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Combinational Study on Mechanical Properties of Alkali Activated Fly Ash Prepared From Different Base Material

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ABSTRACT: *This research represents the development of various physical properties of alkali activated fly ash (AAFA) prepared by various types of fly ash with different combination of alkali activators. Here three types of fly ash have been used as the base material of research experiment. Those are from Class F and Class C category respectively. The alkali activator has been prepared by the mixing of potassium hydroxide (KOH) and sodium silicate (Na_2SiO_3). This study shows how the combinational approach of different types of fly ash with varying quantity of alkali activator has affected the physical properties of AAFA. The properties which have been taken into considerations are compressive strength and water sorptivity. These properties have been broadly discussed in this paper too. A brief analysis of compressive strength with time variation has been discussed here.*
KEYWORDS: *Potassium Hydroxide, Alkali Activator, Fly Ash, Compressive Strength, Sorptivity.*

I. INTRODUCTION

The geopolymer is nothing but an aluminosilicatecementitious material embraced with comparatively superior mechanical, chemical and thermal properties than that of ordinary Portland cement [1]. It is more significantly with lower CO_2 production [1**]**.These materials can be characterized as high strength materials having better durability than ordinary concrete with no alkali aggregate reaction [2]. Significant effects on geopolymer properties can be observed due to various parameters like alkali percentage, silicate modulus, water content etc [3]. Also the curing temperature has a vital role in development of fly ash based geopolymer, which has already been proved [4]. The polymerization process involves synthesizing of polymeric Si-O-Al-O bonds through the controlled process of heat curing in polycondensation reaction [5, 6, 7, 8]. So these materials are expected to be the replacement of cement in near future [9]. Because latest findings suggest that the cement industry produces nearly about one ton CO_2 during the production of one ton cement [10, 11]. Which is an alarming issue related closely with greenhouse effect. More over geopolymer holds considerable potentiality to some aggressive solution comparatively than ordinary cement concrete [12]. It is also capable to resist excessive temperature [13, 14]. So it is all together might be the perfect innovative and economical replacement of ordinary cement concrete in coming era.

This study shows how the combinational approach of different types of fly ash with varying quantity of alkali activator has affected the physical properties of geopolymer. The physical properties to be discussed are compressive strength and sorptivity. That means the developments of various properties of alkali activated fly ash prepared by various types of fly ash sources and with different quantity of alkali activator have been discussed here.

II. EXPERIMENTAL

A. Materials

a. Fly ash: This is the base material of geopolymer. It acts as an aluminosilicate source. There are three types of fly ash that we have used here in our experiments. Those are Class F Fly Ash (Black), Class F Fly Ash (Gray), Class C Fly Ash (White) respectively. We have collected the samples of fly ash from the Kolaghat Thermal Power Plant, Kolaghat, EastMidnapore. The above three samples have been sieved by 75micron before those are used for the experiments. The specific gravity of each fly ash sample has been checked before the experiments.

Fig. 1: Composition Class F Fly Ash (Black)

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%

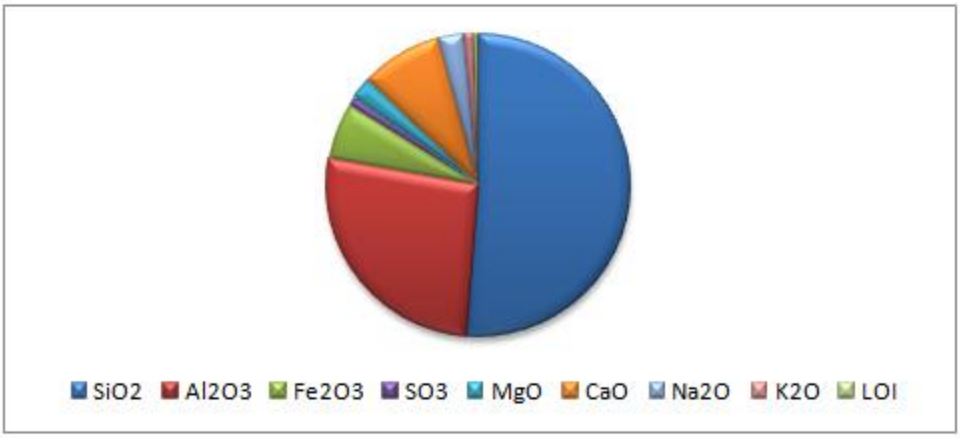

Fig. 2. Composition Class F Fly Ash (Gray)

