Performance of Geopolymer Concrete under Ambient Curing

B. Naga Vinay, A. Venkateswara Rao

Abstract: ***Geopolymer concrete is an advanced material which is formed by long chains and networks of the inorganic molecule and feasible alternative to ordinary Portland cement which is useful in different forms of construction in civil infrastructure applications. Geopolymer materials are obtained from natural materials and industrial by-products. Percentage of the carbon dioxide evolved from the Geopolymer material such as GGBS and class C fly ash is very low. Geopolymer concrete has the fastest setting time rapid development in strength and the carbon dioxide releasing from the source material is very low. In this paper, it describes that alkaline activators such as sodium hydroxide (NaOH) and sodium silicate in different molarities will mix with the class F fly ash and GGBS in different proportions and compressive strength and flexural strength are determined in order to identify the new phase that formed in Geopolymer matrix.***

Index Terms: GGBS, fly ash, Sodiumhydroxide (NaOH), sodium silicate (Na_2sio_3)

I. INTRODUCTION

For the first time in the world, the replacement material in place of cement was introduced in the year 1978 by Davidots. For the formation of Geopolymer, the Geopolymer material and the alkaline binders are the main constituents. Silicon and aluminium material should be rich in Geopolymer material. The source material for the Geopolymer is fly ash, ground granulated blast furnace slag, rice husk ash and red mud.to create the three-dimensional polymeric chain it is necessary to have silica and alumina of fly ash consisting [1]. For matrix bonding Geopolymer concrete do not require any water, instead, the alkaline solution reacts with silica and aluminium present in fly ash. The alkali solution such as NaOH, Koh, Na_2sio_3 is mixed with aluminosilicate material for the formation of Geopolymer.

Geopolymer has three types namely polysialate Al-O-Si chain, polysialate siloxo Al-O-Si-Si chain and polysialatedisiloxo Al-O-Si-Si-Si chain. The structure of Geopolymer and compressive strength effects significantly by Noah. In ambient curing, the compressive strength increases as the age of concrete increases from 7-28 days. The compressive strength of heat cured fly ash based Geopolymer concrete does not increase substantially after 7 days. In terms of Experimental application, it is very important to cure at ambient temperature. Hence the engineering properties of the GGBS and Fly ash to be improved for the production of the Geopolymer concrete [2]. Geopolymers are the group of materials that are manufactured from the alumino-silicate mixture and Alkaline activators. The advantages and uses of Geopolymer have a wide variety when compared over ordinary Portland cement. There is an extreme increase in the durability and major advantage of using geopolymers over ordinary Portland cement. Usage of Geopolymer concrete has an advantage of the increase in durability and effect of environment will be low when compared to ordinary Portland cement. But there will be some troubles in bringing the usage of Geopolymer concrete. In the construction industry there is a lot of interest in this innovative technology that represents Geopolymer materials. Waste products obtained from natural materials are the by-products for Geopolymer material. In transportation infrastructure, there is a lot of interest growing in Geopolymer applications. The cost of Geopolymer is also very low when compared to ordinary Portland cement. Geopolymer are eco-friendly to nature [3]. The factors influencing the development are material performances under special user conditions and another advantage is also more economical and as well as environmental free when compared to ordinary Portland cement. The compressive strength of geopolymers has reported excellent with low calcium fly ash based. In the process of polymerisation, the alkaline solution undergoes through the fast-chemical-reaction which results in the formation of the three-dimensional polymeric chain. The following steps are: -

1) Dissolution of Alumina and silica ion from the source material.
2) condensation of precursor ions into the monomers.
3) setting of monomers into poly structures.

It is observed that the addition of GGBS increases the strength and simultaneously there is a decrease in setting time This study tells that Ambient curing is suitable for Geopolymer concrete [4]. The factor which has slow down the use of fly ash in Geopolymer is due to slow its low reactivity which causes to slow setting and strength development. addition of GGBS solves the problem of slow reactivity [5]. The development of the Geopolymer concrete was presented. In this, they noticed the application of the Geopolymer concrete and future research needs are suggested [6]. The values of the Geopolymer are comparable to similar strength. The durability results of Geopolymer concrete gave better as like as ordinary Portland cement. Geopolymer has a different composition to ordinary Portland cement. Hence the application of the current standard and durability test method is not considered appropriate [7]. In this paper, they discussed the gaps and recommendations needed in Geopolymer concrete are an experimental investigation on serviceability, especially in crack propagation and experimental investigation on full-scale structural elements for non-fly ash based Geopolymer [8].

