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PERFORMANCE OF FLY ASH BASED GEO POLYMER CONCRETE WITH 20 MOLAR NaOH ACTIVATOR

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Abstract

Ordinary Portland cement is a major construction material worldwide. Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with Portland cement, there is a need to develop alternative binders to make concrete. In this project work, low-calcium (Class F) fly ash-based geopolymer from Vijayawada Thermal power plant has been used for the production of geopolymer concrete. The combination of sodium silicate solution and sodium hydroxide solution was used as alkaline solution for fly ash activation. Alkaline solution to fly ash ratio was varied as 0.45.The concentration of sodium hydroxide solution was maintained as 20M (Molars). The curing condition of geopolymer concrete was varied as ambient curing. The compressive strength, Flexural strength, Split Tensile Strength of the geopolymer concrete was tested at various ages such as 3, 7 and 28 days.
Keywords: Geopolymer, green house gaseous, fly ash, strength.

I. INTRODUCTION

1.1 General

Concrete is the widely used construction material that makes best foundations, architectural structures, bridges, roads, block walls, fences and poles. The production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere. Among the green house gases, CO_2 contributes about 65% of global warming. The contribution of ordinary Portland cement (OPC) production worldwide to greenhouse gas emissions is estimated to be approximately 1.35 billion tons annually or approximately 7% of the total green house gas emissions to the earth's atmosphere. However, the cement industry is extremely energy intensive. After aluminum and steel, the manufacturing of Portland cement is the most energy intensive process as it consumes 4GJ of energy per ton. After thermal power plants and the iron and steel sector, the Indian cement

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industry is the third largest user of coal in the country. The industry's capacity at the beginning of the year 2008-09 was about 198 million tones. The cement demand in India is expected to grow at 10% annually in the medium term buoyed by housing, infrastructure and corporate capital expenditures. Considering an expected production and consumption growth of 9 to 10 percent, the demand-supply position of the cement industry is expected to improve from 2008-09 onwards (Ragan & Hardjito, 2006 2005) .Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. GGBS is a glassy, granular, non metallic material consisting essentially of silicates and aluminates of calcium. GGBS has almost the same particle size as cement. GGBS, often blended with Portland cement as low cost filler, enhances concrete workability, density, durability and resistance to alkali-silica reaction.

1.2 Alkali-activators

For the alkali-activators, several choices are adopted. Alkali metal hydroxide (sodium hydroxide), carbonate, sulfate, phosphate, and fluoride (few studies) can be used as the activators.

1.3 NaOH

Sodium hydroxide, also known as lye and caustic soda, is an inorganic compound. Higher NaOH dosages can result in a better workability, higher 3, 7, and 28-day strengths, and shorter demolding time. But too much (excessive) NaOH concentration would adversely affects the strength. The optimal NaOH content depends on other mixture constituents. The concentration of sodium hydroxide (NaOH) liquid measured in terms of Morality (Mol/L) is better in the range of 8 to 20 M (Mol/L). To check which one influences the properties of the geopolymers more, the Na+ or the OH–, the study by Hardjito (2004) concluded that it is the OH– that influences the compressive strength of the geopolymers most.

1.4 Na_2SiO_3

The higher ratio of the sodium silicate to the sodium hydroxide liquid by mass, the higher the compressive strength of the geopolymer concrete is. The reason maybe that Na_2SiO_3 improves the Si: Al ratio and hence the compressive strength.

1.5 Si/Al Ratio

Silica and alumina are the main precursors for the geopolymeric reaction, and the ratio of Si and Al is the fundamental influence factor for the properties of geopolymer. The Silicon oxide (SiO_2) to the aluminum oxide (Al_2O_3) ratio by mass in the source material (fly ash) should preferably be in the range of 2.0 to 3.5 to make a good concrete (Si:Al by Mol is equal to 1.733 to 3.033).

1.6 Objective of the project

The aim of the project is to study the influence of parameters such as alkaline solution to binder ratio, curing condition on compressive strength, flexural strength & split tensile strength of fly ash based geopolymer concrete at various ages.

