

## **NO CEMENT CONCRETE: A GREEN SOLUTION TO SUSTAINABLE CONSTRUCTION**

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**Abstract—** Concrete without using cement as binder has been the topic of interest for the present day researchers as cement production is proved to be not environment friendly due to release of lot of carbon dioxide into the atmosphere. Nearly one ton of cement production releases one tonne of carbon dioxide into the atmosphere. Researchers have made attempts to use industrial waste products like fly ash, silica fume, ground granulated blast furnace slag (GGBFS) and rice husk ash as partial replacement to cement in the concrete production. However this replacement levels are about 25% to 35% only. To further minimise the use of cement in construction industry, geopolymer binders are developed. Geopolymer concrete is essentially concrete having coarse aggregate, fine aggregate bonded with alkali activated Fly ash paste. Fly ash is activated by alkali silicate and alkali hydroxide solution. For the fly alone to be activated by the alkali activator heat curing at 60<sup>0</sup>C for about 24 hours is required. In present investigation an attempt has been made to use class F fly ash along with GGBFS as source material to develop alkali activated concrete which can be cured in the room temperature alone. The study includes the casting and testing of alkali activated concrete using different proportions of source material to alkaline solution ratio, different concentration of sodium hydroxide solution. The results indicated that the alkali activated concrete can be produced using GGBFS and Fly ash as source materials and the curing of such concrete at room temperature alone produce concrete of satisfactory compressive strength.

**Keywords—** Geopolymer , GGBFS, Flyash, Alkali activated concrete

### **I. INTRODUCTION**

Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one tonne for every tonne of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminium. Davidovits of France produced binders by mixing alkalis with burnt mixture of kaolinite, limestone and dolomite. The binder thus produced is named as “Geopolymers” since they have polymeric structure (Davidovits, 1994). During the past two decades, alkali activated cements and concretes have attracted strong interests all over the world due to their advantages of low energy cost, high strength and good durability compared to Portland cements. A major incentive for further development of such cements is generated by the annual output of fly ashes from power plants and other by-product materials, which is so enormous that there is a constant need to find new uses for them. In the present investigation an attempt has been made to develop alkali activated concrete by using Fly ash and GGBFS as source materials and Sodium Hydroxide and sodium silicate as activators to produce alkali activated concrete. The major advantage of using GGBFS is that it totally eliminated the heat curing, which is required in case geopolymer concretes (Rangan , 2005).

### **II. EXPERIMENTAL METHODOLOGY**

In the present investigation, equal proportions fly ash and GGBFS is taken as binder. Alkali Fluid to binder ratio is varied as 0.50, 0.55 and 0.60. Alkali Fluid is responsible for providing workability during the casting and strength after hardening. The alkali activator sodium silicate to sodium hydroxide ratio is fixed as 2.5 and the coarse aggregate content and fine aggregate content are taken as fixed. The variations considered are the molarity of the sodium hydroxide and the alkali fluid to source material ratio. Sodium hydroxide molarity is varied as 2M, 4M, 6M and 8M. Solution to binder ratio is varied as 0.5, 0.55 and 0.60.

The purpose of varying Sodium hydroxide concentration is to observe the strength increase and the variation of solution to binder ratio is to observe the strength enhancement with increase in the alkali solution. The mixed considered in the investigation are presented in Table.1. For all mixes workability of the matrix is maintained constant as 80mm and for this purpose CONPLAST 430 is used to get the required slump. After casting the cubes with the required proportions of the ingredients, the specimens are left for air curing. The average room temperature during the air curing is around 35<sup>0</sup>C during the day time and 20<sup>0</sup>C during the night time. After one day casting the cubes are demoulded from moulds and left in the room temperature for air curing only. Alkali activator is the mixture of sodium silicate (Na<sub>2</sub>SiO<sub>3</sub>) and sodium hydroxide (NaOH) solution of mentioned molarity. The solution is prepared before 24hours of casting. This is due to the reason that the addition of water to sodium hydroxide releases lot of heat. Silicate to hydroxide ratio is kept constant as 2.5 and NaOH solution of 2M is prepared by dissolving 2×40 (since the molecular weight of sodium hydroxide is 40)=80 grams of sodium hydroxide flakes in potable water and making it up to one-litre solution. Sodium Silicate Solution of alkalinity 14.3%, silica 39.7% and water 54% is used.

