Study On Fly Ash and GGBS Based Geopolymer Concrete under Ambient Curing

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Abstract **- Construction has been most important human activity since ancient time. Concrete is widely used and reliable material for construction. Some of challenges in industry are global warming and insufficiency of construction material. One of the methods for replacing concrete constituents is the use of geo-polymer which helps in using very less quantity of cement in concrete. This project represents study on the mechanical properties of geopolymer concrete with various mixes. In this study, Geopolymer concrete is produced with fly ash and sodium hydroxide and sodium silicate is used as a binder. Fly ash is replaced by GGBS in proportions of 25%, 50% and 75% to enhance various properties of concrete. For this project, the mix design is carried out for 11M and 13M concentration of sodium hydroxide. Alkaline activator solution ratio of 2.5 and alkaline liquid to fly ash ratio 0.40 is selected for this investigation. The specimen of size 150x150x150mm cubes, 150x300mm cylinders and 500x100x100mm prisms were casted and the specimens of geo-polymer concrete are cured at ambient temperature for 7 days and 28 days. The cured specimens were then tested for compressive strength, split tensile strength and flexural strength respectively.**

Keywords- **Fly Ash, Ground Granulated Blast Slag, Geopolymer concrete, Sodium Hydroxide, Sodium Silicate, Molarity**

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1. INTRODUCTION

Cement concrete is manmade material which prepared by mixing of cement, water, natural fine and coarse aggregate. The past century developed cement concrete as material for construction work. In 1902 August Perret, first designed building in Paris with structural components beams, slabs and columns. Construction variety of infrastructure and industrial sector by concrete makes it is an essential product. It is widely used manmade material in the globe. It is produced by natural materials; it is reliable material, gives architectural freedom. After water most widely consumed material is concrete as more than ton produced every year for each person in the world. But, the environmental hazard caused by production of concrete material has concerned to make an eco-friendly material for construction. It is been studied that embodied carbon dioxide (ECO_2) ranges from 700-800 kg CO_2 for a tone of concrete. The embodied carbon dioxide varies depending upon methods and type of mix design.

In cement industry, research has been carried out in collection of latest material and up gradation of technology. In India 93% of cement industry uses dry process technology which is environment friendly. The old dry process technology and semi dry process technology is being used by 7% of cement industry. There is reduction in emission level of CO_2 due to the waste heat recovery in cement plant. After steel and aluminium, cement is the next material which produces high energy. It also uses an ample amount of non renewable materials, e.g. coal, lime stone etc. About 65% of global warming is caused by CO_2. The cement industry is not suitable for sustainable industry since it causes high pollution to the environment. So, there is necessity for alternate material for cement in the concrete which should be eco-friendly, should satisfy mechanical properties and durability characteristics. This new material should be more superior, preferable compared to conventional concrete based on cement.

In 1978 Davidots introduced geopolymer as new material for cement and describes the composition of mineral binder which is similar to zeolites with amorphous microstructure. In order to get inorganic polymer system of alumino silicate by utilizing silica (CO_2) and alumina (Al_2O_3) which are available in metakaolin clay. The ordinary Portland cement does not require silicon silicate hydration process to get homogeneous mix and mechanical properties to get desired strength, there is need of polycondensation of silica and alumina. Geopolymer material and alkaline binder solutions are main constituent to form geopolymer. The geopolymer material should be rich in silicon and aluminium. Fly ash, red mud, GGBS and rice husk ash which are the source materials for geopolymer.
To create three dimensional polymeric chain and structure it is necessary to have silica and alumina of fly ash consisting of Si-O. The rate of concentration of solids is higher in aluminium silicate gel during geopolymerisation reaction. The alkaline liquids help to activate minerals containing reactive silicon and aluminium which helps to get inorganic polymeric material. It is found that fly ash and GGBS are best source material for geopolymeric system to get satisfactory strength in geopolymer concrete. The alkaline activator solutions help to activate fly ash, GGBS in concrete, which are easily available in India. The preparation of geopolymer

concrete is same as conventional concrete, which uses alkaline activator solution (AAS) instead of water which acts as binder for the concrete. The following are three basic form of geopolymer:

