Study on Geopolymer Concrete Block

K Santhoshi Revathi[1] EV.Raghava Rao[2] A.Matha Prasad[3]
[1]P.G. Student [2]Professor [3]Assistant Professor
[1,2,3]Department of Civil Engineering
[1,2,3]Visakha Technical Campus

Abstract— The application of geopolymer technology substantially reduces the CO2 emissions by the cement industries and utilizes the waste materials such as fly ash. In this project a study has been carried out on manufacturing of geopolymer binder based compressed blocks using fly ash, GGBS and quarry dust as fine aggregate. A mixture of sodium hydroxide and sodium silicate were used to prepare the blocks which were cured at ambient temperature. This project also covers the material and the mixture proportions, the manufacturing process, the fresh and hardened state characteristics, the influence of various parameters on the fresh and hardened state of geopolymer concrete(GPC), the utilization of the material in structural members, and the long-term behaviour. The huge demand from housing industry due to population explosion has entailed the need for sustainable building materials especially bricks. The most basic building material for construction of houses is the usual burnt clay brick. About 22 million tons of coals are consumed in the production of burnt bricks apart from 10 million tones of biomass. The alternatives to these bricks are compressed cement blocks which have gained popularity recently. The main drawback of cement blocks is consumption of cement which is deterrent to sustainability. It is important to find an alternate material which has less carbon footprint than cement. Researchers have tried to incorporate Fly ash, Ground Granulated Blast Furnace Slag (GGBS), lime stone dust, rice husk ash, welding flux slag and other waste products into bricks so as to improve its sustainability.

Key words: Fly ash, GGBS, Geopolymer Concrete

I. INTRODUCTION

The day to day change in the environment is to be one of the biggest challenges for the society. As a known fact the production of cement contributes to the emission of CO_2 through the decarbonization of limestone. Cement is one of the most important binding materials used across the world for a number of construction purposes namely buildings, C.C. pavements etc...The Cement industry is the main source of emission of carbon dioxide and deserves attention in the assessment of carbon emission reduction options. From earlier studies it is known that one ton of Portland cement is responsible for emission of one ton of CO_2 into the atmosphere.

This research work covers an extensive study on fly ash based geopolymer concrete block which aims at a 100% replacement of cement with fly ash as an alternative binding material. The first part of the research studies the manufacture of low calcium fly ash based geopolymer concrete and properties such as compressive strength, split tensile strength, flexural strength. Geopolymer concrete specimens are also tested for chemical resistance. Property study is performed by casting geopolymer concrete block and hollow blocks.

II. LITERATURE REVIEW

During 1970s, the Structural Engineering Research Centre, Chennai has utilized fly ash in concrete as partial replacement for cement. Based on the research and development work at the centre, a two storied building measuring 300 square meter was constructed as early as in 1975 in Structural Engineering Research Center, Chennai. Fly ash was used as a partial replacement of cement in precast reinforced and prestressed concrete structural elements and in cement mortar for plastering and masonry in the construction of the building. This experimental building was constructed to demonstrate the use of fly ash in concrete construction with a view to effect savings in the use of cement and to study the long term performance of the building.

Ranganath et al (2008) have conducted an experimental investigation on effect of fly ash, water content, ratio of sodium silicate to sodium hydroxide solution by the mass and the duration of elevated temperature curing on the properties of fly ash based geopolymer concrete (GPC). It was found that as the water content increases the optimum fly ash content also increases to obtain maximum strength. In addition the given fly ash content increase in the alkaline solution content does not contribute additional strength. It has been found that long curing at elevated temperature increases the strength of geopolymer concrete; however elevated temperature curing beyond 20 hours does not contribute significant strength.

III. EXPERIMENTAL PROCEDURE

Davidovits [1988] proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term „Geopolymer" to represent these binders. Geopolymer concrete is concrete which does not utilize any Portland cement in its production. Geopolymer concrete is being studied extensively and shows promise as a substitute to Portland cement concrete. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete.