Table.1. Different mix proportions for 1 cum of concrete considered in the investigation

Binder (400kg)		Aggregates, (kg)		A	B (kg)	C	D	E	F (MPa)
Fly Ash (50%)	GGBFS (50%)	Fine	Coarse						
210	210	740	980	0.5	210	2.5	2M	3.5	30.22
							4M	4.5	33.33
							6M	6	35.56
							8M	7	38.67
210	210	740	980	0.55	231	2.5	2M	3	32.00
							4M	4	34.67
							6M	5.5	36.89
							8M	6.5	40.00
210	210	740	980	0.6	252	2.5	2M	2	32.00
							4M	3	35.11
							6M	5	37.78
							8M	6	42.67

A= Solution/binder ratio

B= Alkali Activator Solution (NaOH+Na<sub>2</sub>SiO<sub>3</sub>)

C= Ratio of Sodium Silicate to Sodium Hydroxide in the alkaline activator

D= Molarity of Sodium hydroxide used in the Alkali Activator

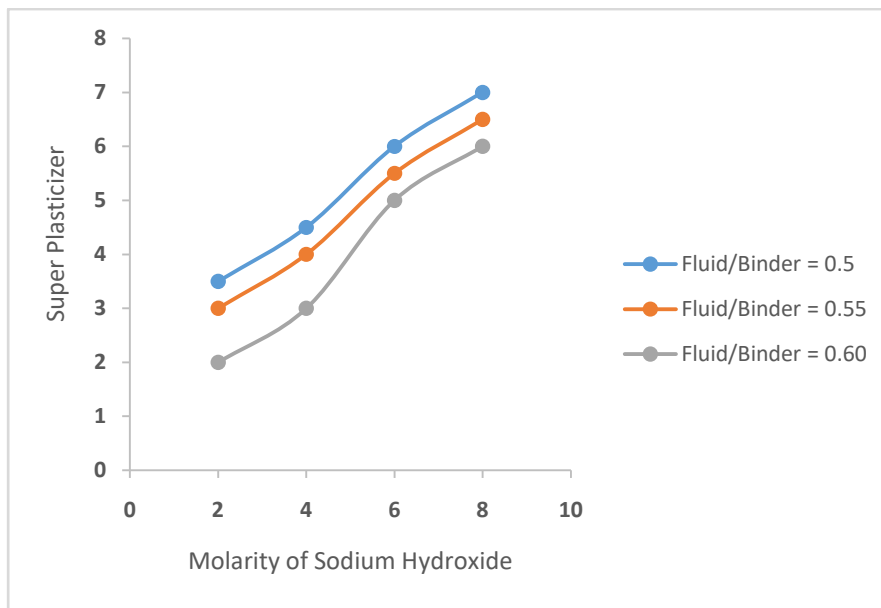
E= Super plasticizer as percentage of binder

F=28 Day Compressive Strength (MPa)

