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Study on the Behavior of Geopolymer Bricks Under Different Curing Temperatures and Alkaline Solution Concentrations

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Abstract

Conventional clay bricks are produced from the agricultural soil, where they contain limited advantages in the field of construction. Geopolymer bricks (GPB) might be an improved alternative to the conventional clay bricks which could produce innumerable environmental problems. These geopolymer bricks are characterized by various parameters such as type of binding materials, type of curing, curing temperature and concentration of alkaline solution, etc., Fly ash (FA) is the base material used in the making of GPB which are rich in silica content and reacts with the alkaline solution and results in better strength properties than the conventional clay bricks. In this study, the various parameters considered for investigation were type of fly ash (class C and F), alkaline solution (NaOH & Na_2SiO_3) concentration (4M, 6M, 8M, 10M, 12M) and curing temperature in oven (Room temperature, 60^0C, 90^0C). It was observed that the class F Fly ash with 10M alkaline solution under 60^0C hot air oven curing produces better results.

Keywords: Geopolymer bricks, Types of Fly Ash, Alkaline Solution, Curing Temperature.

I. INTRODUCTION

Construction industry plays a crucial role in the economic growth of a country. In India, due to rapid urbanization and industrialization construction industry faces many problems like scarcity of raw materials, cost of quality materials, environmental pollution, etc., Hence the whole industry in hunt for determining various alternative materials which could replace the conventional construction materials without compromising its structural but maintaining increases its performance.

Based on the numerous investigations done,FA is an abundant waste fromthermal power plants and will be a better substitute raw material in the production of concrete and bricks. Extensive research has been conducted over the past 30 years to use fly ash in a variety of sectors as it is not considered to be hazardous waste. In general, fly ash recovery programs can be viewed from two angles, namely, Reducing the environmental impact and correcting disposal problems. Percentage use of fly ash in various sectors of Indian economy system is shown in Figure 1.

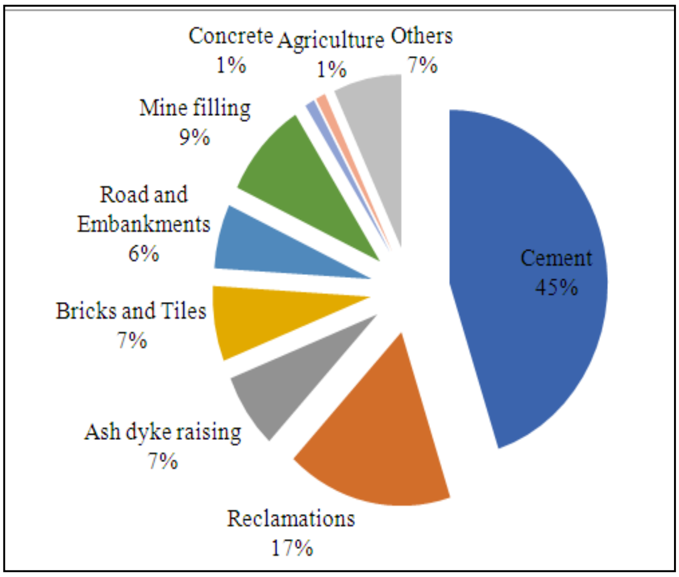

Figure 1: Fly Ash Usage in India (%)

At 1980s, Davidovits a French scientist invented a new technology that will completely eliminate the usage of cement in the process of making concrete[5]. Nowadays the same concept was utilized in the manufacturing of bricks by eliminating the usage of natural clay. The cementing nature of fly ash in brick was induced by adding the alkaline solution into the dry raw mixture instead of water.

Geopolymerization of bricks depends upon the ability of Al ion to makethe crystallographic and chemical variations with Si content and various factors like type of source materials, type of curing, curing temperature, curing time, testing age, type and concentration of alkaline solution[2]. In order to resolve the problems related to the scarcity of natural riversand, M-Sand was utilized as a fine aggregate. Preliminary study on the GPB bricks was done on varying the type of fly ash by keeping the curing temperature as 60^0C. Then the structural behavior of GPB was assessed by crushing strength, water absorption, shape and size, acid resistance etc.

II. MATERIALS USED& MIX PROPORTIONING

These are the materials used in this investigation.

- Fly Ash (Class F & C)
- Coarse Aggregate (Crushed Stone)
- Fine Aggregate (M-Sand)
- Alkaline Activators (NaOH & Na_2SiO_3)
- Water (For the Preparation of Alkaline Solution)

A. Fly Ash (FA)

Different grades of fly ash got from mechanical or electrostatic precipitators of Mettur Thermal Power Plant was used as per IS 3812-2003[2] [6]. The usage of fly ash reduces the amount of liquid content required for the making of concrete or bricks. Properties ofFA were tabulated in Table 1 and 2.