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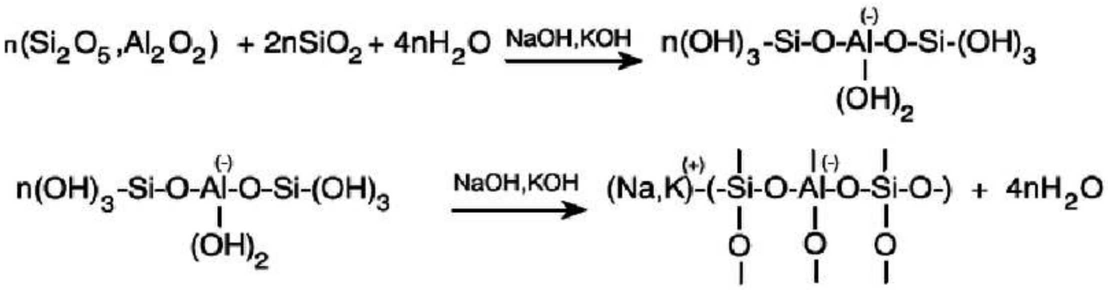


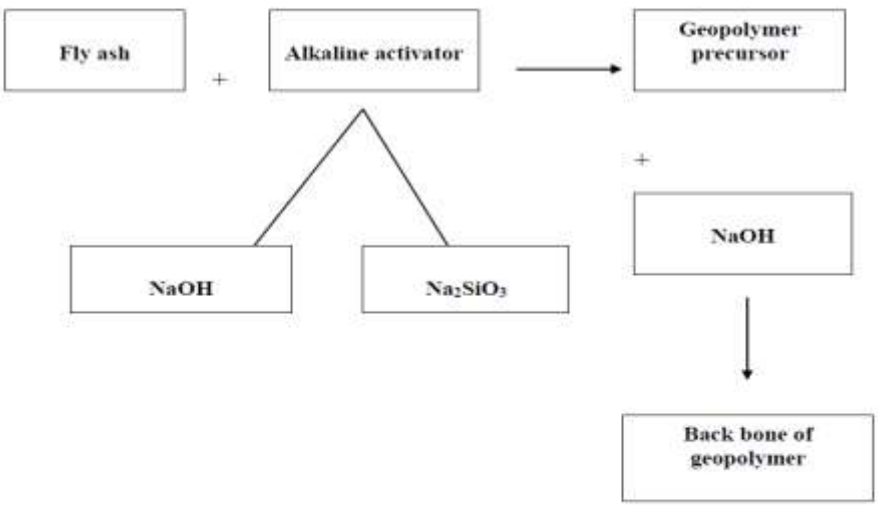
1.6 Scope of the project

- To study the effect of alkaline solution to binder ratio, concentration of sodium hydroxide solution and curing conditions on fly ash based geopolymer concrete.
- Ambient curing was adopted.
- To determine the compressive strength, flexural strength & split tensile strength of fly ash based geopolymer concrete at various ages such as 3 days, 7 days and 28 days.

II. GEOPOLYMER

In 1978, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash and rice husk ash. These binders were termed as geopolymers, because the chemical reaction that takes place in this case is a polymerization process. Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds are formed. The schematic formation of geopolymer material can be described by the following equations (Ragan & Hardjito 2006).

2.1 Chemical reaction of geopolymer



S.No.	Si:Al Ratio	Applications
1	1	Bricks, Ceramics, Fire protection
2	2	Low CO2 cements and concretes, Radioactive and toxic waste encapsulation
3	3	Fire protection fiber glass composite, Heat resistant composites
4	>3	Sealants for industry,200°C-600°C
5	20-35	Fire resistant and heat resistant fiber composites

Table 1: Applications of Geopolymers

2.2 Fly ash: Present Class F fly ash is collected in Vijayawada Thermal Power Station. Class F fly ashes with calcium oxide (CaO) content less than 6%, designated as low calcium ashes, are not self hardening but generally exhibit pozzolanic properties. These ashes contain more than 2% unburned carbon determined by loss on ignition (LOI). Quartz, mullite and hematite are the major crystalline phases identified fly ashes, derived from bituminous coal. Essentially, all the fly ashes and, therefore, most research concerning use of fly ash in cement and concrete are dealt with Class F fly ashes.

S. No.	Name of the Chemical	% by weight
1	Sulfate (SO4)	1.24%
2	Magnesium Oxide (MgO)	0.91%
3	Titanium Dioxide (TiO2)	0.42%
4	Ferric Oxide (Fe2O3 + Fe3O4)	4.17%
5	Calcium Oxide (CaO)	6.20%
6	Alumina (Al2O3)	20.21%
7	Silica (SiO2)	64.08%
8	Loss on Ignition (LOI)	1.07%

Table 2: Chemical composition of fly ash

2.3 Metakaolin

Metakaolin is one of the Pozzolanic materials used in concrete as a binder replaced by cement. Metakaolin is a dehydroxylated form of the clay mineral kaolinite. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. 80% of fly ash and 20% metakaolin were used in this experimental work. The quality and reactivity of metakaolin is strongly dependent of the characteristics of the raw material used.

