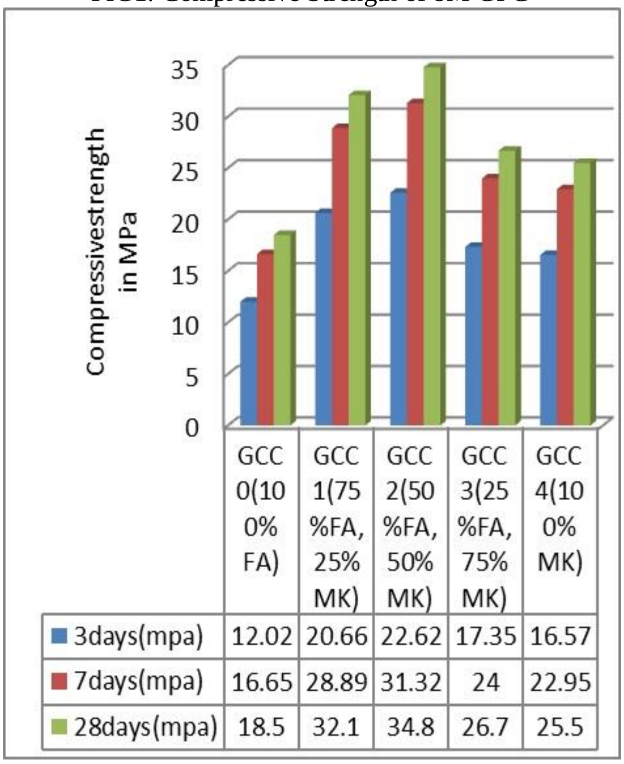
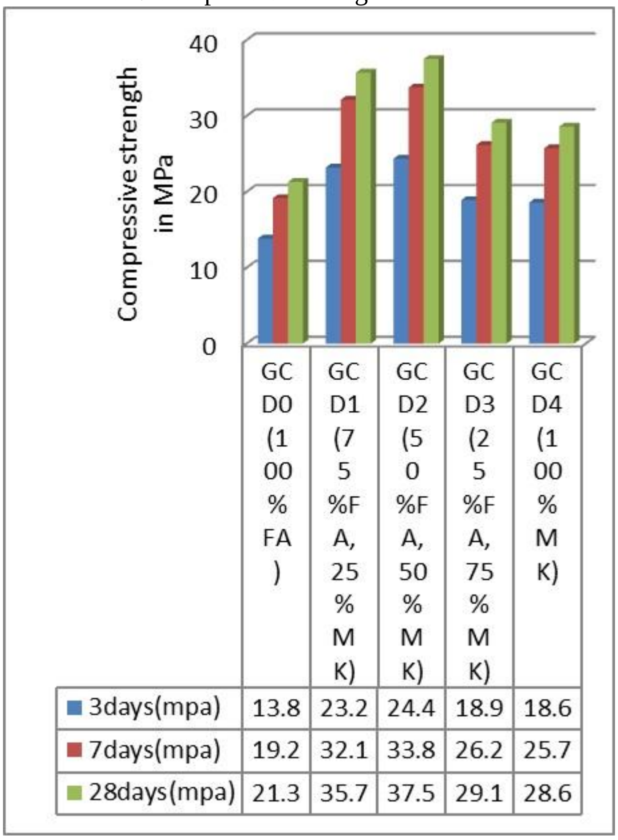


TABLE4. Compressive Strength Of 10M GPC

Mix	3days(mpa)	7days(mpa)	28days(mpa)
GCD0(100% FA)	13.84	19.17	21.3
GCD1(75%FA,25% MK)	23.20	32.13	35.7
GCD2(50%FA,50% MK)	24.37	33.75	37.5
GCD3(25%FA,75% MK)	18.91	26.19	29.1
GCD4(100%MK)	18.59	25.74	28.6

FIG2. Compressive Strength of 10M GPC



B. Split tensile Test

With reference to the Table 5 and Fig 3 GPC mix of GSC2(8M) gave maximum split tensile strength of 3.19 Mpa and mix GSD2(10M) gave maximum strength of 3.36 Mpa when compared with other mixes as shown in Table 6. The values are also plotted in Fig 4.