Figure 2: Class F and Class C FA

Table 1: Properties of FA

Parameter	Type of FA		IS 3812-2003
	Class F	Class C	
Fineness (Blaine's Area) (m^2/kg)	440	345	≥ 320
S.G*	2.35	2.25	-
Residue on 45μ sieve (%)	67.8	18.6	34
Moisture content (%)	0.4	0.35	-
Autoclave expansion (%)	0.045	0.029	≤ 0.8
Color	Light Grey	Dark Grey	-

[S.G* - Specific Gravity]

Table 2: Chemical Composition of FA

Composition	Type of FA		IS 3812-2003
	Class F	Class C	
CaO	0.07	0.03	≤ 5
Na_2O	0.79	0.73	≤ 1.5
SO_3	1.32	1.06	≤ 3
MgO	1.47	2.13	≤ 5
LOI	2.03	1.60	≤ 12
Fe_2O_3	8.19	8.06	-
Al_2O_3	26.98	27.13	-
SiO_2	56.4	57.3	≥ 35
SiO_2 + Al_2O_3 + Fe_2O_3	91.57	92.49	≥ 70

B. M-Sand (MS)

Aggregates consume most volume of the GPB since it consumes 70 to 75% of its total volume. Properties of crushed MS conforms to IS 383-2016 used in this study are illustrated in Table.

Table 3: Properties of MS

Property	Values
Type	Crushed
Shape	Spherical
Size (mm)	4.75
S.G*	2.88
W.A*(%)	1.60
Bulk density (kg/m^3)	1780

[W.A* - Water Absorption]

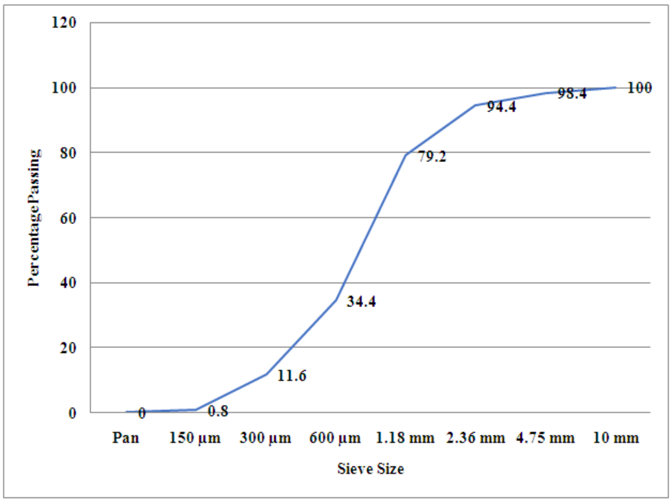

Figure 3: Particle Size Distribution on MS

C. Coarse Aggregate (CA)

For this study, the well-graded and locally available 12-mm coarse aggregates were selected.

Table 4: Properties of CA

Property	Result
Type	Crushed
Shape	Angular
S.G*	2.76
Size (mm)	12
W.A*(%)	0.80
Crushing value (%)	13.9
Impact value (%)	11.3
Fineness modulus	6.52
Bulk density (kg/m^3)	1635

D. Alkaline Solution

Geopolymericaction was induced in the brick element through alkaline activators such as NaOH and Na_2SiO_3 which are commercially available,by taking into account the high cost of K-based chemicals. NaOH with 98% purity have been dissolved in distilled water to make NaOH solution. Commercially available Na_2SiO_3 is in a solution form which was used as such.

E. Mix proportioning

Mix design was performed as per the guidelines mentioned in ACI 211.1 and weigh batching is implemented to make the GPB.

Table 5: Mix Proportioning

Materials	FA	MS	CA	NaOH	Na_2SiO_3
kg/m^3	412	559	1286	45	113

III. EXPERIMENTAL INVESTIGATION

Preliminary investigation done on both types of FA to forecast the suitability of using in the entire investigation was organized in Table 6.

Table 6: Preliminary Investigation

Type of FA	Crushing Strength of GPB at Days (MPa)			
	1	3	7	28
Class F	8.5	14.4	18.9	24.7
Class C	7.1	12.6	15.2	20.3

Based on the preliminary investigation, F class FA exhibits higher strength than C class at all ages of curing. It happens due to the thermal curing enhances the strength properties of FA.

