Effect of Potassium Hydroxide As An Activator on Compressive Strength of Activated Class F &Class C Fly Ash

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ABSTRACT: *This research paper highlights the details of development of variousphysical properties of geopolymer with respect to time. Compressivestrength and sorptivity arethe most important physical properties which are broadly discussedbelow. Fly ash is the main constitute material of this Geopolymer. Sothis investigation here is basically based on the three types of thefly ash which is Class F (Black), Class F (Gray) and Class C (White)respectively. Apart from fly ash potassium hydroxide and sodiumsilicate are the two main constituents materials used here. Fly ashchanges in silicate modulus and in percentage of K_2O have also made anobvious impact on it. Again the changes in compressive strength withtime variation graphs strongly focus on the above statement. So, thispaper represents the very changes in physical properties of geopolymerdue to the application of potassium hydroxide, changes in silicatemodulus and in percentage of K_2O with respect to time.*

KEYWORDS: *Potassium Hydroxide (KOH), Geopolymer,Silicate Modulus, Percentage of K_2O, Compressive Strength.*

I. INTRODUCTION

Geopolymer materials represent a very new technology that is generating huge amount of interest in the construction industry considering sustainable material in construction field [1]. The rapid increase in the capacity of thermal power generation has resulted in the production of a huge quantity of fly ash. The prevailing disposal methods are not free from environmental pollution and ecological imbalance [2].The uses of this material gives us a enormous amount of positive results in compare to normal concrete. Geopolymer materials exhibit high early strength with better durability but having almost no alkali-aggregate reaction in the polymerisation process [3]. These materials are therefore likely to take place of cement in coming years [4]. The prime polycondensation reaction of geopolymers with the help of precursors produces polymeric Si-O-Al bonds [5].Alkali percentage, silicate modulus, water content etc are generally those kind of properties on which significant effects of geopolymer properties (basically compressive strength) can be observed [6]. The dissolved source or pozzolonic compounds containing silica is a considerable source of geopolymeric precursor. These sources also contribute in geopolymerisation [7]. This paper reflects generally on the changes of compressive strength characteristics due to the variation of percentage of K_2O and more over silicate modulus of geopolymer specimens under this investigation. The aim of this paper is to study the compressive strength changes with combinational approach of varying silicate modulus and varying percentage of K_2O.

II. MATERIALS

A. Fly Ash

This is the main constituent of geopolymer. There are three types of fly ash being used which are black (class A), gray (class F), white (class C) respectively. The fly ash samples are collected from Kolaghat Thermal Power Plant, Kolaghat, East Midnapore. The samples are sieved first with 75 micron and then the specific gravity of each samples are checked.
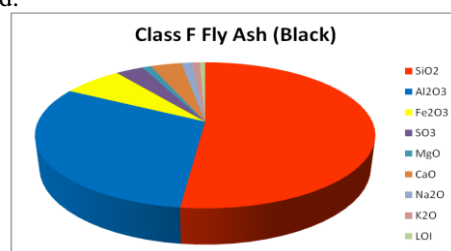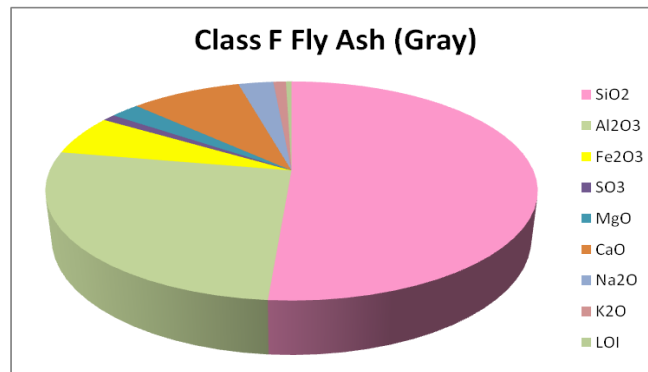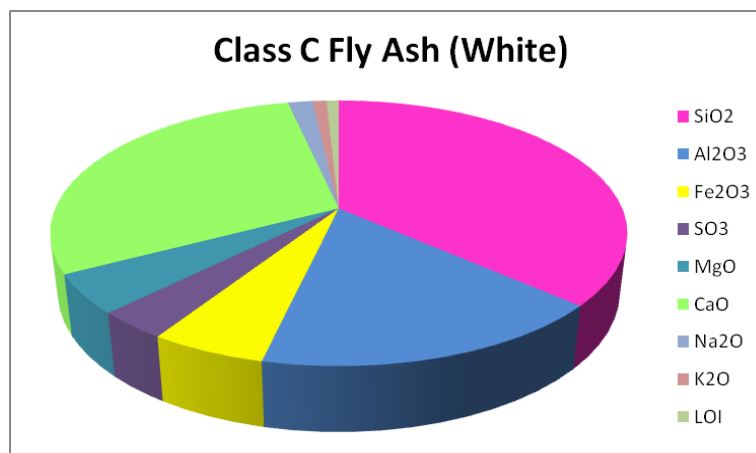