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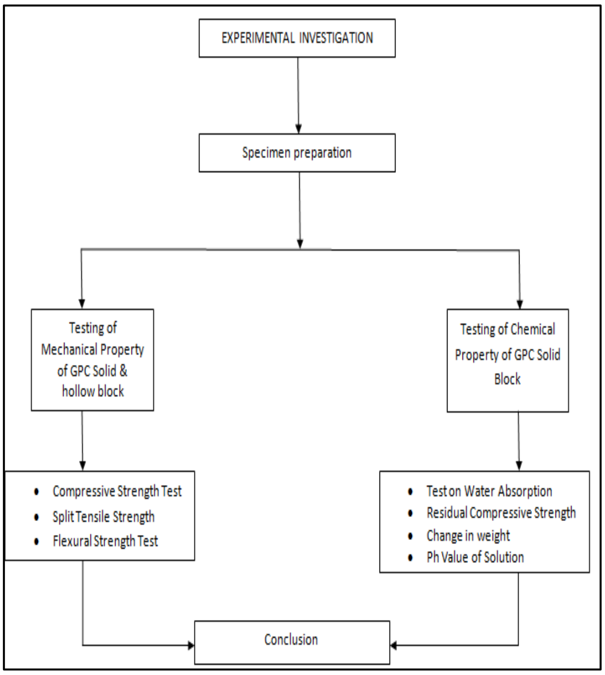

Fig. 1: Methodology

The laboratory program conducted in this investigation focused on four basic mixes and these were designated with the molarity of NaOH. The concentration of NaOH used in the experimentation was based on the review of previous research (Hardjito and Rangan 2005). Accordingly the performances of geopolymer concrete block specimens made with 8M, 10M, 12M and 14M of NaOH were evaluated. The ratio of sodium silicate solution to- sodium hydroxide solution was fixed as 2.5. The ratio of fly ash: sand: coarse aggregate was 1:1.1:2.6 with ratio of activator solution to fly ash as 0.4.The geopolymer concrete mixes were designated as GP1, GP2, GP3 and GP4 respectively.

Specimens were prepared based on the following test conditions:

1) Mixes: GP1, GP2, GP3, GP4.
2) Curing days: 7, 14 and 28 days.
3) Concentration of NaOH: 8M, 10M, 12M and 14M.
4) Curing: Room Temperature and Elevated temperature.
5) Ratio of activator solution-to-fly ash, by mass: 0.4.
6) Mix Ratio: The trail ratio was chosen as 1:1.1:2.6.
7) 7.Ratio of sodium silicate -to-sodium hydroxide solution: 2.5.
8) Ratio of fly ash to binder: 1:0.54.

IV. RESULTS

A. *Workability Results*

The workability of geopolymer concrete which uses fly ash as a substitute for cement was studied and the slump values for four mixes are furnished in Table 5.1. The workability of the geopolymer concrete decreases with increase in the grade of the concrete as presented in Table 1, this is because of the decrease in the ratio of water to geopolymer solids. As the molarity of the NaOH solution increases the workability of the geopolymer concrete decreases, because of the decrease in the water content. This means that as the grade of the concrete increases, the mix becomes stiffer reducing the workability.

Sl.no	Mix Designation	Slump (mm)
1	GP1	213
2	GP2	210
3	GP3	200
4	GP4	198

Table 1: Workability Results

B. *Compressine Strength*

Compressive strength is considered to be the paramount property of concrete. The effect of introduction of fly ash as a replacement of cement on compressive strength of solid block is presented in Tables 2 and 3. The strength of concrete is dependent on the quantity of the alkaline chemical used and the concentration of the sodium hydroxide (NaOH) called Molarity. The higher the molarity of the NaOH solution, the more proportionate is the increase in the strength of the concrete. This aspect is revealed on casting and testing of trail mixes using variable molar NaOH solutions from 8M, 12M and 16M.