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II. RESEARCH SIGNIFICANCE

In this paper, it discusses the durability and strength of the Geopolymer concrete. The strength was developed by using of cured Geopolymer at room temperature. In faster constructions, Geopolymer concrete is used to decrease the setting time and increase the strength and durability within a short time of duration. By using Geopolymer concrete we can save the environment by partial replacement of cement.

III. III. METHODOLOGY

A. Materials:

Fly ash: (class F) In this experiment work, fly ash was obtained from Vijayawada thermal power station in Krishna district, Andhra Pradesh state. The specific gravity of fly ash is 1.84. The composition of the fly ash is tabulated below in Table I.

Table I: Chemical composition of Fly Ash

Sl.No	Characteristics	Fly ash (% wt.)
1	Silica	55-65
2	Aluminium oxide	22-25
3	Iron oxide	5-7
4	Calcium oxide	5-7
5	Magnesium oxide	<1
6	Titanium oxide	<1
7	Phosphorus	<1
8	Sulphates	0.1
9	Alkali oxide	<1
10	Loss of ignition	1-1.5

GGBS (Ground Granulated Blast Furnace slag):

GGBS is stored in tight bags. The specific gravity of GGBS is 2.6. The chemical composition of the GGBS is tabulated below in Table II.

Fine Aggregate: In this Fine aggregate used is natural river sand. It was obtained from local sources Fine aggregate physical properties are tabulated below in Table III.

Coarse Aggregate: The aggregate consisting of natural occurring crushed uncrushed stones. It should be strong, clear, hard, durable, dense and free from coating.20mm Aggregates are used in this mix. The physical properties of Coarse aggregates are tabulated in Table IV.

Fig. 1: Cube cast for 8 Molarity

Table II: Chemical composition of GGBS

Sl no	Characteristics	GGBS (% wt.)
1	Aluminium oxide	7-12
2	Calcium oxide	34-43
3	Sulphur	1.0-1.9
4	Magnesium oxide	0.15-0.76
5	Silica	27-38
6	Manganese oxide	7-15
7	Iron oxide	0.2-1.6

Table III: Physical properties of Fine Aggregates

Specific Gravity	2.6
Fineness Modulus	3.02%
Water absorption	0.5%
Silt content	3%

Sodium Hydroxide: The availability of sodium hydroxide (NaOH) is crystal form with purity of 97-98%. The crystal is diluted in distilled water in required Molarity to make the solution. The specific gravity of NaOH is 1.99. Based on the Molecular weight of NaOH the dilution of sodium crystal in 1 litre of distilled water for different molarities. For an 8M solution, 320gms of the crystal is diluted in 1 litre of distilled water. For a 10M solution, 400gms of the crystal is diluted in 1 litre of distilled water. For a 12M solution, 480gms of the crystal is diluted in 1 litre of distilled water. The solution should be prepared before 24hrs from the time of use.

Sodium silicate: Sodium silicate will be in the form of a gel. The specific gravity of Na_2sio_3 is 1.61.

B. Experimental procedure

Binder is the only difference between Geopolymer concrete and ordinary Portland cement. GGBS and Fly ash are the polymer materials to react with alkaline activator solution to form Geopolymer paste. For the formation of Geopolymer mix coarse aggregate and fine aggregate binds with an alkaline activator solution. 80% mass of Geopolymer concrete occupies bye fine and coarse aggregate. The Fly ash and GGBS were taken in different proportions in the mix. The density of Geopolymer concrete was taken as 2400kg/m^3. The properties of the material that makes Geopolymer concrete are influenced by strength and workability. The percentage of GGBS and Fly ash was in a range of 20,40,60,80,100 respectively. The ratio of NaOH to Na_2sio_3 is 2.5 and the ratio of alkaline activator to fly ash is 0.40 kept constant.

Preparation of Alkali Solution:

The sodium hydroxide solution is prepared in required molarity. In this 8M, 10M, 12M as shown in Fig. 1 concentrated solution was prepared as per Tables IV-VII.