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%

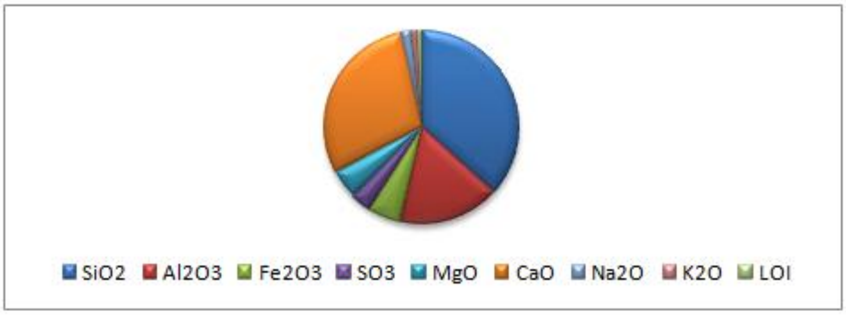

Fig. 3. Composition of Class C Fly Ash (White)

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 needs to prepare the alkali activator. Generally KOH is available in the market in pallets or flakes form. Here the sample of KOH is with 84% purity. The solution of KOH was prepared by dissolving it in water. It is recommended that the solution of KOH should be prepared 24 hours before casting the geopolymer. The samples are supplied from Loba Chemie Ltd, India.

c. Sodium Silicate (Na_2SiO_3): It also acts an activator and available in the market in the jelly form. It initiates polymerization process. The above samples are supplied from Loba Chemie Ltd, India, which is locally available. (Na_2O= 8%, SiO_2 =26.5% and 65.5% water).

d. Water:The water is used in amount of 33% of fly ash for optimum result [15]. This water is normal drinkable water.

B. Preparation of specimen & tests

The process is very simple and short. Three main ingredients were used in this process are fly ash, sodium silicate and potassium hydroxide. First of all the fly ash was sieved with 75 micron to eliminate the impurities. The KOH solution was prepared with both 8% and 5.58% K_2O of fly ash 24 hours before casting. Then before 3 hours of casting the required quantity (maintain silicate modulus as 1 and 1.43 respectively) Na_2SiO_3 was mixed with the KOH solution to prepare the alkali activator[16]. In Hobart mixture the fly ash and the activator were mixed with each other thoroughly to have a sticky mix. Then the mix is transferred in to the 50×50×50 mm cubic wooden mould.Table vibration for at least 2 minutes confirmed the elimination of any entrapped air in the filled mould. Then the samples were kept in oven at nearly 85 degrees for 48 hours for curing and allowed to cool inside the oven [17, 18]. After curing specimens were demoulded and stored at room temperature ata dry place before testing. In addition, unexposed specimens were subjected to water sorptivity and compressive strength tests to assess the pore characteristics. The change in compressive strength with time was also observed here.

Activator Combination

Fly Ash	Sample ID	% of K_2O	SiO_2/ K_2O	SiO_2/ X_2O	Water/ Fly Ash
Class F Fly Ash (Black)	P1	8	1	0.77	0.33
	P4	5.58	1.43	1	0.33
Class F Fly Ash (Gray)	P2	8	1	0.77	0.33
	P5	5.58	1.43	1	0.33
Class C Fly Ash (White)	P3	8	1	0.77	0.33
	P6	5.58	1.43	7	0.33