Mix designation	Molarity of NaOH	Curing Condition	Compressive Strength(Mpa) (Days)		
			7	14	28
GP1	8M	30˚C	22.32	25.25	30.12
GP2	10M	30˚C	27.02	30.08	31.22
GP3	12M	30˚C	29.83	32.21	34.02
GP4	14M	30˚C	30.42	34.34	36.24

Table 2: Compressive Strength Results of Solid block at curing condition of 30˚C

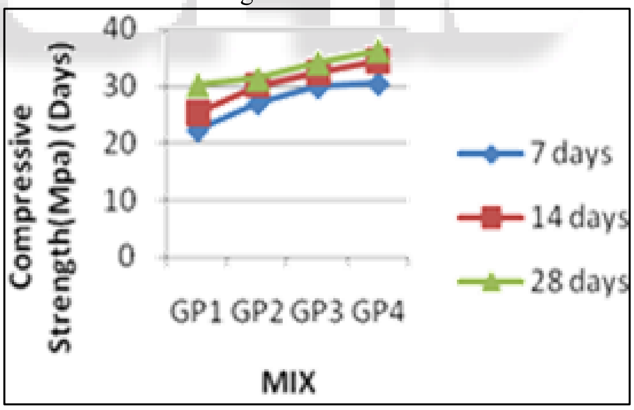

Fig. 2: Compressive Strength vs. Mix at 30˚C

Mix designation	Molarity of NaOH	Curing Condition	Compressive Strength(Mpa) (Days)		
			7	14	28
GP1	8M	60˚C	24.25	27.12	32.01
GP2	10M	60˚C	28.18	30.42	33.32
GP3	12M	60˚C	30.1	32.11	35.98
GP4	14M	60˚C	32.42	34.34	36.96

Table 3: Compressive Strength Results of Solid block at curing condition of 60˚C

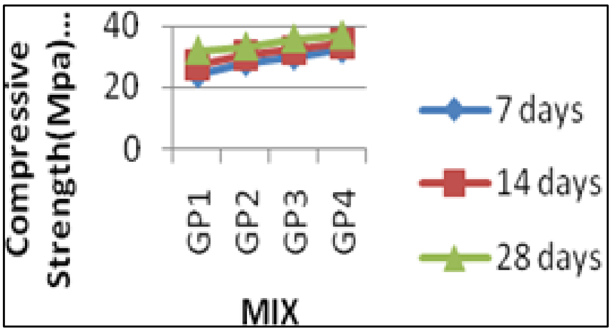

Fig. 3: Compressive Strength vs. Mix at 60˚C

Mix Designation	Molarity of NAOH	Curing Condation	Compressive Strength(Mpa) (Days)		
			7	14	28
GP1	8M	30°C	8.1	10.18	12.16
GP2	10M	30°C	10.21	12.31	14.42
GP3	12M	30°C	11.14	14.21	16.52
GP4	14M	30°C	12.32	15.63	17.42

Table 4. Compressive Strength Results of Hollow Solid block at curing condition of 30˚C

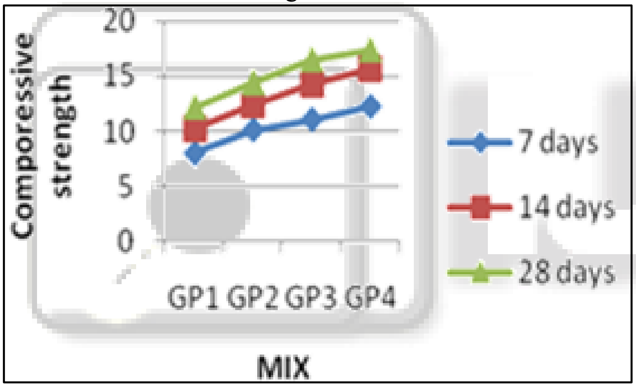

Fig. 4: Compressive Strength vs. Mix at 30˚C

Mix Designation	Molarity of NAOH	Curing Condation	Compressive Strength		
			7	14	28
GP1	8M	60°C	10.12	12.16	15.24
GP2	10M	60°C	11.31	14.2	17.42
GP3	12M	60°C	12.6	15.32	20.24
GP4	14M	60°C	14.36	18.14	22.14

Table 5: Compressive Strength Results of Hollow Solid block at curing condition of 60˚C