Fig. 1

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	CaO	Na_2O	K_2O	LOI
Class F Fly Ash (Black)	51.3%	30.5%	6.7%	3.1%	1.0%	3.5%	1.2%	0.86%	0.6%

Fig. 2

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	CaO	Na_2O	K_2O	LOI
Class F Fly Ash (Gray)	46.5%	24.1%	5.4%	0.9%	2.1%	7.9%	2.5%	0.9%	0.4%

Fig. 3

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	CaO	Na_2O	K_2O	LOI
Class C Fly Ash (White)	35.4%	16.4%	5.3%	3.3%	4.6%	28.4%	1.6%	0.9%	0.8%

B. Potassium Hydroxide (KOH): It is also a prime constituent in preparation of alkali activator. Here the pallets of KOH are with 84% purity.

C. Sodium Silicate (Na_2SiO_3): This jelly like ingredient also contributes in preparation of alkali activator. It takes part in initiation of the polymerization process. ($Na_2O = 8\%$, $SiO_2 = 26.5\%$ and 65.5% water).

D. Water: A very negligible amount of water is needed to prepare a good sticky mix for better casting and in preparation of alkali activator. But this excess water expels the geopolymer during heat curing process.
All chemicals are supplied from LOBA CHEMI PVT LTD, India.

III. PREPARATION

Fly ash, potassium hydroxide and sodium silicate are the main constituent of geopolymer. The preparation involves a few significant stages. The first stage is of course prepare the alkali activator. The solution of KOH is prepared 24 hours before casting with some water. The required quantities of potassium hydroxide, sodium silicate is mixed together with a very little amount of water to prepare the main activator before 3 hours of casting. After that the sieved (by 75 micron) fly ash is weighted. The second stage is all about mixing the activator with the sieved fly ash. Whole thing is mixed properly by Hobart mixture until the formation of a sticky solution. After that it is casted in $50 \times 50 \times 50$ mm^3 sized wooden moulds properly followed

by table vibration to eliminate the entrapped air. Then it is time for the last stage of heat curing. The proposed heat curing was done for 48 hours at 85 degrees continuously to get the final geopolymer specimen [8]. Then these samples are tested with in an interval of 3days, 7days, 10 days and right after the 48 hours heat curing to get the result of development of compressive strength.

Activator Combination

Fly Ash Type	Sample ID	% of K_2O	SiO_2/K_2O	SiO_2/X_2O	Water/Fly Ash
Black	GB1	8	1	0.77	0.32
	GB3		1.15	0.85	0.32
	GB2	6	1	0.77	0.32
	GB4		1.15	0.85	0.32
Gray	GR1	8	1	0.77	0.32
	GR3		1.15	0.85	0.32
	GR2	6	1	0.77	0.32
	GR4		1.15	0.85	0.32
White	GW1	8	1	0.77	0.32
	GW3		1.15	0.85	0.32
	GW2	6	1	0.77	0.32
	GW4		1.15	0.85	0.32