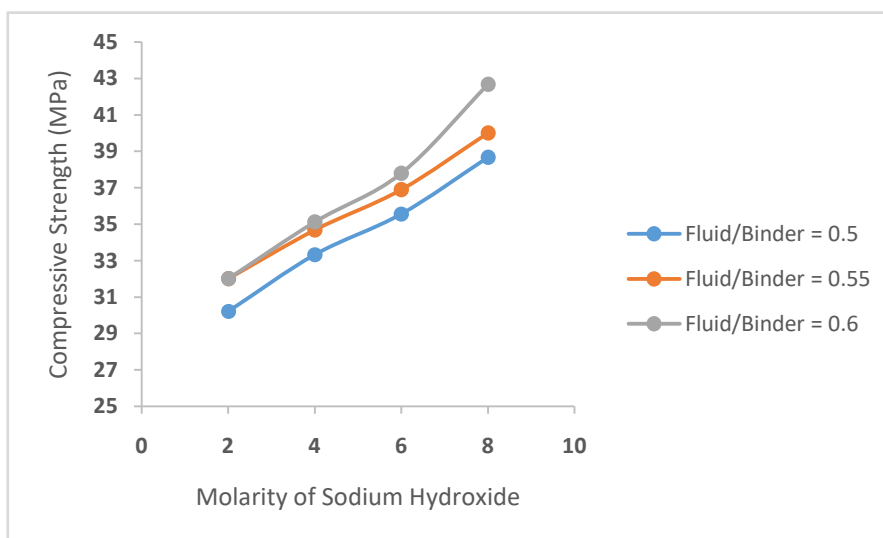
### III. RESULTS AND DISCUSSION

Total 12 mixes are considered in this investigation varying the concentration of sodium hydroxide and alkali activator to binder ratio. Alkaline activator provides workability to the mix in its green state and strength to the matrix at its hardened state. Insufficient quantity of alkaline fluid may not be sufficient in completing the polymerisation of the source material fly ash and GGBFS, while higher dosages of alkaline solution may hamper the compressive strength of the mix leaving pores in the hardened concrete. The requirement of super plasticizer to improve the workability of the matrix in its green stage to attain a slump of 80mm is presented in Table.1. The variation of super plasticizer requirement is presented in fig.1. From fig.1, it can be found that super plasticizer requirement increased with the increase in the molarity of sodium hydroxide solution. The reason for this can be attributed to the fact that increase in molarity of Sodium hydroxide increases the viscosity of the alkali activator and hence decreases the workability of the matrix. In the case of alkali activated concrete with 8M molarity Sodium Hydroxide, with 210kg of alkali activator, the super plasticizer requirement is found to be 7% of binder. At higher alkali fluid to binder ratio (0.6) the super plasticizer requirement is observed.

From this observation it concluded that Alkali Activated Concrete with Fly ash and GGBFS as source material are less workable and need more super plasticizer. Hence for achieving good workability of alkali activated concrete with Fly ash and GGBFS as source material, research in the direction of agents that promote workability of the mix are needed. The compressive strength of different mixes tested in this investigation are presented in Figure 2. From figure 2, it clear that alkali activated concrete can be achieved with curing at room temperature in the range of 30 MPa to 42.66MPa. This aspect of alkali activated concrete increases the usage of this material in the construction sector as heat curing very difficult to achieve in the regular construction practices. One of the major constraint of adopting fly ash based geopolymer concrete in construction industry is its need for heat curing. The variation of compressive strength of the mix tend to increase with alkaline activator to binder ratio. However this increase is not in case of fluid to binder ratio above 0.55. Increase in molarity of Sodium Hydroxide solution increased the compressive strength of the mix. From this discussion it can be concluded that a mix design procedure for alkali activated concrete can be developed using fly ash and GGBFS as source materials.



*Fig.1. Super plasticizer requirement with variation in molarity of NaOH Solution*



*Figure 2. Variation of Compressive strength with variation in molarity of NaOH Solution*

#### IV. CONCLUSIONS

Based on the experimental investigation the following are the conclusion arrived at.

1. Alkali Activated concrete with Fly ash and GGBFS as source material possess less workability and require super plasticizer.
2. With increase in the molarity of Sodium Hydroxide solution, the workability of the matrix decreases and needs more super plasticizer for a desired workability.
3. Alkali Activated concrete with equal proportions of Fly ash and GGBFS as source materials, give noticeable compressive strength when cured at room temperature.
4. With increase in the molarity of Sodium Hydroxide solution, the compressive strength of the matrix increases.
5. Increase in alkali fluid to binder ration beyond 0.55, may not increase the compressive strength.

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