TABLE5. Split Tensile Strength Of 8M GPC

material	3days(mpa)	7days(mpa)	28days(mpa)
GSC0(100% FA)	1.62	1.95	2.09
GSC1(75%FA,25%MK)	2.25	2.82	3.03
GSC2(50%FA,50%MK)	2.39	2.98	3.19
GSC3(25%FA,75%MK)	2.01	2.49	2.67
GSC4(100%MK)	1.95	2.42	2.59

FIG3. Split Tensile Strength Of 8M GPC

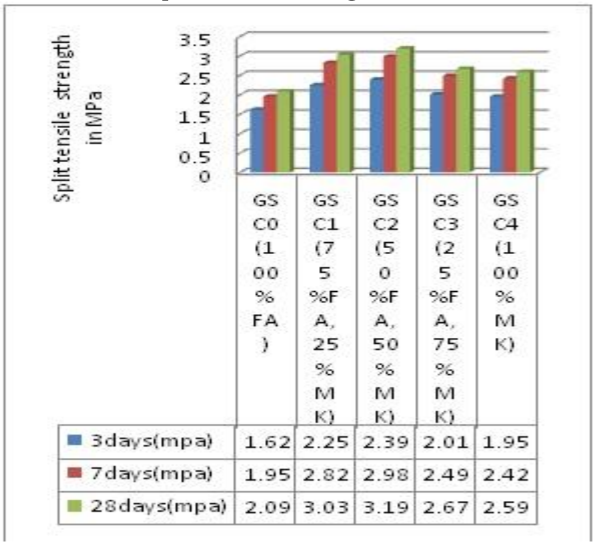
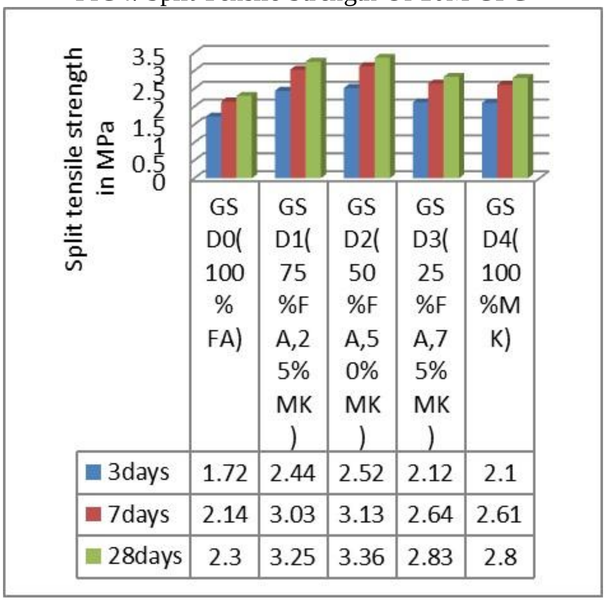


TABLE6. Split Tensile Strength Of 10M GPC

material	3days	7days	28days
GSD0(100% FA)	1.72	2.14	2.30
GSD1(75%FA,25%MK)	2.44	3.03	3.25
GSD2(50%FA,50%MK)	2.52	3.13	3.36
GSD3(25%FA,75%MK)	2.12	2.64	2.83
GSD4(100%MK)	2.10	2.61	2.80

FIG4. Split Tensile Strength Of 10M GPC



C. Flexural Strength Test

The results of flexural strength from the table shows that GPC mix of GFC2(8M) gave maximum flexural strength of 5.22 Mpa and mix GSD2(10M) gave 5.625 Mpa when compared with remaining mixes. The results are shown in Figures 5 and 6 also.

