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EXPERIMENTAL STUDY ON THE PROPERTIES OF FLY ASH BASED GEO POLYMER CONCRETE

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Abstract: The demand of concrete is increasing day by day and cement is used for satisfying the need of development of infrastructure facilities, 1 tone cement production generates 1 tone CO_2, which adversely affect the environment. In order to reduce the use of OPC and CO_2 generation, the new generation concrete has been developed such as Geopolymer concrete. It uses fly ash and alkaline solution as their Binding Materials. However it should be noted that with the variation in the parameters such as Na2SiO3/ NaOH Ratio, Molarity of NaOH, Curing temperature, Curing time makes the Variation in the Strength. In this project we are focusing on strengthening characteristics of fly ash based geo polymer concrete. Here we are conducting different tests on geo polymer concrete and comparing these test results with conventional concretes. To conduct different tests on geo polymer concrete we are adopting M25 grade of concrete. We are finding strength of geo polymer concrete at 7 , 14 and 28 , 56 days.

Index Terms – Geo polymer concrete, Strength parameters, Workability

INTRODUCTION

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 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) . Coal-based thermal power installations in India contribute about 65% of the total installed capacity for electricity generation. In order to meet theGrowing energy demand of the country, coal-based thermal power generation is expected to play a dominant role in the future as well, since coal reserves in India are expected to last for more than 100 years. The ash content of coal used by thermal power plants in India varies between 25 and 45%. However, coal with an ash content of around 40% is predominantly used in India for thermal power generation. As a consequence, a huge amount of fly ash (FA) is generated in thermal power plants, causing several disposal-related problems In spite of initiatives taken by the government, several non-governmental organizations and research and development organizations, the total utilization of FA is only about 50%. India produces 130 million ton of FA annually which is expected to reach 175 million ton by 2012 and may exceed 225 million tons by 2017. Disposal of FA is a growing problem as only 15% of FA is currently used for high value addition applications like concrete and building blocks, the remainder being used for land filling. Globally, less than 25% of the total annual FA produced in the world is utilized. FA has been successfully used as a mineral admixture component of Portland cement for nearly 60 years. There is effective utilization of FA in making cement concretes as it extends technical advantages as well as controls the environmental pollution (Vijai 2006).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. Alternative utility of FA and GGBS in construction industry that has emerged in recent years is in the form of Geopolymer concrete (GPC), which by appropriate process technology utilize all classes and grades of FA and GGBS, therefore there is a great potential for reducing stockpiles of these waste materials. „Geopolymer concrete (GPC) are inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing or supplementing the conventional concretes. GPC have high strength, with good resistance to chloride penetration, acid attack, etc. These are commonly formed by alkali activation of industrial alumino-silicate waste materials such as FA and GGBS, and have a very small Greenhouse footprint when compared to traditional concretes (Ravikumar et al., 2010).

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 of fly ash based geopolymer concrete at various ages.

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.
- Ratio of alkaline solution to binder by mass varies as 0.35, 0.40 & 0.45.
- Ambient curing and oven curing (60ºC & 100ºC) was adopted.
- To determine the compressive strength of fly ash based geopolymer concrete at various ages such as 7days, 14 days and 28 days.

Experimentation and Methodology:

Table-1: Chemical composition of Ennore fly ash as reported by Naik et al., [3]

Components	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Loss on ignition
% by mass	56.77	31.88	2.82	2.77	0.78	2.39	0.68	1.96	0.93

Table-2: Properties of coarse aggregate

Sl. No	Properties	Test results
1	Specific gravity	2.68
2	Fineness modulus	8.65
3	Bulk density	1540 Kg/m^3
4	Water absorption	0.5%

Alkaline solution

A combination of sodium silicate solution and sodium hydroxide solution was used as alkaline solution. The sodium silicate solution A53 with SiO_2 to Na_2O ratio by mass approximately 2, ie (Na_2O = 14.7%, SiO_2=29.4% and water 55.9% by mass) was used. The sodium with 97-98% purity, in flake or pellet form was used. The solids must be dissolved in water to make a solution with the required concentration. The concentrations of sodium hydroxide solution as 8 Molar. The ratio of sodium silicate solution to sodium hydroxide solution by mass was fixed as 2.5.The reason being the sodium silicate solution was cheaper than the sodium hydroxide solution.

Super Plasticizer

In order to improve the workability of fresh concrete, a sulphonated, naphthalene formaldehyde condensate-based super plasticizer was used for the concrete mixtures as water reducing agents. The super plasticizer was a dark brown solution containing 42% solids.