IV.   RESULT & DISCUSSION

As far as the association with cement concrete specimens is concerned sorptivity is the most noteworthy property of geopolymer [9]. The ingression of water in to a non-saturated cement concrete, driven either by the capillary forces or by surface tension is known as sorptivity. This happens due to sorption. This test is simply measuring the capillary sorption with respect to time. Typical curves are plotted for finding out sorptivity values for the geopolymer specimens for cumulative water absorption against square root of time in the Fig. 5 and Fig. 6 below, according to our investigation [10]. The Fig. 5 represents the rapid sorption of water by the geopolymer specimens in the initial stages. Now slopes for each of those curves are determined for the initial linear portion of the graphs and finally plotted in a chart which represents the sorptivity values for each of the test specimens and significantly low sorption of water in the later stages during the experiment. It is obvious from the Figure that cumulative sorption is highest for GW2 specimen for silicate modulus of 1. GR3 and GB3indicate very poor cumulative water sorption. From the second chart it is more than obvious that specimen GW2 is having highest sorptivity value. In case of sample GB1, GR1, GW1 for 8% K2O there is no vast impact on sorptivity due to optimized polymerization. And sample GB2, GR2, and GW2 for 6% K_2O low alkalinity values are obtained, due to impact on average pore size. Therefore the specimen GR4, with gray fly ash and low alkalinity, is undesirable with respect of us.
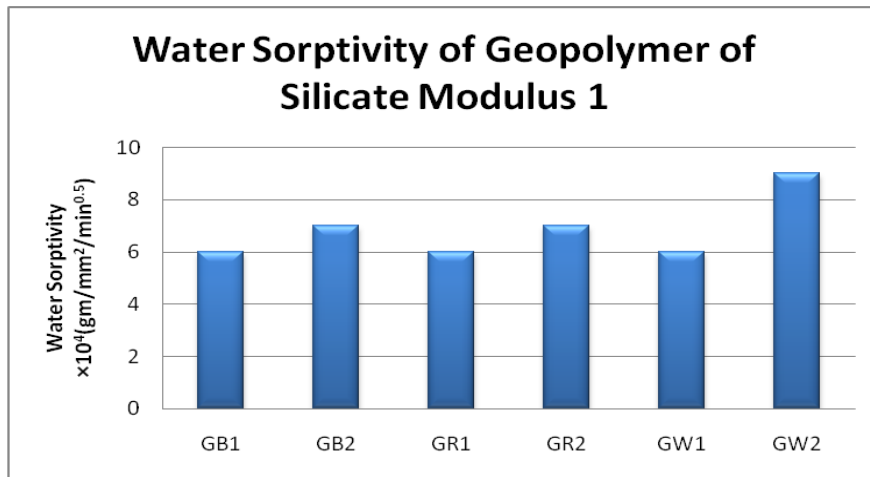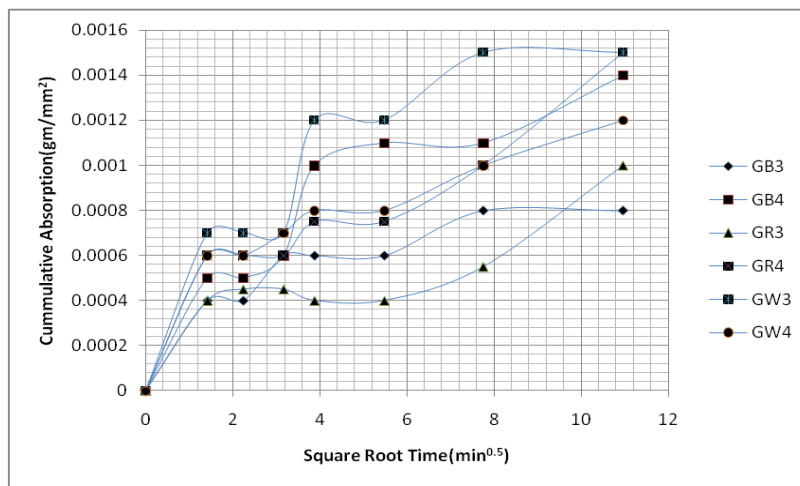
Water Sorptivity of Geopolymer of Silicate Modulus 1
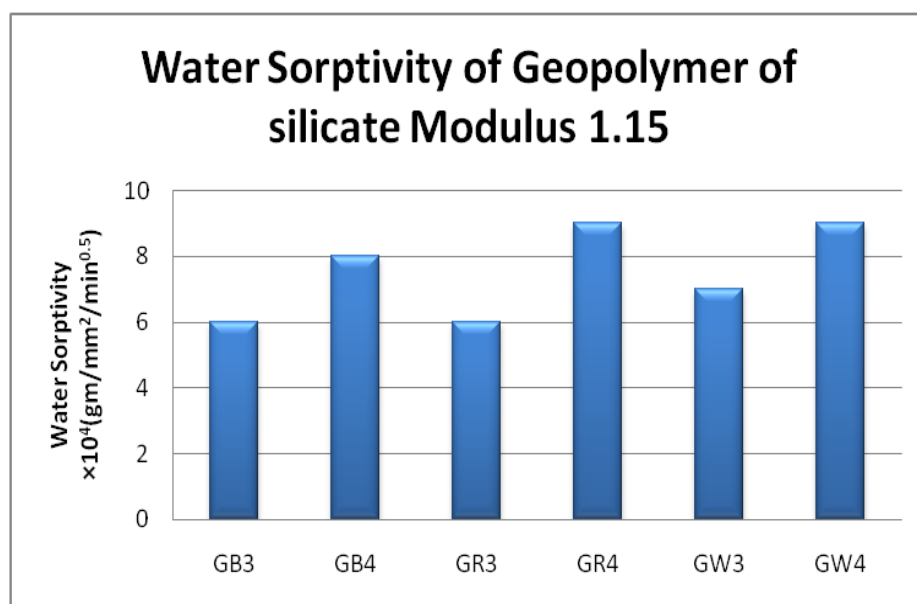
Fig. 4