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Table IV: Mix Proportions for 8 Molarity specimens

ZZXMIX	FLY ASH %	GGBS %	QUANTITY (Kg)					
			GGBS	FLY ASH	C.A.	F.A.	NaOH (ml)	Na_2Sio_3 (ml)
M1	100	0	0	1.108	5.34	2.8	0.1425	0.427
M2	80	20	0.221	0.88	5.34	2.8	0.1425	0.427
M3	60	40	0.44	0.66	5.34	2.8	0.1425	0.427
M4	40	60	0.66	0.443	5.34	2.8	0.1425	0.427
M5	20	80	0.88	0.22	5.34	2.8	0.1425	0.427

Table V: Mix Proportions for 10 molarity specimens

MIX	FLY ASH %	GGBS %	QUANTITY (Kg)					
			GGBS	FLY ASH	C.A.	F.A.	NaOH	Na_2Sio_3
M1	100	0	0	1.108	5.34	2.8	0.1425	0.427
M2	80	20	0.221	0.88	5.34	2.8	0.1425	0.427
M3	60	40	0.44	0.66	5.34	2.8	0.1425	0.427
M4	40	60	0.66	0.443	5.34	2.8	0.1425	0.427
M5	20	80	0.88	0.22	5.34	2.8	0.1425	0.427

Table VI: Mix Proportions for 12 molarity specimens

MIX	FLY ASH %	GGBS %	QUANTITY (Kg)					
			GGBS	FLY ASH	C.A.	F.A.	NaOH	Na_2Sio_3
M1	100	0	0	1.108	5.34	2.8	0.1425	0.427
M2	80	20	0.221	0.88	5.34	2.8	0.1425	0.427
M3	60	40	0.44	0.66	5.34	2.8	0.1425	0.427
M4	40	60	0.66	0.443	5.34	2.8	0.1425	0.427
M5	20	80	0.88	0.22	5.34	2.8	0.1425	0.427
M6	0	100	0	1.108	5.34	2.8	0.1425	0.427

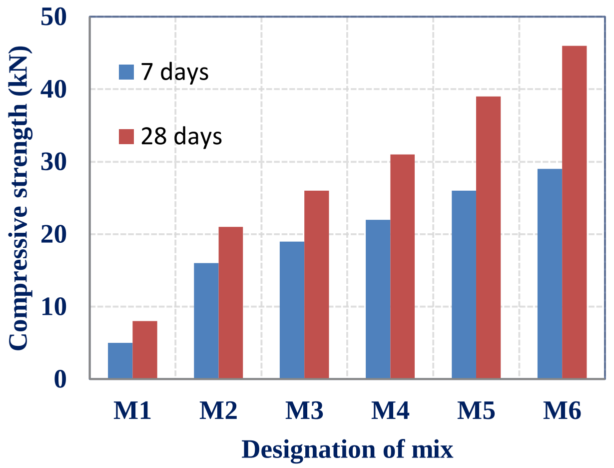

Fig. 2 : Compressive strength results for 8 Molarity

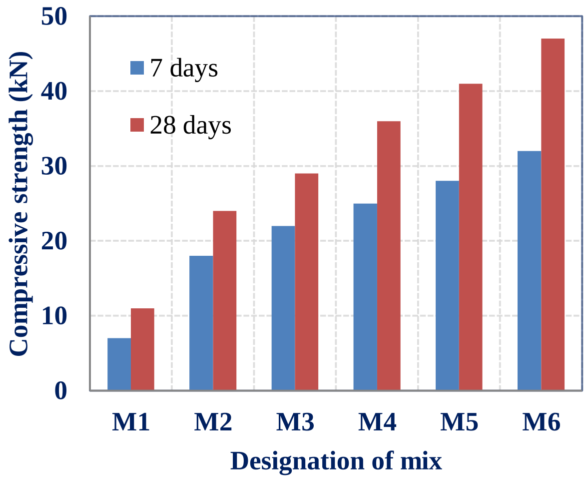

Fig. 3 : Compressive strength results for 10 Molarity

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IV. CASTING AND TESTING

Considering an beam dimension of 150mm depth,300mm depth and length of 2200 mm and cube of 150 × 150 × 150 mm. The M40 mixes is considered by [9].Take random samples from the mix in Gamela and pour concrete in three layers. Compact each layer with 35 numbers of strokes with tamping rod. After compaction of the last layer, finish the top surface by trowel. After 24 hours remove the specimen from the mould. Code the cube with marker in definite proportion and also the date of casting .The specimen from the mould .Code the cube with marker in definite proportion and also the date of casting. The specimen should be kept in room temperature and testing will done after 7, 28 days. The beam specimens are tested under four point bending test by considering simply supported conditions under loading frame .The cubes are tested for 28 days under compression. The values are compared with conventional concrete.