Water Content of Mixture

In ordinary Portland cement (OPC) concrete, water in the mixture chemically reacts with the cement to produce a paste that binds the aggregates. In contrast, the water in a low-calcium fly ash-based geopolymer concrete mixture does not cause a chemical reaction. In fact, the chemical reaction that occurs in geopolymers produces water that is eventually expelled from the binder. However, water content in the geopolymer concrete mixture affected the properties of concrete in the fresh state as well as in the hardened state. The water content in the geopolymer concrete mixtures was expressed by a single parameter called „water to geopolymer solids ratio by mass.

In this parameter, the total mass of water is the sum of the mass of water contained in the sodium silicate solution, the mass of water in the sodium hydroxide solution, and the mass of extra water added to the mixture. The mass of geopolymer solids is the sum of the mass of fly ash, the mass of sodium hydroxide solids, and the mass of solids in the sodium silicate solution. In this project work, the „water to geopolymer solids‟ ratio was fixed as 0.26 a constant value, to find out the influence of other parameters on the compressive strength of Geopolymer concrete.

Mix Design:

1. Target mean strength
   Fck = 38.25 MPa
2. Selection of quantity of fly ash
   From Fig. 1, the quantity of fly ash required is 405 kg/m^3 for the target mean strength of 38.25 MPa at solution-to-fly ash ratio of 0.35 and for 430 m^2/kg fineness of fly ash
3. Calculation of the quantity of alkaline activators
   Calculate the quantity of alkaline activators considering:
   Solution/Fly ash ratio by mass = 0.35
   i.e Mass of (Na_2SiO_3 + NaOH)/Fly ash = 0.35
   Mass of (Na_2SiO_3 + NaOH)/405 = 0.35
   Mass of (Na_2SiO_3 + NaOH)/405 = 141.75 kg/m^3
   Take the sodium silicate-to-sodium hydroxide ratio by mass of 1
   Mass of sodium hydroxide solution (NaOH) = 70.88 kg/m^3
   Mass of sodium silicate solution (Na_2SiO_3) = 70.88 kg/m^3
4. Calculation of total solid content in alkaline solution
   Solid content in sodium silicate solution = (50.32/100) × 70.88
   = 35.67 kg/m^3
   Solid content in sodium hydroxide solution = (38.50/100) × 70.88
   = 27.29 kg/m^3
   Total Solid content in both alkaline solutions = 62.96 kg/m^3
5. Selection of water content
   For medium degree of workability and fineness of fly ash of 430 m^2/kg, water content per cubic meter of geopolymer concrete is selected from Table 2 Water content = 110 kg/m^3
6. Adjustment in water content
   For sand conforming to grading-I, correction in water content is taken fromTable 3
   Adjustment in water content = —1.5 %
   Total quantity of water required = 110 — (1:5/100) × 110
   = 108.35 kg/m^3
   Water content in alkaline solutions =141:75 — 62:96
   = 78.79 kg/m^3
7. Calculation of additional quantity of water
   = [Total quantity of water] − [Water present in alkaline solutions]
   = 108.35 − 78.79 = 29.46 kg/m^3
8. Selection of wet density of geopolymer concrete
   From Fig. 3, wet density of geopolymer concrete is 2,528 kg/m^3 for the finenessof fly ash of 430 m^2/kg
9. Selection of fine-to-total aggregate content
   From Fig. 2, Fine-to-total aggregate content is 35% for fineness modulus of sandof 3.35
10. Calculation of fine and coarse aggregate content
    Total aggregate content = [Wet density of GPC] — [Quantity of fly ash
    + Quantity of both solutions þ extra water; if any]
    =2,528 — [405 141.75 + 29.46]
    = 1,951.79 kg/m^3
    Sand content = [Fine — to — total aggregate content in %]
    × Total quantity of all-in-aggregate]
    = (35/100) × 1,951.79
    = 683.13 kg/m^3
    Coarse aggregate content = [Total quantity of all-in-aggregate] — [Sand content]
    = 1,951.79 — 683.13
    = 1,268.66 kg/m^3

Table-3: Mix Proportions

Ingredients of geopolymer concrete	Fly ash	NaOH	Na_2 SiO_3	Sand	Coarse aggregate	Total water (W/GPB)	Extra water
Quantity (kg/m^3)	405	70.88	70.88	683.13	1,268.66	108.35	29.46
Proportion	1	0.35		1.82	3.37	0.211	0.07

Casting:

In this project the compressive strength of geo-polymer concrete is examined for the mixes of varying molarities of Sodium hydroxide (8M, 10M, and 12M). The molecular weight of sodium hydroxideis 40. To prepare 8M i.e. 8 molar sodium hydroxide solution, 320g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 liter solution. For this, volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution. The weights to be added to get required molarity are given in Table-4.

