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Mechanical Properties of White Fly Ash Activated With Wavering Alkalinity

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ABSTRACT: *This research is an outcome of the development of alkali activated fly ash paste obtained from various combinations of KOH and Na_2SiO_3 as prime activator. Test data are used to identify the effects of salient factors that influence the properties of the geopolymer. The geopolymer specimens were kept for a heat curing below 85^{o}Ctemperature for 48 hours. The different tests like compressive strength, water sorptivity, water absorption were carried out to compare different properties of geopolymer. Tests show that geopolymer issuitable for infrastructure improvements. Class C fly ash was used as base material for this research. Potassium Hydroxide pellets& Sodium silicate solution were used as ingredients.*

Keyword: *geopolymer, sorptivity, fly ash, compressive strength*

I. INTRODUCTION

Geopolymers are a completely new kind of cross linkedaluminosilicate network manufactured by activating fly ash, with a highly alkaline solution and thermal curing. In the recent years, curiosity on geopolymer is increased rapidly due to their advantages over ordinary Portland cements.Geopolymer materials are found to gain, better strength and moreoverthere is no alkali-aggregate reaction in these materials[1].It has the promising quality to replace the cement entirely as binding material.High compressive strengths and excellent performance of fly ash based geopolymer manufactured with different activators have beenobserved when it is exposed to different aggressive exposure [2].Alkaline activation of fly ash yields materials whose strength exceeds that of standard Portland cements. In the process (mostly taking place by the through solution mechanism) the atoms of Al (and probably also those of Ca) penetrate the originally silicate lattice of fly ash, producing a 2D-3D inorganic hydrated polymer (geopolymer)[3].The increment of compressive strength with the increase in activator combination may happen due to excessive sodium silicate that slowed the geopolymerisation process by the precipitation of Al-Si phase, which prevented contact between the reacting material and activating solution and decreased the activator content [4].But here KOH is used instead of NaOH in order to check the change of several properties of the geopolymer. As it was reported that sodium hydroxide (NaOH) is widely used for the synthesis of geopolymer compared to potassium hydroxide (KOH)[5]. The difference between KOH and NaOH is due to ionic size where Na^+ is having smaller ionic size compares to K^+.

II. MATERIALS AND METHODS

2.1Materials

Class C fly ash wasused in this study. Class C fly ash was collected from Kolaghat Thermal Power Plant near Kolkata, India.Table-1 shows the chemical composition of the fly ash as the main constituent material of geopolymer.Sieving of the samples of fly ashwas done by using 75 micron sieve and specific gravity of the samples was found as 2.04. Apart from fly ash as the main constituent of Geopolymer; potassium hydroxide and sodium silicate were the activator used in the formation of geopolymer.Laboratory gradepellet form Potassium Hydroxidehaving 84% purity was supplied by LobaChemie Ltd, India. Sodium silicate solution (SiO_2 =26.5%, Na_2O= 8% and 65.5% water) with silicate modulus ~ 3.31 was supplied by LobaChemie Ltd, India. The water to fly ash ratiowas kept as 0.32 in this below investigation.

Figure-1: Fly Ash Specimens

Table-1: Chemical analysis report of Fly ash

Chemical composition	Class C fly ash
SiO_2	42.4
Al_2O_3	13.5
Fe_2O_3	2.3
TiO_2	2.1
CaO	27.13
MgO	4.6
K_2O	0.6
Na_2O	0.4
SO_3	0.1
P_2O_5	0.2
Loss on ignition	0.40

2.2 Sample Preparation

Thepreparation of geopolymer involves some basic steps. At first the sample of fly ash of class C is sieved with 75 micron and then the alkaline activator (mixture of Potassium Hydroxide and sodium silicate) wasprepared. Before 24 hours of casting the KOH solution was prepared by mixing with water.Andbefore 3 hours of casting, the alkaline activator solution was prepared by mixing the sodium silicate to the KOH solution. Then manual mixing was done with alkaline activator solution to the fly ash and with water (of 32% of weight of fly ash). The prepared sticky geopolymer paste was then moulded in cubes of 50mm each side. The last and final step ended with the heat curing at 85^0C for 48 hours[5]. After 48hours of heat curing the samples were left for 3 days. After 3 days samples were finally ready for various tests. The combination of activators, used in the Geopolymer, is given in Table-2 and Table-3.

Table-2: Details of Geopolymer test specimens

Sample Id	Type Of Specimen	K_2O Content In Activator (%) Of Fly Ash	Equivalent Silicate Modulus (SiO_2/K_2O)	Equivalent Silicate Modulus (SiO_2/X_2O Ratio)	Water/ Fly Ash Ratio	Curing Temp. And Duration
GPWF1	PASTE	8	1	0.77	0.32	85^oC and 48 hrs
GPWF2	PASTE	5.58	1.43	1	0.32	85^oC and 48 hrs

Table-3: Combination of different Alkali-Oxide

Sample Id	X_2O %	Na_2O %	K_2O %	Na_2O/K_2O
GPWF1	10.42	2.42	8	0.30
GPWF2	8	2.42	5.58	0.43

III. RESULT & DISCUSSION

3.1 Compressive Strength Test

The compressive strength of geopolymer was determined after 3 days from manufacture.12 specimens were loaded in compression testing machine. Thespecimenwere kept one by onein the center of the base plate of

compressive test machine and the load was gradually applied at a rate of 10kN/sec until the specimen failed. Here the reading implies the average of 12 reading.