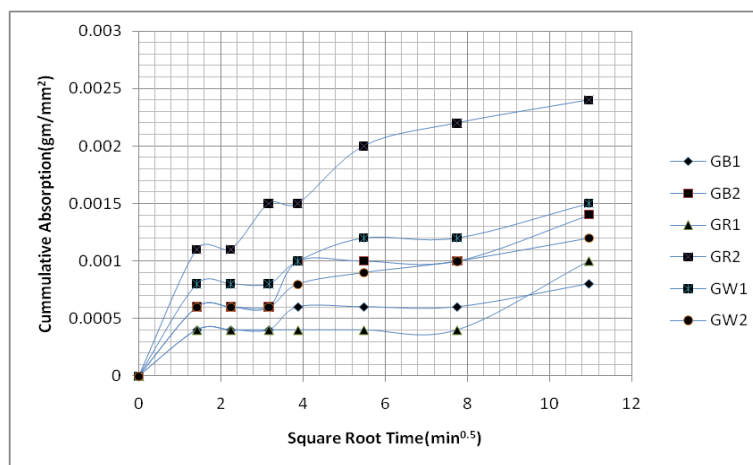**Fig. 5** (Sorptivity graph of Silicate Modulus 1.15)

Fig. 6 (Sorptivity Graph of Silicate Modulus 1)
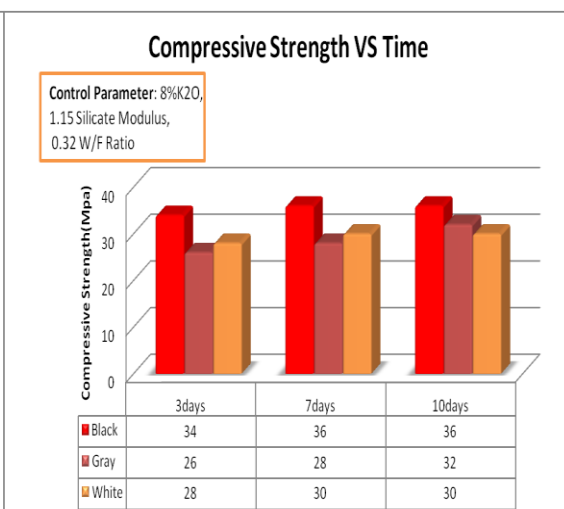
V. COMPRESSIVE STRENGTH ANALYSIS