Table-4: Weights of NaOH flakes

Required Molarity	Weight in g. of Sodium hydroxide flakes
8M	320
10M	400
12M	480

The conventional method used in the making of normal concrete is adopted to prepare geo-polymer concrete. First, the quarry dust, coarse aggregate and Flyashare mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super-plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding ofall the materials. After the mixing, the cubes are casted with the mixes GP1 toGP3 by giving proper compaction. The sizes of the cubes used are of size 150mmX150mmX150mm.

Results and discussions:

TABLE-5: Compressive strength

Name of the mix	Compressive strength in N/mm^2 of specimens Cured by			
	7days	14days	28days	56 days
CC	18.6	23.4	27	29.5
GP1	19.23	23.6	27.5	30.75
GP2	20.26	24.2	28.2	33.5
GP3	21	25.2	29.4	35.67

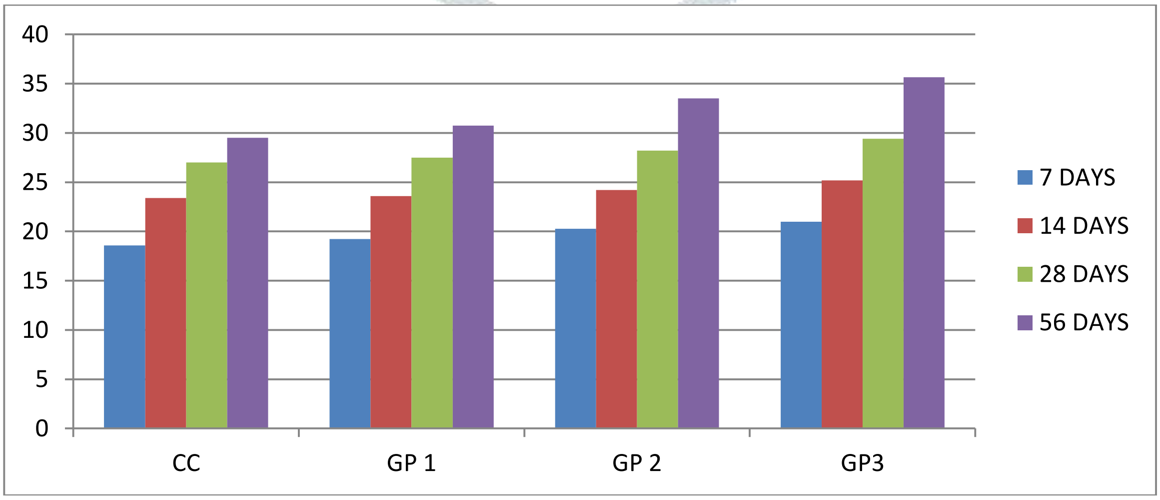

Figure-1: Variation Of Compressive strength

TABLE 6: Split strength

Name of the mix	Split Tensile Test in N/mm^2 of specimens Cured by			
	7days	14days	28days	56 days
CC	1.7	2.25	2.87	3.15
GP1	1.9	2.34	2.74	3.57
GP2	2.2	2.47	2.85	3.89
GP3	2.3	2.52	2.96	4.75