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III. MIXTURE PROPORTIONS

As in the case of Portland cement concrete, the coarse and fine aggregates occupy about 75 to 80% of the mass of geopolymer concrete. The performance criteria of a geopolymer concrete depend on the application. The compressive strength of hardened concrete and the workability of fresh concrete are selected as the performance criteria.

S.No.	Materials	Quantities		
		1:2 (kg/m3)	1:25 (kg/m3)	1:3 (kg/m3)
1	Fly Ash	331.04	331.04	331.04
2	Metakaolin	82.76	82.76	82.76
3	Fine aggregate (Passing through 4.75 mm size sieve)	540	540	540
4	10mm size coarse aggregate	1260	1260	1260
5	Mass of NaOH Solution	62.1	53.2	46.6
6	Mass of Na2 SiO3 Solution	124.1	133	139.6
7	Extra water	45.5	45.5	45.5

Table 3: Quantities of materials per m^3 of GPC Mix

IV. RESULT AND DISCUSSIONS

4.1 Compressive Strength

Compressive strength is an essential property for all concrete as it also depends on curing time and curing temperature. When the curing time increase the compressive strength also increases. Compression tests were carried out at 3, 7and 28 days curried at ambient indoor room temperature.

Alkaline solution	Compressive strength (N/mm^2)		
	3 days	7 days	28 days
1:2	4.49	8.55	15
1:2.5	4.93	9.59	15.4
1:3	7.84	12.35	21.9

Table 4: Compressive Strength of geopolymer concrete

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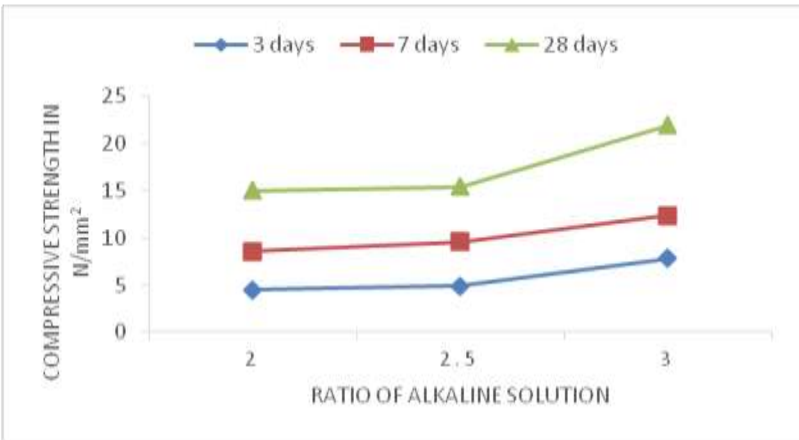


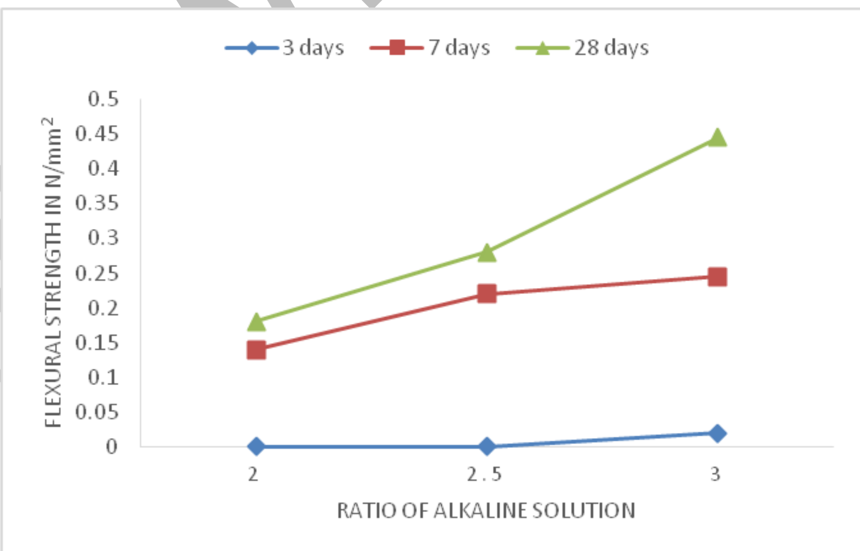
Graph 1: Compressive strength Vs. Alkaline ratio

4.2 Flexural Strength:

Flexural test was carried out on beam specimens and load deflection curve, maximum deflection and maximum load is noted. Flexural strength tests were carried out at 3, 7and 28 days curried at ambient indoor room temperature This test was carried out on the compression testing machine as per IS: 516: 1959.