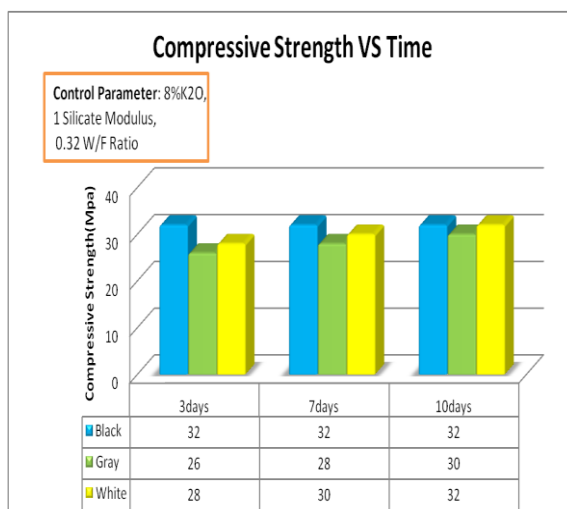In order to know the impact in practical field it is important to tally the variance of Compressive strength properties of geopolymer. Here we are framing the changes in compressive strength considering the results of different day's observations after curing. Silicate modulus, percentage of K_2O and time are the variable parameters. The charts and graphical representations are showing this result of investigations. Here X
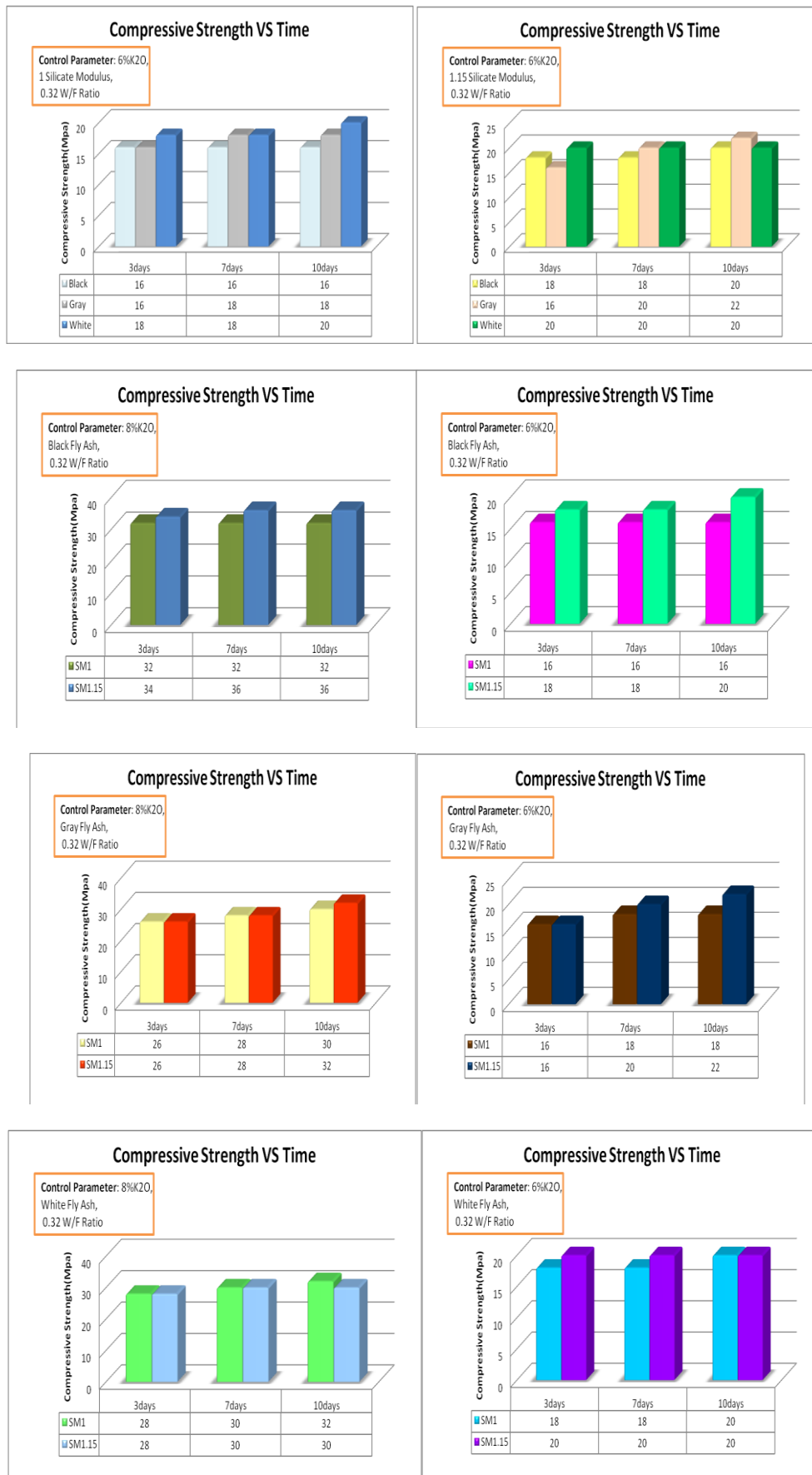
axis represents the time, after 48 hr heat curing and the change in compressive strength is denoted by Y axis. The values depict that the Class F (black) fly ash is giving the highest strength when the silicate modulus is 1.15 (higher value amongst two) and also it has 8% of K_2O percentage after 10 days. Both class F (black) and class C (white) fly ashes are showing considerably lower values of compressive strength when silicate modulus is 1 and with 6% K_2O percentage. Class F (gray) is reflecting the moderate value for both 6% and 8% of K_2O percentage and for irrespective of silicate modulus values. In most of the cases time delayed achievements of compressive strengths have been observed when the alkali percentage in activator is low. Where as in higher concentration of alkali activator almost ultimate strength have been obtained in case of black fly ash. For gray and white again there is late compressive strength growing with time being but not in the noticeable count. At lower alkali content the rate of reaction is slow due to the absence of optimized cat ions. In compare to 6% alkali activator, 8% K_2O always depicts higher compressive strength. Now the question is that between GB2, GB4, GR2, GR4, GW2, GW4, the GR2, GR4, GW2, GW4 poses better compressive strength in time being. it can be supported in a manner, that the presence of more Ca content emphasize secondary crystallization structure along with primary amorphous structure. Though continuous progression of compressive strength has been observed in earlier studies [6,8], But only to have the impact of chemical morphology on compressive strength. In this study time domain has been limited.