III. RESULT & DISCUSSIONS

A. Water Sorptivity

Sorptivity is Undoughtably one of the most significant property as far as its association with cement concrete specimens are concerned [19]. Sorptivity is nothing but the ingression of water in to a non-saturated cement concrete, driven by the capillary forces in it, due to sorption. This test is all about the measurement of capillary sorption with respect to time. Typical curves are plotted for finding out sorptivity values for the geopolymer specimens. These curves are plotted for cumulative water absorption against square root of time in the Fig. 4 below according to the test results [20]. Now slopes for the initial linear portion for each of those curves are determined and finally plotted in a chart which represents the sorptivity values for each of the geopolymer test specimens. The Fig. 4 represents the rapid sorption of water by the geopolymer specimens in the initial stages and significantly low sorption of water in the later stages during the experiment. It is obvious from the Fig. that cumulative sorption is highest for P4 specimen.P3 indicates very poor cumulative water sorption. From the second chart it is more than obvious that specimen P5 is having highest sorptivity value.In case of sample P1, P2, P3 for 8% K_2O there is no impact on sorptivity due to optimized polymerization. And sample P4, P5, and P6 for 5.58% K_2O low alkalinity values are obtained, due to impact on average pore size. Therefore the specimen P5, with gray fly ash and low alkalinity, is undesirable with respect of uses.

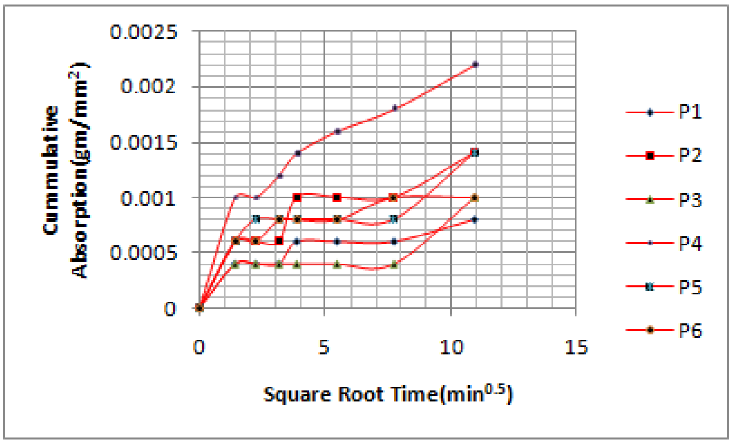

Fig.4

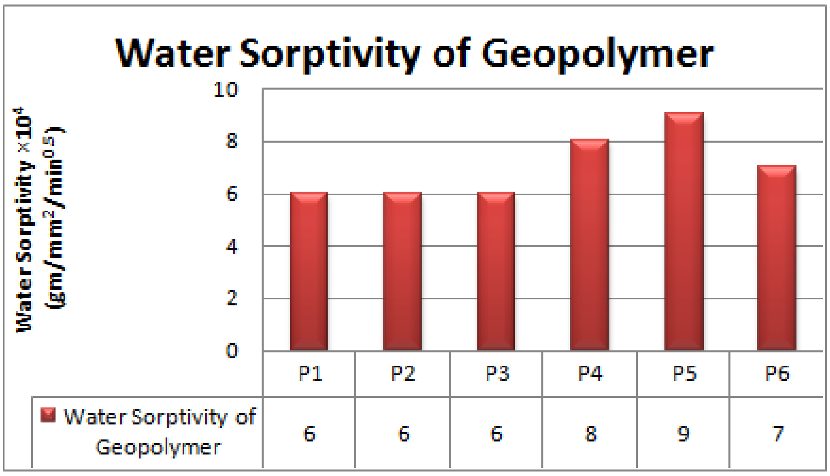

Fig.5

B. Changes in Compressive Strength

Fig. 6 represents the changes in compressive strengths after 3, 7 and 10 days respectively. From the Fig. 6 it can be seen that sample P1 gives the highest strength where sample P4 gives the lowest of all. The rapid increasing trends of compressive strengths of the respective samples for the first 3 days and then slowly coming to a saturation period can be observed from the figure below. Considering other graphs if the activator or fly ash types are changed then also the strength developed independently with respect of time only. Therefore compressive strength is increased anyway and gaining strength far better than the cement. Higher temperature contributes higher strength for the non-blendedgeopolymer samples [21].From Fig. 7 it is probable that the vivid change in case of Class F Fly Ash (Black) is not occurs with respect to time, even if by changing the percentage of K_2O. The silica content for this fly ash is considerably high so that the polymerization process occurs quickly without any interruption.But from Fig. 8 in case of Class F Fly Ash (Gray) we observed the positive increasing change in strength with respect of time. Most probable prediction for the phenomena is that the silica and calcium content of gray fly ash is nearly equal. So that the reactions of polymerization and crystallization which occurs simultaneously at the very beginning. Moreover the polymerization completes sooner than the other. Thereforethe pores in the polymer filled with hydration process (C-S-H formation)by the crystals. In Fig. 9 the same phenomena occurs in case of Class C Fly Ash (White), because of the silica and calcium content is more nearly equal than the previous fly ashes. That’s why curves are stepper and clear. It can be seen from both Fig. 10 and Fig. 11 that the steeper changes in compressive strength for white fly ash with respect to time is irrespective of varying percentages of K_2O from others.