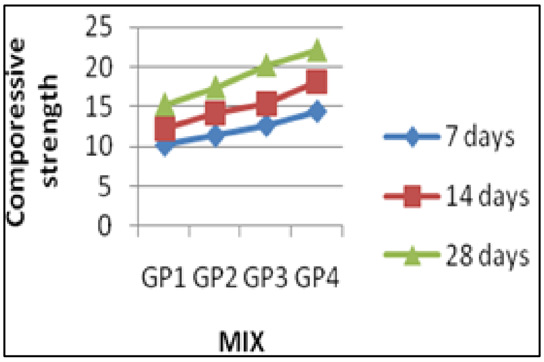

Fig. 5: Compressive Strength vs. Mix at 60˚C

C. *Split Tensile Strength*

The tensile strength characteristics of concrete are of considerable importance and the split tensile test is a simple and reliable method of measuring the tensile strength. These test results show that the tensile strength of geopolymer concrete is only a fraction of the compressive strength, as in the case of Portland cement concrete. The variation of split tensile strength with the age of curing at 30oC and 60oC curing temperatures data presented in Table 5.5 to 5.7. The specimens of 100 mm diameter cylinder have been tested at the age of 7, 14 and 28 days for GP1, GP2, GP3 and GP4 grade concretes. It can be seen from the Figures and Tables that the tensile strength increases with increase in concentration of NaOH. The split tensile strength of concretes mix varies between 1.5 to 3.54 MPa at 60ºC and 1.2 to 2.32 MPa at 30ºC room temperatures respectively for 7 day, 14 days and 28 days for concrete mixes.

Mix Designation	Molarity of NAOH	Curing Condation	Split tensile strength(Mpa)(Days)		
			7	14	28
GP1	8M	30°C	1.12	1.67	2.32
GP2	10M	30°C	1.45	2.63	2.65
GP3	12M	30°C	1.89	2.56	2.59
GP4	14M	30°C	2.32	2.78	3.05

Table 6: Split Tensile Strength Results of Solid block at curing condition of 30˚C

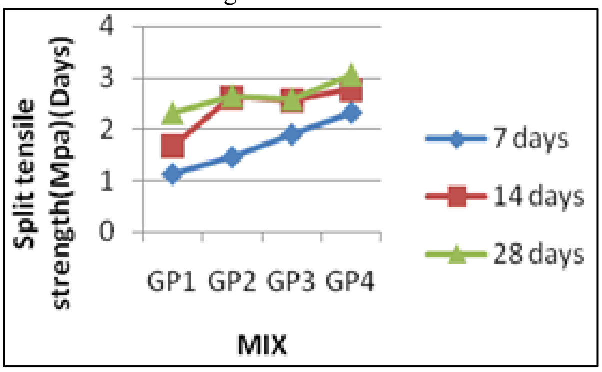

Fig. 6: Split Tensile Strength vs. Mix at 30˚C

Mix Designation	Molarity of NAOH	Curing Condation	Split tensile strength(Mpa)(Days)		
			7	14	28
GP1	8M	60°C	1.5	2.43	2.89
GP2	10M	60°C	2.21	2.56	3.02
GP3	12M	60°C	2.87	2.65	3.48
GP4	14M	60°C	3.54	3.75	3.98

Table 7. Split Tensile Strength Results of Solid block at curing condition of 60˚C

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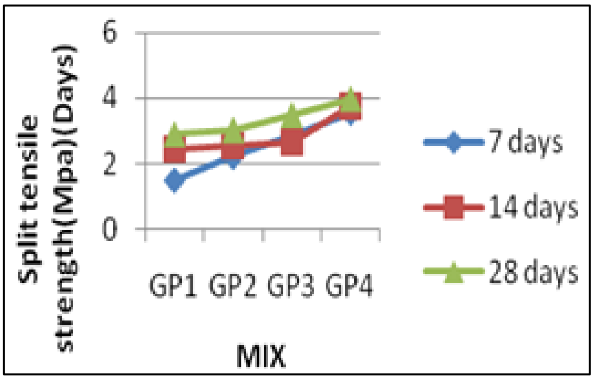