- Poly (sialate), which has [-Si-O-Al-O-] as the repeating unit.
- Poly (sialate-siloxo), which has [-Si-O-Al-O-Si-O-] as the repeating unit.
- Poly (sialate-disiloxo), which has [-Si-O-Al-O-Si-O-Si-O-] as the repeating unit

Geopolymer concrete is new material to be developed for use in construction work which should be eco-friendly. The following are the properties of geopolymer concrete

- Geopolymer concrete sets at room temperature
- It is non toxic
- It has long life
- It is impermeable
- It is a bad thermal conductor and possess high resistance to inorganic solvents
- It gives more strength.

2. EXPERIMENTAL INVESTIGATIONS

2.1 Materials

a) Fly ash (Class F)

In this experiment work fly ash was obtained from Raichur thermal power station of Riachur district, Karnataka state. The fly ash having specific gravity 1.84.The chemical composition of fly ash is given below

Table: 1 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	Phosphorous	<1
8	Sulphates	0.1
9	Alkali oxide	<1
10	Loss of ignition	1-1.5

b) GGBS (Ground Granulated Blast Slag)

GGBS is obtained from Bellary JSW (Jindal steel). It is stored in tight bags. The GGBS having specific gravity 2.6. The chemical composition is given below.

Table: 2 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

c) Fine Aggregate

In this investigation natural river sand is used as fine aggregate. Sand was obtained from local sources. Fine aggregate which is passing through IS 4.75mm sieve and retained on IS 150 micron sieve is considered for the experimental programme.

Table: 3 Physical Properties of Fine Aggregate

Specific gravity	2.6
Fineness modulus	3.02
Water absorption	0.5%
Silt content	3%

d) Coarse Aggregate

The aggregate consists of natural occurring crushed, uncrushed stones, gravel and sand. It should be strong, clear, hard, durable, dense, and free from adherent coating and free from disintegrate pieces, alkali, and other deleterious substances as far as possible. Flaky and elongation pieces should be avoided. In this investigation the locally available aggregates from crusher 20mm sieve passing and 12.5mm sieve retained is used. It should be angular in shape.

Table: 4 Physical Properties of Coarse Aggregate

Specific gravity	2.7
Fineness modulus	7.54
Water absorption	0.5%
Bulk density	1366.27kg/m^3

e) Sodium hydroxide

The sodium hydroxide is available in flakes with purity of 97%-98% purity. According to required concentration sodium hydroxide is added in water to make solution. The specific gravity of sodium hydroxide is 1.99 used in this project work.

f) Sodium silicate

The sodium silicate (Na_2O =10%, SiO_2 = 27%, water = 63%) was purchased from supplier in form of gel. The specific gravity of sodium silicate is 1.61 used in this project work.

3. METHODOLOGY

3.1 Mix design of Geopolymer Concrete

The primary difference between geopolymer concrete and Portland cement concrete is the binder. To form geopolymer paste alkaline activator solution used to react with silicon and aluminium oxides which are present in fly ash and GGBS. This alkaline activator solution helps to bind coarse aggregate and fine aggregate to form geopolymer mix. The fine and coarse aggregate occupy nearly 75% to 80% mass of geopolymer concrete. The fine aggregate was taken as 30% of total aggregate. The density of geopolymer concrete is taken 2400 kg/m3.The workability and strength of concrete are influenced by properties of materials that make geopolymer concrete. Fly ash is replaced by GGBS in the range of 25%, 50% and 75%. The ratio of sodium silicate to sodium hydroxide is 2.5 and is kept constant throughout this study. The ratio of alkaline activator to the fly ash is 0.40 kept constant.