Compressive Strength of Typical Specimens

		Activator				Compressive Strength(MPa)			
Fly Ash Type	Sample ID	%K_2O	SiO_2 /K_2O	SiO_2 /X_2O	Water /FA	At 48hr Heat curing	At 3Days after 48hr heat curing	At 7Days after 48hr heat curing	At 10Days after 48hr heat curing
Class F Fly Ash (Black)	P1	8	1	0.77	0.33	30	32	32	32
	P4	5.58	1.43	1	0.33	20	20	20	22
Class F Fly Ash (Gray)	P2	8	1	0.77	0.33	22	26	28	30
	P5	5.58	1.43	1	0.33	15	20	22	26
Class C Fly Ash (White)	P3	8	1	0.77	0.33	20	28	30	32
	P6	5.58	1.43	1	0.32	20	20	24	26

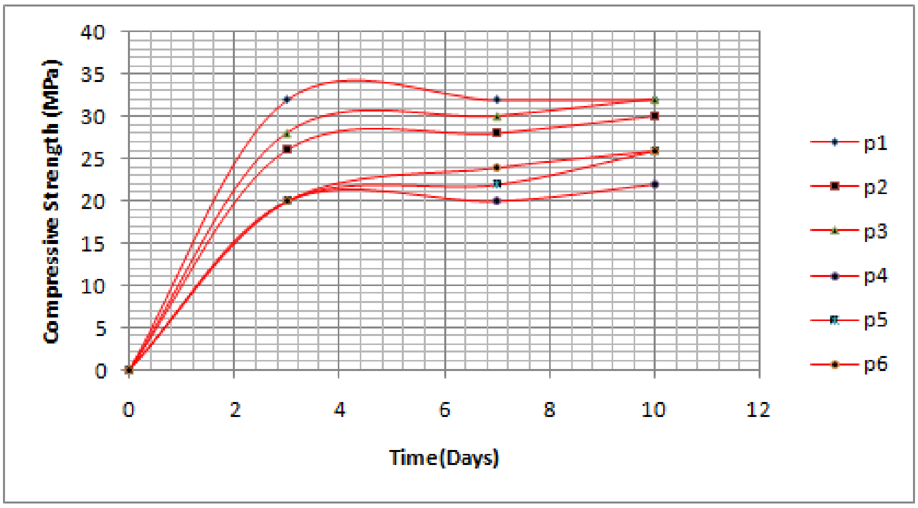

Fig. 6

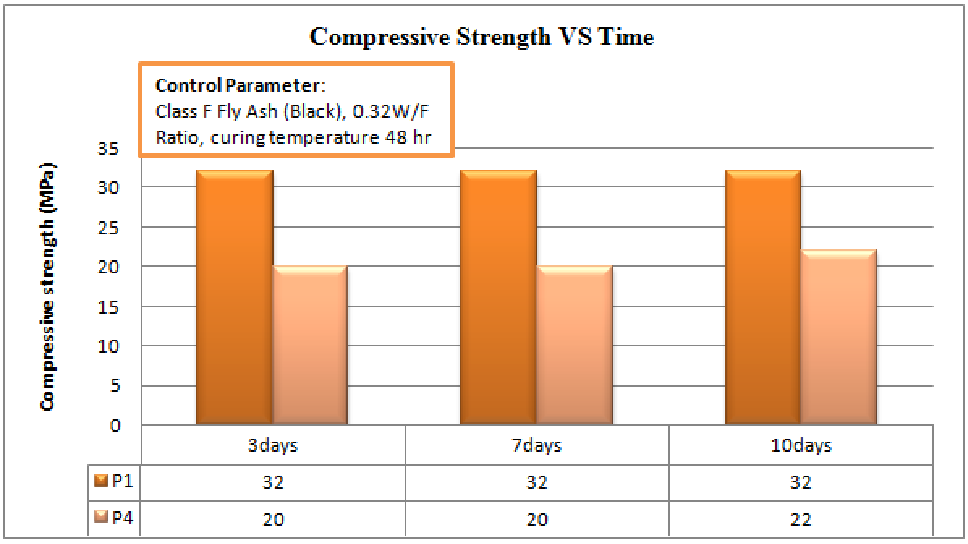

Fig. 7

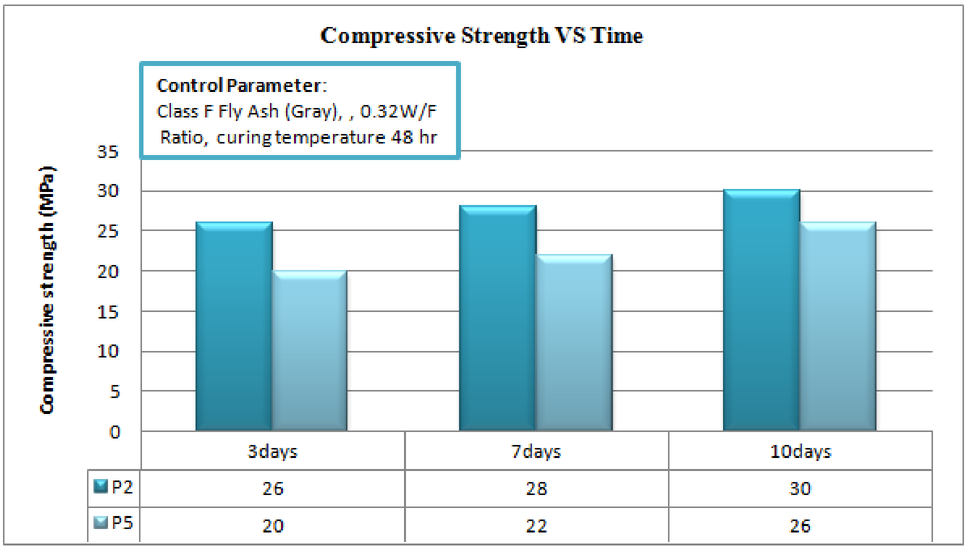

Fig. 8

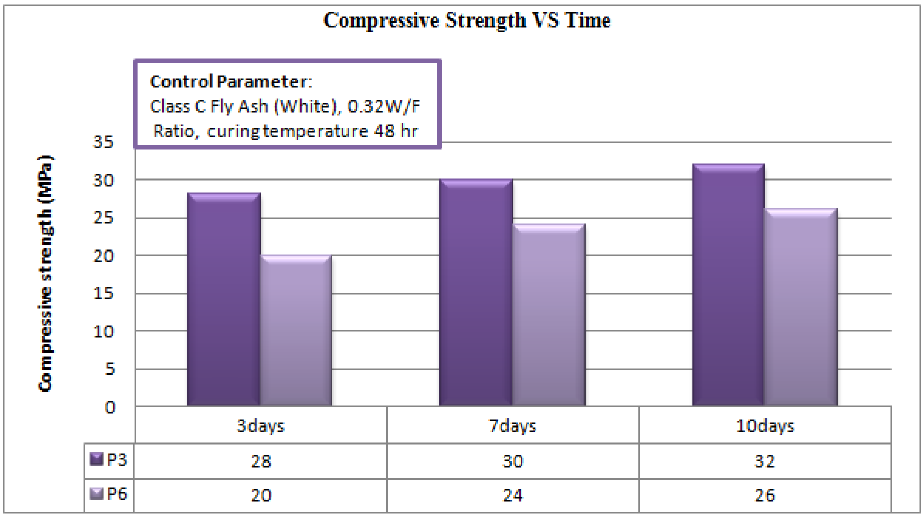

Fig. 9

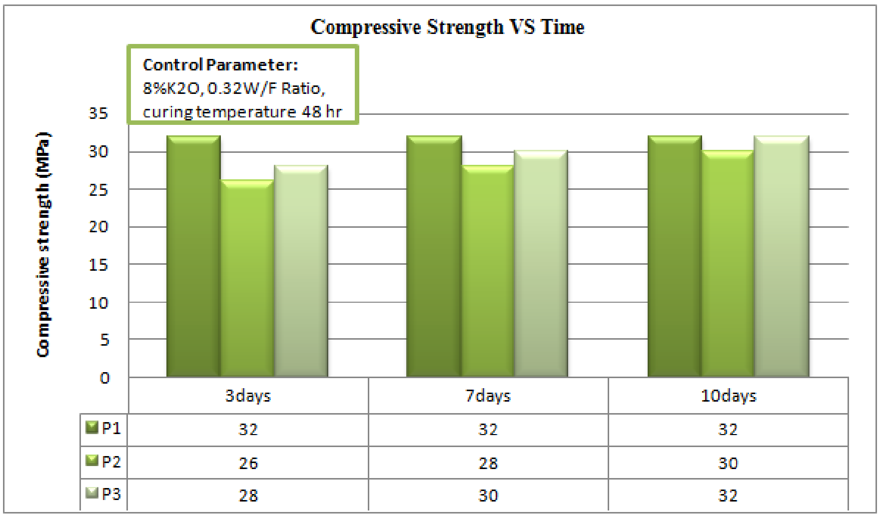

Fig. 10

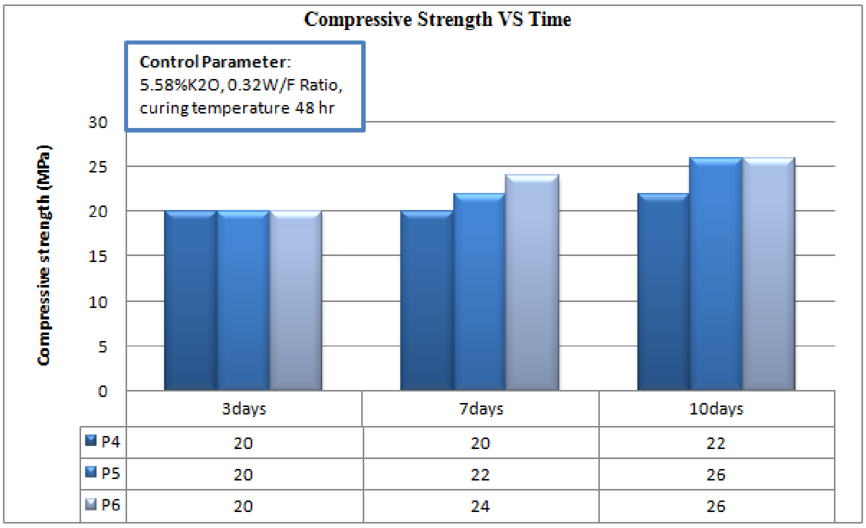

Fig. 11

IV. CONCLUSION