Fig. 7: Split Tensile Strength vs. Mix at 60˚C

1) *Hollow block*

Mix Designation	Molarity of NAOH	Curing Condation	Split tensile Strength		
			7	14	28
GP1	8M	30°C	1.87	1.96	2.34
GP2	10M	30°C	1.84	2.32	2.54
GP3	12M	30°C	1.96	2.66	2.76
GP4	14M	30°C	2.49	2.76	3.12

Table 8: Split Tensile Strength Results of Hollow Solid block at curing condition of 30˚C

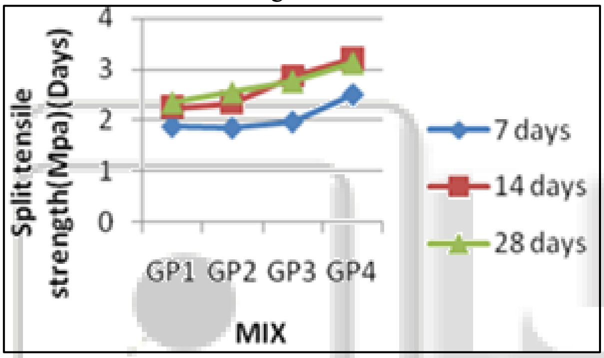

Fig. 8: Split Tensile Strength vs. Mix at 30˚C

Mix Designation	Molarity of NAOH	Curing Condation	Split tensile Strength		
			7	14	28
GP1	8M	60°C	1.75	2.24	2.89
GP2	10M	60°C	2.21	2.34	3.2
GP3	12M	60°C	2.78	2.85	3.48
GP4	14M	60°C	2.84	3.2	3.56

Table 9: Split Tensile Strength Results of Hollow Solid block at curing condition of 30˚C

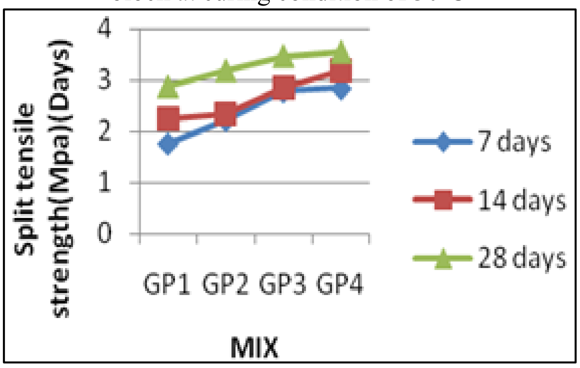

Fig. 9: Split Tensile Strength vs. Mix at 60˚C

V. Conclusion and Future Work

A. *Conclusion*

Depending upon above results and methodology adopted following conclusion were made.

– Compressive strength and split tensile strength increases with increase in concentration of NaOH from 8M to 14M. Increase in compressive strength was also observed with increase in curing time for GPC solid and hollow block.

– Maximum compressive strength achieved for GPC solid block for curing at 60˚C was 36.96 MPa. For GPC hollow block the maximum value of compressive strength is 22.14 MPa. The maximum value of split tensile strength for GPC solid and hollow block cured at 60ºC was 3.98 MPa and 3.56 MPa respectively

B. *Future Scope*

Practical recommendations on the use of geopolymer concrete technology in practical applications such as precast concrete products and waste encapsulation need to be developed in Indian context.

Only qualitative information is available the mechanical strength which can be used to decide about any particular combination of geopolymer mixes to achieve the desired level of strength.

Several studies have shown that fiber addition is an effective method to improve the mechanical characteristics of brittle material such as concrete by providing crack arresting mechanism. Future study has to focus on the effect of fiber addition on the post crack performance of geopolymer concrete. It is also necessary to study the effect of steel and glass fibers in geopolymer concrete.

The mechanical characteristics of geopolymer concrete specimens at elevated temperature (600–800°C) need to be assessed for checking its potential applications as heat resisting construction material.

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