3.2 Preparation of Alkali Solution

The preparation of solution is done by dissolving sodium hydroxide in water. The concentration of sodium hydroxide changes with molarity. The quantity of sodium hydroxide solution with a concentration of 11M and 13M is calculated. The mass of NaOH solids in solution varied depending on the concentration of the solution expressed in terms of molar, M. The NaOH solution with concentration of 11M consisted of 11*40 = 440gm of NaOH solids per liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 306gm per kg of NaOH solution of 11M concentration. Similarly, the mass of NaOH solids per kg solution for 13M concentration was measured as 342gm. The sodium hydroxide is added to the water and stirred about fifteen minutes to get cool down. Then the sodium silicate is added to solution. This solution is used after 24 hours of its preparation.

Table: 5 Material for 11M and 13M NaOH

Designation of Mix	Fly ash (kg/m^3)	GGBS (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Alkaline solution	
					NaOH (kg/m3)	Na_2SiO_3 (kg/m3)
M1&N1	394.28	-	554.4	1293.6	45.06	112.65
M2&N2	295.71	98.57	554.4	1293.6	45.06	112.65
M3&N3	197.14	197.14	554.4	1293.6	45.06	112.65
M4&N4	98.57	295.71	554.4	1293.6	45.06	112.65

3.3 Preparation of Tests Specimens

Mixing
The alkaline activator solution is prepared before 24 hours of casting. Initially, all dry materials were mixed properly for three minutes. Alkaline activator solution is added slowly to the mixture. Mixing is done for 5 minutes to get uniform mix

Casting
Properly mixed geopolymer concrete is poured immediately into the moulds. Concrete is placed in three layers and tamping is done for each layer by giving more than 25 blows, in order to get fully compacted geopolymer concrete specimens. Then the top surface is well finished. The sizes of the moulds used are cube (150mmx150mmx150mm), cylinder (150mm dia and 300mm height), and prism (500mmx100mmx100mm).

Curing
After 24 hours moulds were demoulded and were kept in room temperature for curing. The average temperature recorded during the period of curing was 38ºC. The curing is done for 7 days and 28 days.

4. RESULTS

4.1 Compressive Strength
The compression test on cubes were conducted according to Indian standard specification (IS:516-1959). Figure shows compressive strength for various mixes.

Table: 6 Result for 11 Molarity

Designation of Mix	Fly ash	Ground Granulated Blast Slag (GGBS)	Compressive strength @7days in (Mpa)	Compressive strength @28 days in (Mpa)
M1	100%	-	7	10
M2	75%	25%	18	33
M3	50%	50%	22	35
M4	25%	75%	25	40

Table: 7 Result for 13 Molarity

Designation of Mix	Fly ash	Ground Granulated Blast Slag (GGBS)	Compressive strength @7days in (Mpa)	Compressive strength @28 days in (Mpa)
N1	100%	-	9	13
N2	75%	25%	20	35
N3	50%	50%	24	38
N4	25%	75%	28	43