Compressive Strength of Typical Geopolymer Specimens

Fly Ash	Sample ID	Activator			Water /FA	Compressive Strength(MPa)		
		% K_2O	SiO_2 /K_2O	SiO_2 /X_2O		At 3Days after 48hr heat curing	At 7Days after 48hr heat curing	At 10 Days after 48hr heat curing
Black	GB1	8	1	0.77	0.32	32	32	32
	GB3		1.15	0.85	0.32	34	16	36
	GB2	6	1	0.77	0.32	16	16	16
	GB4		1.15	0.85	0.32	18	18	20
Gray	GR1	8	1	0.77	0.32	26	28	30
	GR3		1.15	0.85	0.32	26	28	32
	GR2	6	1	0.77	0.32	18	18	18
	GR4		1.15	0.85	0.32	16	20	22
White	GW1	8	1	0.77	0.32	28	30	32
	GW3		1.15	0.85	0.32	28	30	30
	GW2	6	1	0.77	0.32	18	18	20
	GW4		1.15	0.85	0.32	20	20	20

Compressive Strength VS Time

Control Parameter: 8%K2O, 1 Silicate Modulus, 0.32 W/F Ratio

	3days	7days	10days
Black	32	32	32
Gray	26	28	30
White	28	30	32

Compressive Strength VS Time

Control Parameter: 8%K2O, 1.15 Silicate Modulus, 0.32 W/F Ratio

	3days	7days	10days
Black	34	36	36
Gray	26	28	32
White	28	30	30

Fig. 7

VI.   CONCLUSION

On the basis of above calculation following conclusions can be made

- The class F (Black) fly ash gives the satisfactory result as the compressive strength is highest amongst all for the particular silicate modulus of 1.15 and for K_2O percentage of 8% may be due to the formation of amorphous structure which is probably take place majorly and faster than crystallization process. Class F fly ashes have low calcium content which probably the cause of low rate crystal formation in geopolymer.
- Higher percentages of K_2O and also higher silicate modulus represent comparatively better compressive strength among the others and vice versa probably because of the silica content. It
- Is firmly speculated by comparing the values that polymerization process is quite quick in case of higher value of silicate modulus. The amorphous structure formation is   accelerated with more silica content. Which results higher compressive strength.
- As the time elapse increases the strength increases accordingly. In case of 10 days result we are getting comparatively high value. But it may show different results with more increment of time accordingly. As the reactions are complex and those reactions have other impacts on strength.
- Pore is one of the important vital thing of geopolymer. The pore capillary formation increases the sorptivity. This is may be the cause by which the geopolymers are get weakened. More water sorps less it gives the strength.
- The geopolymeric strengths are depends on all above factors as types of fly ash are one of the prime parameter. may be the calcium content is very much crucial and decisive, because calcium results the crystalline structure and geopolymer is amorphous structure. The more amorphous formation gives more compressive strength. That's why the less calcium content fly ash give more compressive strength.

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