In this paper combinational study of geopolymer constitutes are discussed. Geopolymersare projected as alternate to conventional cement in future because of their high early strength and of course higher durability [22, 23] The effects of factors like fly ash with the presence of potassium hydroxide as an alkali activator in place of sodium hydroxide on geopolymer and changes in physical and mechanical properties like compressive strength, sorptivity have been described thoroughly. Based on the above investigation the following conclusions can be easily drawn.

- Use of potassium hydroxide results in good adhesive properties at the time of mixing and molding creating a sticky paste.
- The incorporation of potassium hydroxide in case of water absorption test indicates highest sorptivity value for the maximum silicate modulus (SiO_2/K_2O) of 1.43 among the two trails for Class F Fly Ash (Gray) due to impact of change in average pore size.
- For fly ash based geopolymer the increment in percentage of K_2O gives better strength of all.
- The compressive strength results in case of geopolymer are way better and faster than ordinary cement concrete. As cement matures at 28 days and we are getting enormous strength in just 10 days in case of geopolymer specimen P1 and P3 both with 32 MPa. This is better than the strength of ordinary M30 concrete after 28 days of curing.
- In case of compressive strength the Class C Fly Ash (White) is showing better compressive strength day by day from other samples of fly ash.
- The compressive strength data in case of all samples are satisfactory. The sample having 8% K_2O and Class F Fly Ash (Black) with silicate modulus value 1, shown highest compressive strength amongst all and the sample having 5.58% K_2O and Class F Fly Ash (Black) with silicate modulus value 1.43, has shown lowest compressive strength after 48 hours of heat curing at 85˚C.

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