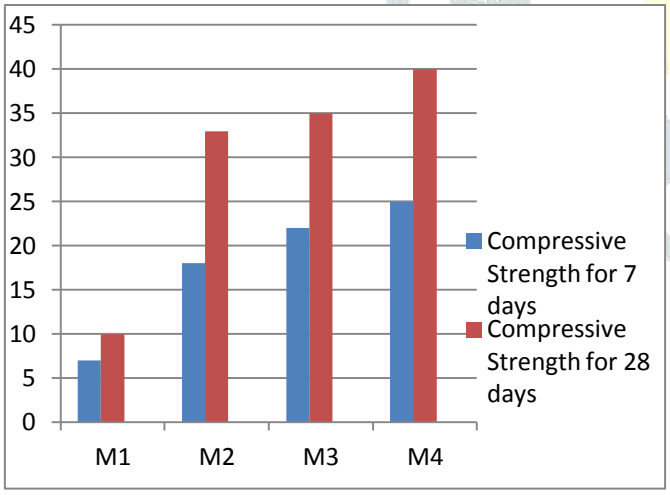

Fig 1 Comparison of Strength for 11M

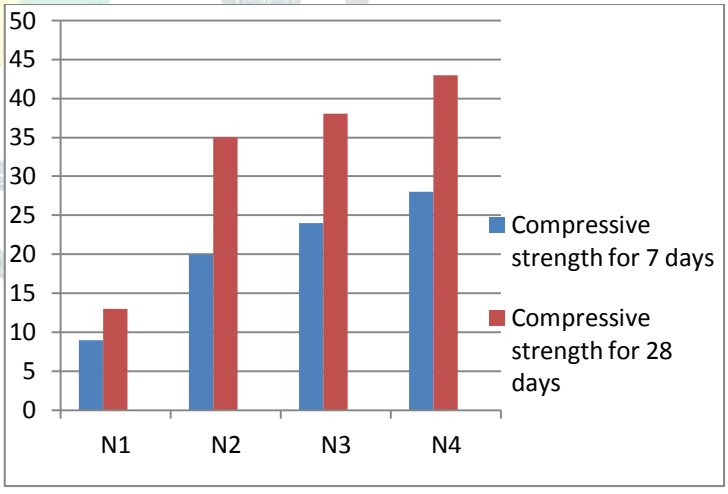

Fig 2 Comparison of Strength for 13M

4.2 Split Tensile Strength

A direct measurement of ensuring tensile strength of concrete is difficult. One of the indirect tension test method is split tension test. The split tensile strength test was carried out on the compression testing machine. The casting and testing of the specimens were donr as per IS 5816- 1999.

Table: 8 Result for 11 Molarity

Designation of Mix	Fly ash	Ground Granulated Blast Slag (GGBS)	Split Tensile Strength strength @7days in (Mpa)	Split Tensile strength @28 days in (Mpa)
M1	100%	-	1.17	3
M2	75%	25%	2.08	3.20
M3	50%	50%	2.52	3.95
M4	25%	75%	2.99	4.40

Table: 9 Result for 13 Molarity

Designation of Mix	Fly ash	Ground Granulated Blast Slag (GGBS)	Split Tensile Strength strength @7days in (Mpa)	Split Tensile strength @28 days in (Mpa)
N1	100%	-	1.60	2.54
N2	75%	25%	2.60	3.92
N3	50%	50%	2.79	4.30
N4	25%	75%	3.35	4.94

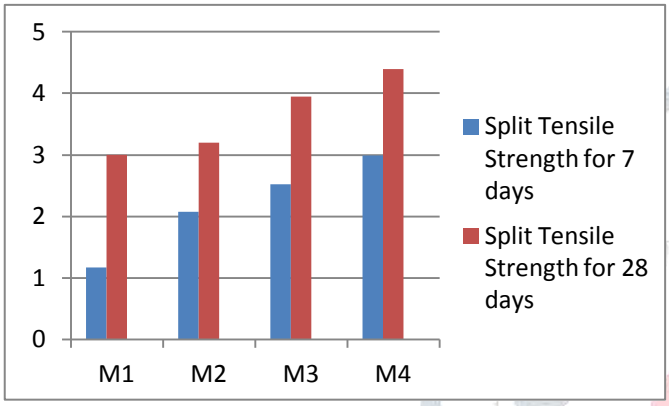

Fig 3 Comparison of Strength for 11M

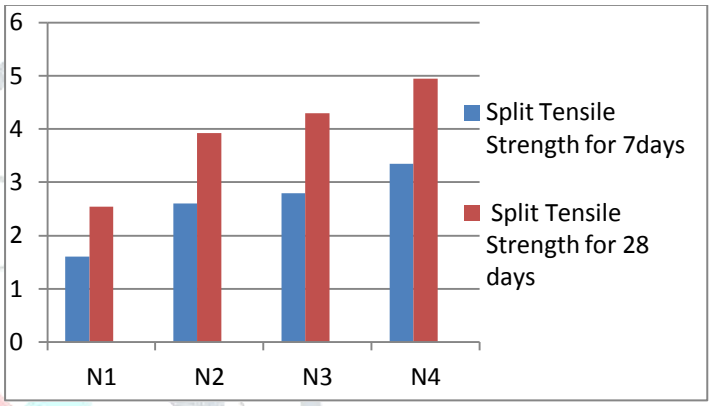

Fig 4 Comparison of Strength for 13M

4.3 Flexural Strength

This test is conducted in order to determine the flexural strength of concrete and this test is carried out on beams of size 100mmx100mm and having a length of 500mm. Flexural strength was conducted as per IS 516 -1959.