TABLE7. Flexural strength of 8M GPC

material	3days	7days	28days
GFC0(100% FA)	1.80	2.49	2.77
GFC1(75%FA,25%MK)	3.09	4.33	4.81
GFC2(50%FA,50%MK)	3.39	4.69	5.22

GFC3(25%FA,75%MK)	2.60	3.6	4.0
GFC4(100%MK)	2.48	3.44	3.82

FIG5. Flexural Strength of 8M GPC

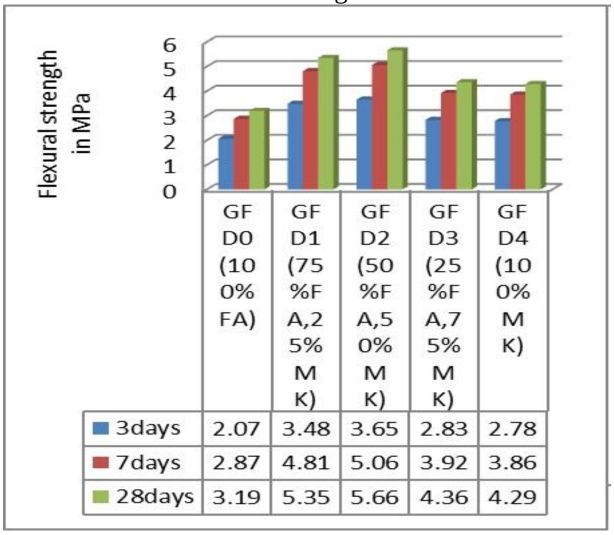
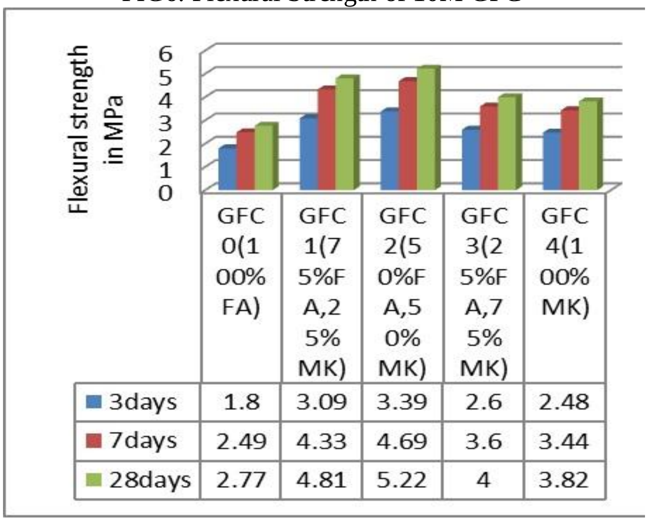


TABLE8. Flexural Strength of 10M GPC

Material	3days	7days	28days
GFD0(100% FA)	2.07	2.87	3.19
GFD1(75%FA,25%MK)	3.48	4.81	5.35
GFD2(50%FA,50%MK)	3.65	5.06	5.66
GFD3(25%FA,75%MK)	2.83	3.92	4.36
GFD4(100%MK)	2.78	3.86	4.29

FIG6. Flexural Strength of 10M GPC



IV. CONCLUSIONS

From the results obtained from the above experimental investigation, following conclusions can be drawn.

- Increase in molarity of NaOH as an alkaline activator appears to provide better compressive strength when compared with lesser molarity.
- Mix with 50% of flyash and 50% of metakaolin seems to have better compressive strength than other mixes. This may be due to increase in alkaline reaction between flyash particles and calcium in metakaolin.
- Workability of geopolymer concrete decreased as the metakaolin content increases with flyash. But increase in flyash does not affect the workability.
- Nearly 90% of total strength of GPC is achieved within age of 7days.
- Then increase in strength of GPC between 7days and 28days appeared to be less when compared with 3days and 7days.It shows that even after 7days geopolymer reaction is taking place but at a slower rate.

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