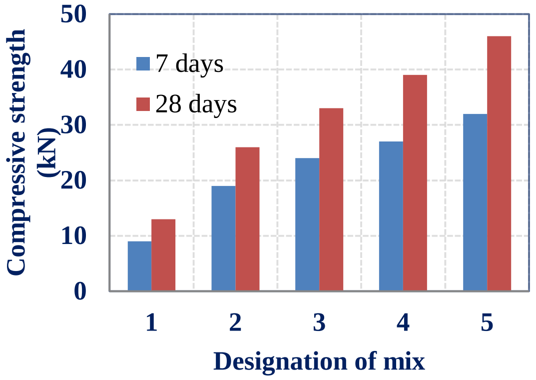

Fig. 4: Compressive strength results for 12 Molarity

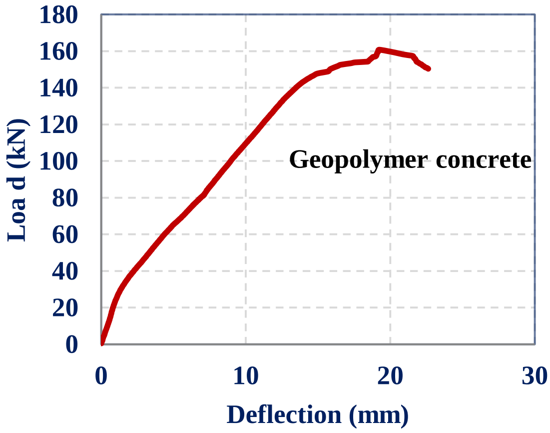

Fig. 5: Load vs. Deflection curve

V. RESULTS AND DISCUSSIONS

A. Compressive Strength:

The compressive strength on cubes were conducted according to Indian Standard Specifications (IS : 516-1959).The compressive strength results of 8M,10Mand 12M have been shown in Fig. 2, Fig. 3, Fig. 4. The graph is drawn between Compression load vs. Designation mix.

The maximum compressive strength obtained for 8 molarity specimens at 40% flyash and 60%GGBS is 19Mpa for 7days and 26Mpa for 28days. Similarly, for 10M, the maximum obtained compressive strength at 40% flyash and 60%GGBS is 22Mpa for 7days and 29Mpa for 28 days. And for 12M, the maximum compressive strength at 40%flyash and 60%GGBS is 24Mpa for 7days and 33Mpa for 28 days.so the compressive strength is directly proportional to molarity with increase in percentage of GGBS.

B. Flexural Strength:

The Flexural strength is determined by using the formula $f_{b=}pl/bd^2$ [10]. The load vs. Deflection curve is drawn for the Geopolymer concrete beam for 28 days as shown in Fig. 5. This is compared with conventional concrete. The ultimate load of 165.7kN is obtained .15kN is more than the conventional concrete.

VI. CONCLUSION

The Geopolymer concrete specimens are cast and tested under Compression and Four point bending test. These are compared with conventional concrete. The conclusions are as follows:

1. Hence the replacement of the material in place of cement with GGBS and Flyash can be done without any problem.
2. In case of 8M, the replacement of 60% of GGBS and 40% of flyash the compressive strength results gave much better than ordinary Portland cement as conventional concrete gave 22Mpa and 31Mpa for 7 days and 28 days respectively. Since for 10M and 12M the results also gave good strength when compared to ordinary Portland cement.
3. In the preparation of Geopolymer concrete, GGBS and Fly ash can be replaced by cement. It helps in reducing the carbon dioxide emission.
4. It is observed that setting time decreases with increase in GGBS.
5. With increase in GGBS the compressive strength increases.
6. The strength increases with increase in molarity.

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