Table-4: Compressive strength table

Sample Id	Fly Ash Type	Strength Developed at 3days(MPa)	Strength Developed at 10days(MPa)
GPWF1	Class C	20	32
GPWF2	Class C	20	26

Both sample GPWF1 and GPWF2sustains a load of 50 KN with strength value equal to20MPa.

Figure-2: Compression Strength Set up

Figure-3: Compression Test Results

Variation of K_2O for 8% and 5.58% in cases of white fly ash is giving same compressive strength. Excessive presence of calcium in class C fly ash emphasize the Ca^{++} to take role of charge balancer of aluminum rather potassium ion. So immediate precipitation or polycondensation is experienced. Due to this nature change in alkalinity does not contribute towards the change in strength characteristics. Whereas higher alkalinity drives the formation of secondary C-S-H product with time being. It is the prime cause of differential strength gain after 10 days.

3.2 Water Absorption and Apparent Porosity Test

The test on Water absorption and Apparent Porosity of geopolymer was done to judge their pore features[5].The sample was placed properly in a wire basket and immersed in distilled water at room temperature.The basket and sample were immersed for a period of 24 hours.Weight of the samples was taken, before immersing and after 24 hours[5].

Table-5: Results of water absorption, apparent porosity

Specimen ID	Water absorption (%)	Apparent porosity (%)
GPWF1	6.6	9.8
GPWF2	6.3	9.5

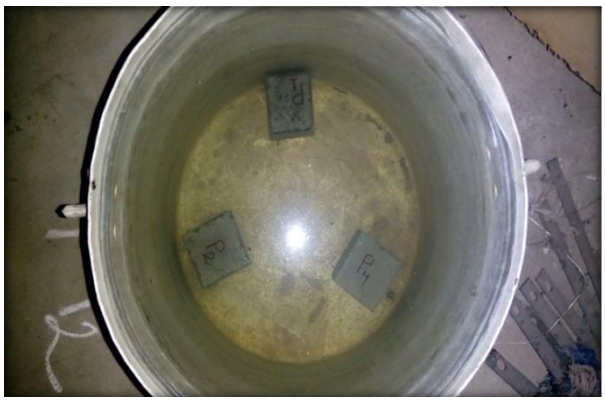

Figure-4: Water Absorption Test Set Up

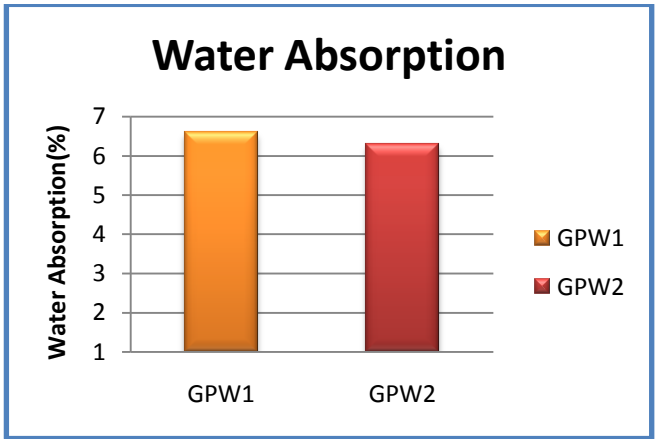

Figure-5: Water absorption Chart

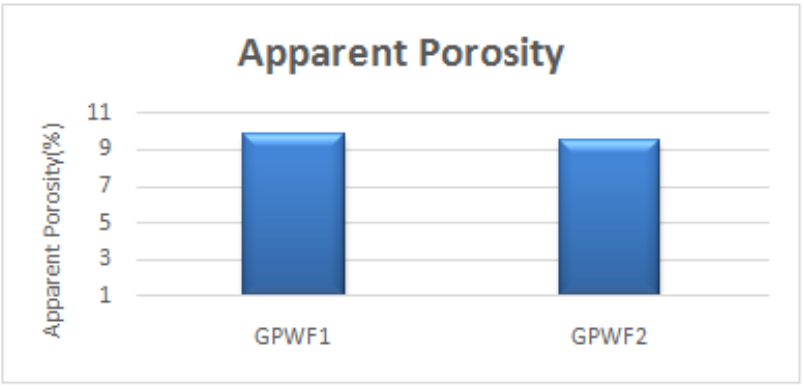

Figure-6: Apparent Porosity Chart

This test was conducted to determine the amount of pores and voids present in the geopolymer. From Figure-5 we have found thatthe water absorption value of sample GPWF1 is 6.6 and sample GPWF2 is showing a value of 6.3. Figure-6 indicates that apparent porosity value of sample GPWF1 and GPWF2 are 9.8 and 9.5 correspondingly.Lower value of water absorption indicates lesser permeable voids present in the geopolymer cubes which is desirable. Class C Flyash activated with 5.58% K_2O is absorbing less amount of water than the fly ash having 8% K_2O.