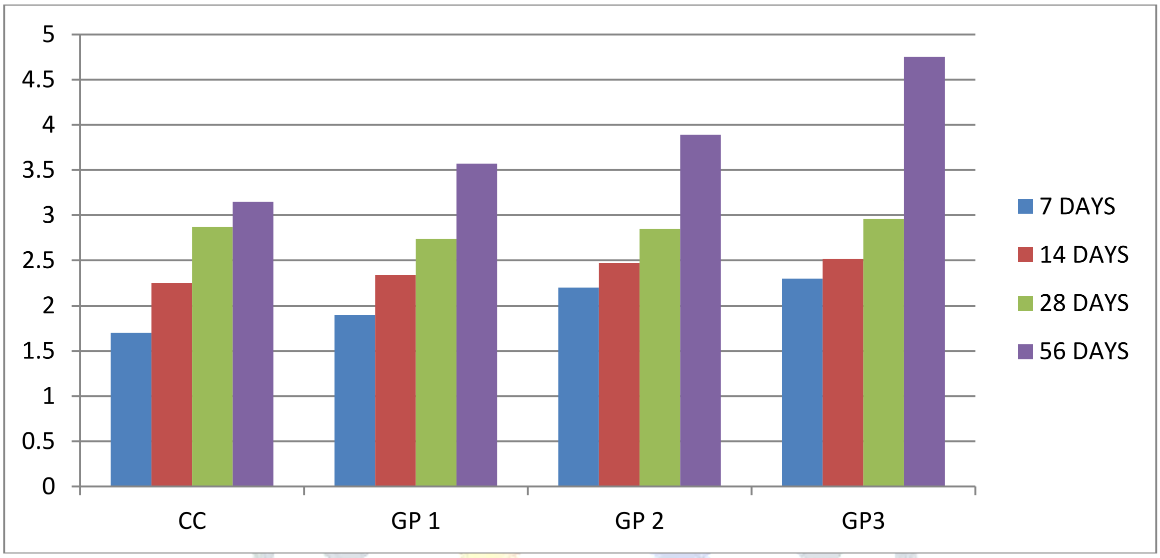

Figure 2: Variation of split tensile strength

TABLE-7: Flexural strength

Name of the mix	Flexural Strength Test in N/mm^2 of specimens Cured by			
	7days	14days	28days	56 days
CC	2.1	2.75	3.15	4.97
GP1	2.57	3.33	4.13	4.75
GP2	2.89	3.17	3.75	5.15
GP3	2.95	3.39	3.95	5.27

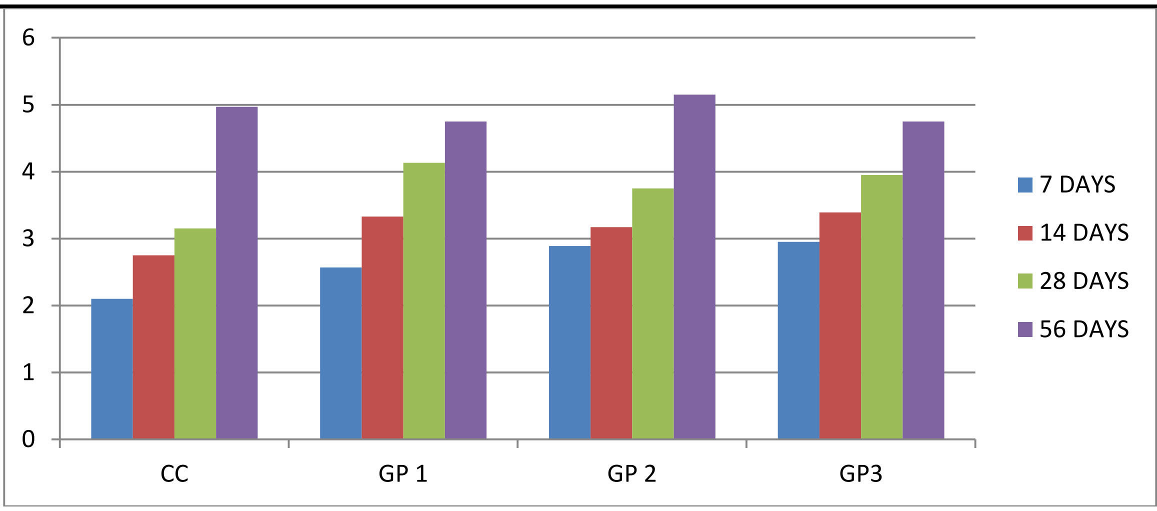

Figure-3: Variation of flexural strength

Conclusions:

Based on the experimental work reported in this study, the following conclusions are drawn:

- Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of fly ash & quarry dust based geo-polymer concrete.
- Longer curing time, in the range of 4 to 96 hours (4 days), produces higher compressive strength offly ash &quarry dust based geo-polymer concrete. However, the increase in strength beyond 24 hours is not significant.
- The fresh flyash-based geo-polymer concrete is easily handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.
- The mix GP3 gives higher compressive strength, as it has high molarity of NaOH
- we Observe that the compressive strength is increased with the increase in the molarity of the sodiumhydroxide
- After three days of curing the increase the compressive strength is not sufficient
- The geo-polyemer concrete shall be effeviely used for the beam coloumn junction of the reinforced concrete structure
- Geo-polymer concrete shall also be used in the Infrastructure works.
- In addition to that fly ash shall be effectively used and hence no land fills are required to dump the fly ash.

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