Table: 10 Result for 11 Molarity

Designation of Mix	Fly ash	Ground Granulated Blast Slag (GGBS)	Flexural Strength @7days in (Mpa)	Flexural strength @28 days in (Mpa)
M1	100%	-	1.07	1.66
M2	75%	25%	2.10	3.10
M3	50%	50%	2.52	3.88
M4	25%	75%	2.78	4.10

Table: 11 Result for 13 Molarity

Designation of Mix	Fly ash	Ground Granulated Blast Slag (GGBS)	Flexural Strength strength @7days in (Mpa)	Flexural strength @28 days in (Mpa)
N1	100%	-	1.42	2.10
N2	75%	25%	2.41	3.70
N3	50%	50%	2.70	4.01
N4	25%	75%	2.85	4.20

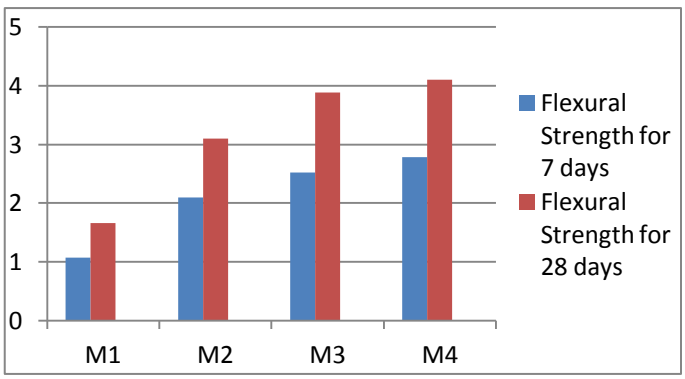

Fig 5 Comparison of Strength for 11M

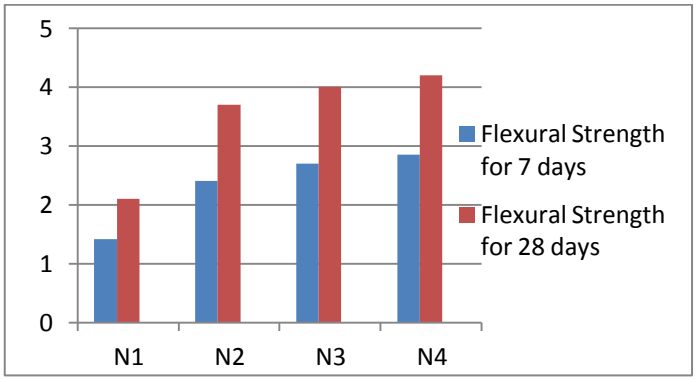

Fig 6 Comparison of Strength for 13M

5. CONCLUSION

In this study, the following conclusions are made for fresh state as well as hardened state of geopolymer concrete:

- Cement can be replaced by using fly ash, GGBS in the preparation of geopolymer. It helps in reducing carbon dioxide emission.
- It is observed that increase in GGBS content reduces the setting time and increases the degree of workability.
- The increase in slag content in the geopolymer concrete, increases in compressive strength, split tensile strength and flexural strength
- It is observed that, nearly 80% of the strength is achieved in 7days at ambient curing.
- Compressive strength of Mix M4 and N4 (75% replacement slag) concrete shows maximum strength
- Split tensile strength of Mix M4 and N4 (75% replacement slag) concrete shows maximum strength
- Flexural strength of Mix M4 and N4 (75% replacement slag) concrete shows maximum strength
- It is observed that the strength is increased as molarity increases.

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