3.3 Water Sorptivity Test

This test measures the rate of absorption of water by capillary suction as well as cumulative amount of water absorbs[12].Water was used as a test fluid. Dry weight of each sample was taken.Then the specimens were coated with grease on other surface to allow water ingress into the geopolymer cube only from the bottom flat surface.The specimens were immersed in trey containing water and supported in such a way that about 1 cm

of the lower part of the specimens was in water.The weights of two samples were taken in certain interval of time.The procedure was same as D.Dutta et al[5]. Figure-9 shows the sample GPWF1 is having sorptivity value of 3 and the sample GPWF1 is having highest sorptivity value of 5 in between two.

Table-6: Weights of Samples

SAMPLE ID	DRY WEIGHT OF SAMPLE in (gm)	WEIGHT OF SAMPLE AT DIFFERENT TIME INTERVAL in gm						
		2 min	5 min	10 min	15 min	30 min	60 min	120 min
GPWF1	199	200	200	200	200.5	201	201	201.5
GPWF2	197.5	199	199	199.5	199.5	200	200	201

Figure-7: Water sorptivity Set Up

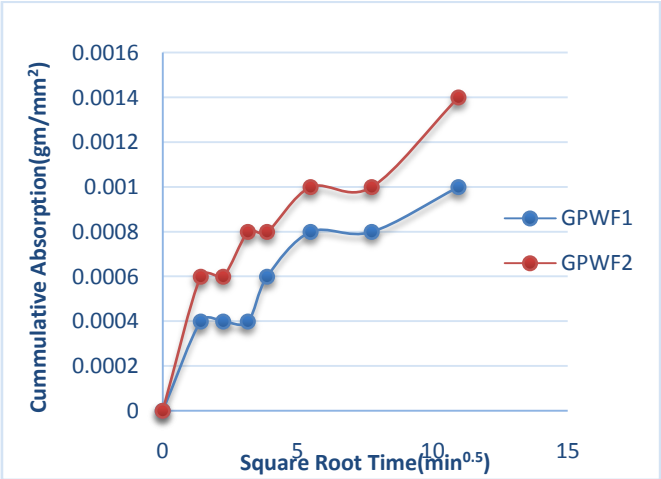

Figure-8: Water Sorptivity Graph

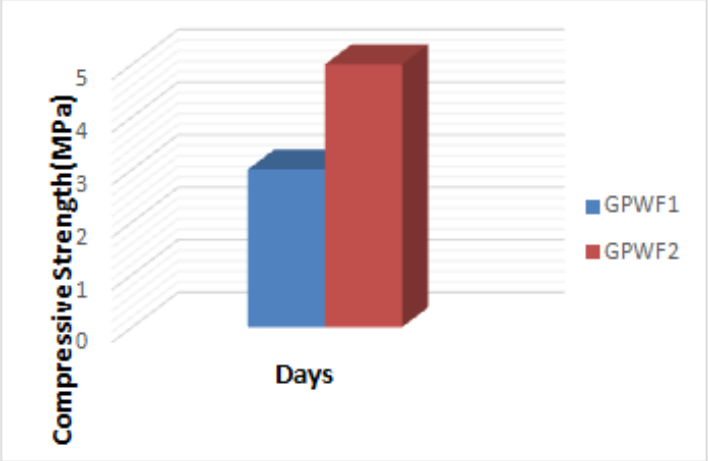

Figure-9: Water Sorptivity Result

Water absorption is the total amount of water absorbed, but water sorptivity is the rate of absorbtion of water. Water sorptivityis the function ofstructural pore distribution. Higher value of sorptivity results more surface tension in sample thus causing more permeable material.Sorptivity of geopolymer based on class C increases with thehigher percentage of K_2O.It is because of the presence of lower pore sizes.

IV. CONCLUSION

1. Compressive strength value is a function of time while the base material is class C fly ash.3 days compressive strengths are almost similar for GPWF1 and GPWF2 samples whereas after 10 days GPWF1 gains much strength in compare to GPWF2
2. The water absorption and the apparent porosity value for GPWF1 and GPWF2 are 6.6, 6.3 and 9.8, 9.5 respectively. These similar outcome is mainly because of rapid precipitation of polymer sample in presence of calcium as charge balancing cat-ions.
3. As per water sorptivity test, class C fly ash based geopolymer with higher percentage of activator gives rise in sorptivity. It is because of the lowering of average pore size.
4. It may be suppose that secondary C-S-H formation is emphasized in presence of higher alkalinity. Though this phenomena is somehow give rise in the strength characteristic for a certain time. But this tendency may bring fracture due to post developed pore pressure. That, geopolymer containing 5.58% alkaline activator provide better result in case of strength, durability, porous characteristics and may be used in replacement of ordinary Portland cement.

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