A. Crushing Strength (CS)

The GPB specimens were produced at room temperature and kept for curing in hot air oven for prescribed curing duration[4]. Results were organized in the subsequent table.

Table 7: Crushing Strength

Curing Temperature	Molarity	Crushing Strength at Days (MPa)		
		1	3	7
Clay Brick (CB)		2.8	4.9	10.6
Fly Ash Brick (FAB)		3.3	5.5	12.7
Room temperature	4	3	5.1	10.5
	6	3.1	5.3	11.2
	8	3.2	5.7	12.8
	10	3.7	6.6	15.4
	12	2.2	6.4	14.1
60^0C	4	9.2	13.5	25.3
	6	9.7	13.9	27
	8	10.6	15.2	30.4
	10	11.4	16.4	36.5
	12	8.1	14.3	27.6
90^0C	4	5	7.2	14.1
	6	5.3	7.4	15.0
	8	5.9	8	17.2
	10	6.2	9.2	20.6
	12	3.7	7.7	18.9

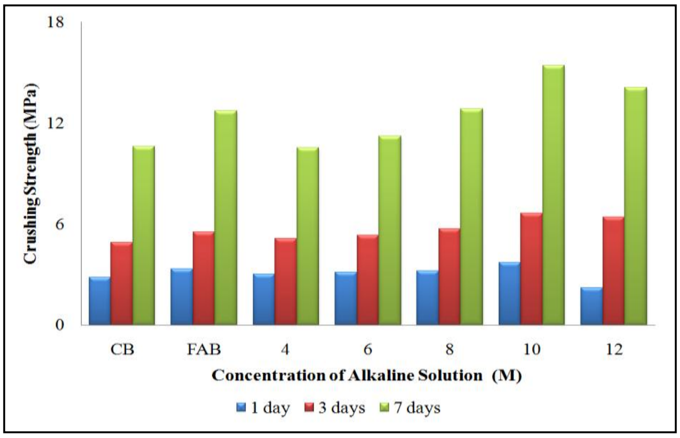

Figure 4: CS Test results(CB and FABwith GPB at Room Temperature)

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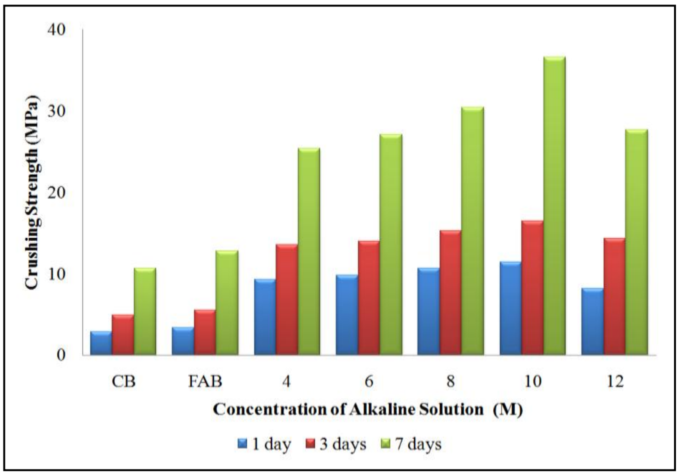

Figure 5: CS Test results(CB and FAB with GPB at 60^0C)

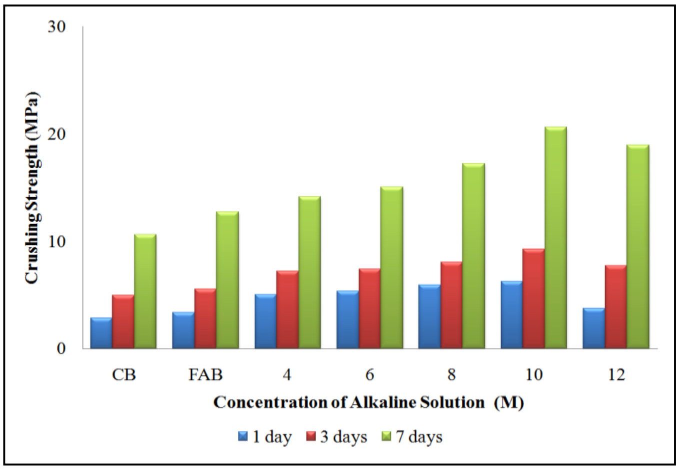

Figure 6: CS Test results(CB and FAB with GPB at 90^0C)

B. Water Absorption (WA) Test

WA test was done by keeping the GPB bricks in potable water for 28 hours confirming to IS 3495 (Part II) and the increase in weight was observed and tabulated in table 8.