Alkaline solution	Flexural strength (N/mm²)		
	3 days	7 days	28 days
1:2	0	0.14	0.18
1:2.5	0	0.22	0.28
1:3	0.02	0.245	0.445

Table 5: Flexural strength of geopolymer concrete



Graph 2: Flexural strength Vs. Alkaline ratio

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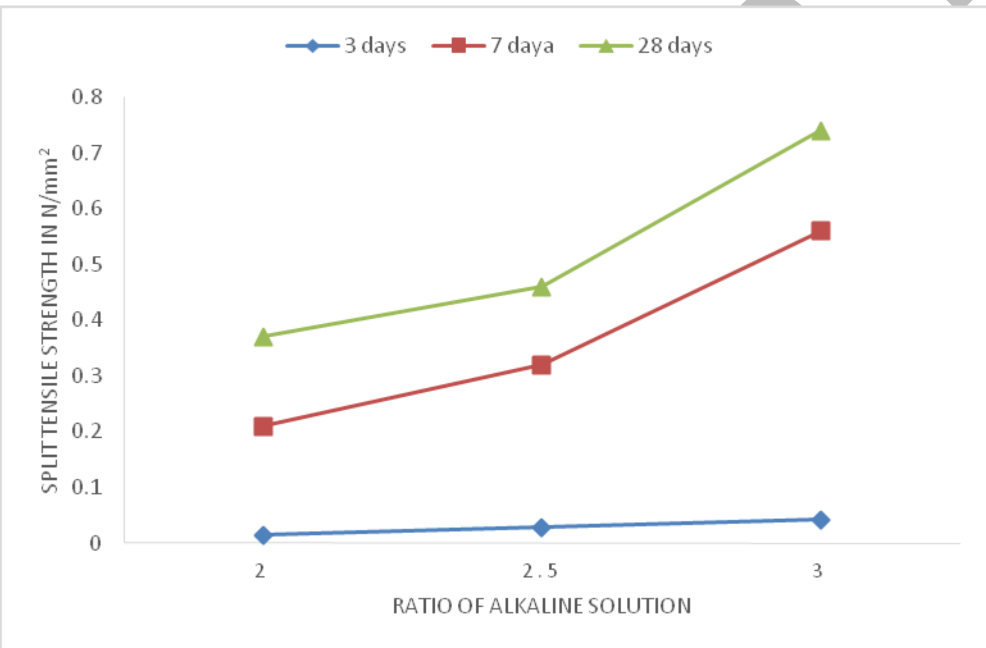
4.3 Split Tensile Strength Test

The split tensile strength is one of the indirect tension test. This test was carried out on the compression testing machine as per IS: 5816: 1999. Split tensile strength tests were carried out at 3, 7and 28 days curried at ambient indoor room temperature.

T = 2P/ π LD.

Alkaline solution	Split Tensile strength (N/mm²)		
	3 days	7 days	28 days
1:2	0.014	0.21	0.37
1:2.5	0.028	0.32	0.46
1:3	0.042	0.56	0.74

Table 6: Split tensile strength of Geopolymer concrete



Graph 3: Split tensile strength Vs. Alkaline

V. CONCLUSIONS

Based on the test results, the following conclusions are drawn:

- The Na_2SiO_3 to NaoH by mass equal to 1:2.5 has resulted into the higher strength as compared to the ratio of 1:2 and 1:3 for the geopolymer concrete.
- Compressive strength of concrete increases 30% for 7days, flexural strength of concrete increases 40% for 7 days and split tensile strength 50% for 7 days when compared to 3 days strength.
- Compressive strength of concrete increases 42% for 28 days, flexural strength of concrete increases 45% for 28 days and split tensile strength 60% for 28 days when compared to 7 days strength.

- The fly ash can be used to produce geo polymeric binder phase which can bind the aggregate systems consisting of fine and coarse aggregate to form geo polymer concrete. Therefore these concrete can be considered as eco-friendly material
- Compressive, flexural and split tensile strengths are increases with the Higher the ratio of sodium silicate-to-sodium hydroxide ratio by mass.
- The workability of the geopolymer concrete in fresh state increases with the increase of extra water added to the mix.
- Geopolymer concrete tends to show no significant physical change in its properties at normal operating room temperature which is observed in case of normal variety. The complete setting of Geopolymer concrete specimens will take up to 72 hours without any reminisces on the surface on which it is hardened.

VI. APPLICATION

1. Geopolymer technology is most advanced in precast applications due to the relative ease in handling sensitive materials (e.g., high-alkali activating solutions).
2. It is also used in precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites.

VII. LIMITATIONS

The followings are the limitations of geopolymer concrete.
1. High cost for alkaline solution
2. Safety risk associated with the alkalinity of the activating solution.

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