Table 8: WA test results (Increase in Weight) (%)

Curing Temperature	Alkaline Solution Concentration (M)				
	4	6	8	10	12
Room Temperature	11.2	10.4	9.6	8.1	13.7
60^0C	8.3	7.2	6	5.5	9.1
90^0C	9	8.7	7.7	6.8	10.4

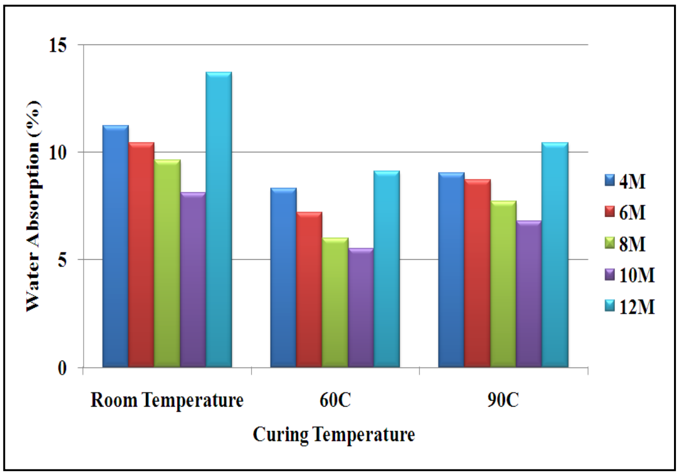

Figure 7: WA Test Results

C. Acid Resistance Test

Acid resistance of GPB specimens were determined by keeping them in 3% H_2SO_4 solution. Concentration of solution was maintained constantly throughout the investigation. After that the specimens were taken out and surface of the specimens were cleaned and weighed. Loss of weight is tabulated in table 9.

Table 9: Acid Resistance Test Results (Loss of Weight) (%)

Curing Temperature	Alkaline Solution Concentration (M)				
	4	6	8	10	12
Room Temperature	9.39	8.1	7.34	6.98	9.12
60^0C	4.98	3.71	3.38	2.64	4.57
90^0C	5.32	5.18	4.7	4.16	6.28

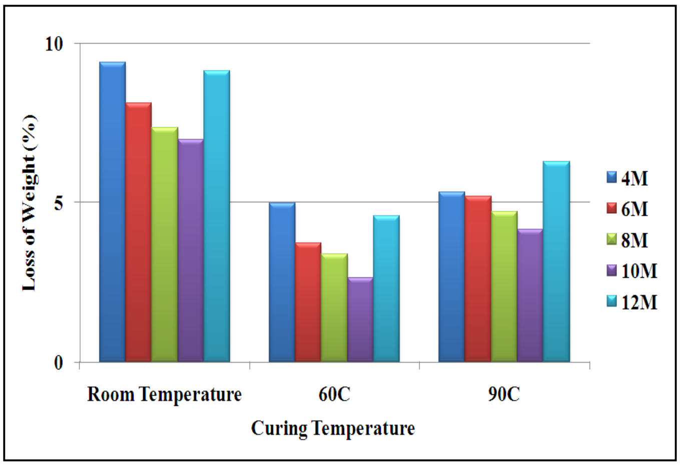

Figure 8: Acid Resistance Test Results

IV. CONCLUSIONS

The following conclusions are arrived from the experimental study done on GPB with different concentrations of alkaline solution and curing temperatures.

- Geopolymer bricks can be used as a viable alternative to the conventional clay bricks.
- Class F fly ash produces better strength values than the GPB specimens made with Class C fly ash.
- It was concluded that the optimum results are obtained at 10M alkaline solution and 60^0C hot air oven curing temperature. Beyond 10M, the strength property doesn't show better results than other concentrations and increases the cost of GPB. Increase in curing temperature increases the strength of GPB mixes, but 90^0C also doesn't produce viable results.
- Thermal curing temperature of 60^0C shows better results with the ratio of Na_2SiO_3/NaOH is 2.5, whereas the previous literatures shows that the curing temperature increases to 100^0C when the ratio of alkaline activator is around 1.5 [12].
- At 7 days, the crushing strength GPB specimen with 10M and 60^0C is 137.01% and 77.18% higher than the specimens with room temperature and 90^0C respectively.
- Increment in alkaline solution concentration reduces that pores on the surface of the GPB. It results in reduced water absorption at optimum parameters.
- Generally, GPB is alkali resistive nature and shows appreciable results when the specimens are immersed in 3% H_2SO_4 solution, whereas the reduction in molarity of solution shows less than 1% loss of weight will be observed [3].

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