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Experimental Investigation of Geopolymer Concrete with Hyposludge

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Abstract

Concrete is one of the most widely used construction materials in the world. Cement is among the most energy intensive construction material whose production is on an increase of 3% annually. The production of one ton of cement liberates about 1 ton of carbon dioxide to the atmosphere. In order to address environmental effects associated with Portland cement, there is need to use other binders to make concrete. In recent years, attempts to increase the utilisation of fly ash to partially replace the use of Portland cement in concrete are gathering momentum. Geopolymer concrete is a 'new' material that does not need the presence of Portland cement as a binder, instead activating the source materials such as fly ash that are rich in Silicon (Si) and Aluminium (Al) using high alkaline liquids produces the binder required to manufacture the concrete. The experiments were conducted on fly ash based Geopolymer with Flyash GGBS and hyposludge concrete composites for 3 different aspect ratio. The concentration of NaOH is kept as 10M. Alkaline solution is prepared by mixing the sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) in the ratio of 1: 2.5. Compressive strength, Split tensile strength, Flexural strength test were conducted on the concrete specimens. The test results of specimens were compared with the control specimens. The overall result shows that the Geopolymer concrete has a great potential for utilization in construction industry as it is environmental friendly and also facilitates the use of fly ash, which is a waste product from coal burning industries.

Keywords - Fly ash, Ground Granulated Blast Furnace Slag, hyposludge, Sodium Hydroxide, Sodium Silicate.

I. INTRODUCTION

The climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere by human activities. The cement industry is responsible for about 7% of all CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 in to the atmosphere. The efforts include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated furnace slag, hyposludge, rice-husk ash and metakaolin, and finding alternative binders to Portland cement

Recently, another form of cementitious materials using silicon and aluminum activated in a high alkali solution was developed. This material is usually based on flyash as a source material and is termed geopolymer or alkali-activated flyash cement. Currently, hydrated ordinary Portland cement (OPC) is the most common binder used in concrete. The production of OPC requires large amounts of energy, and has a large carbon footprint, emitting approximately 5-7% of global CO_2 emissions annually. Therefore there is a need to find alternative type of binders to produce more environmentally friendly concrete

GEOPOLYMERS

Geopolymer cement (GPC) is a relatively new material, with the potential to be an alternative to OPC. GPC has a lower environmental impact, resulting in approximately 85% less CO_2 in production as compared to OPC.

In 1978, Joseph Davidovits developed a binder and coined the term called "geopolymer" as a result of polymerization process of silicon and aluminum from the source materials with alkaline solutions. Geopolymers are inorganic polymeric material produced by reacting solid aluminosilicate with highly concentrated aqueous alkali hydroxide and silicate solution.

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II - MATERIALS USED

The various material used in the preparation of geopolymer concrete composite specimen are collected and studied for various parameters. The material used are

- Fly ash
- Ground Granulated Blast Furnace Slag
- hyposludge
- Fine Aggregate (Natural sand)
- Coarse Aggregate (12mm)
- Alkaline Solutions - Sodium Hydroxide (10M) - Sodium Silicate
- Steel Fiber (Hooked end Anchorage)
- Water

Fly Ash

Fly ash is inorganic, non-combustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace. Class F dry fly ash conforming to IS 3812-2003 obtained from Mettur Thermal power station thermal power station of Tamilnadu from southern part of India was made use of in the casting of the specimens.

Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast furnace slag (GGBS) is a by product which is obtained during the manufacturing process of pig iron in blast furnace and obtained through rapid cooling by water or quenching molten slag. It is off white in coloured by appearance. The specific gravity is 3.09.

Hyposludge

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Hyposludge production in a large amount as by product of paper industry and is usually used in concrete production as replacement of cement. It contains low calcium and minimum amount of silica and it's due to presence of silica and magnesium properties that it behaves like a cement.

Fine Aggregate & Coarse Aggregate

The sand used for the experimental programme was locally procured and confirmed to grading zone II as per IS: 383:1970. The fine aggregate (sand) used was clean dry sand. The sand was sieved in 4.75 mm Sieve to remove all pebbles **.**Hard stones of size less than 12mm were used as coarse aggregate

TABLE 1 PHYSICAL PROPERTIES OF FINE AGGREGATE AND COARSE AGGREGATE

S.NO	***Description***	**Fine Aggregate**	**Coarse Aggregate**
1	Specific gravity	2.62	2.91
2	Bulk density	1756.2 kg/m^3	1517 kg/m^3
3	Fineness modulus	2.6	5.3

Sodium Hydroxide

Sodium hydroxide solids in the form of flakes with 97% purity.

Sodium Silicate

The chemical composition of Sodium silicate solution is as follows: 14.7%, of Na_2O, 29.4% of SiO_2 and 55.9% of water by mass.

Alkaline Liquid

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution.

III MIX DESIGN

The design mix can be arrived by assuming the density of geopolymer concrete as 2400 kg/m^3. The total volume occupied by fine and coarse aggregate is around 70-80%.

- Let us we adopt 70%.
- The alkaline liquid to flyash and GGBS ratio is kept as 0.4.
- The ratio of sodium hydroxide to sodium silicate is kept as 2.5.

The ordinary Portland cement was replaced with the combination of various proportion of fly ash, ggbs and hyposludge. For each aspects three different ratios are used GPC1 (fly ash 80%, ggbs 10%, hyposludge 10%), GPC2 (fly ash 70%, ggbs 10%, hyposludge 20%), GPC3 (fly ash 60%, ggbs 20%, hyposludge 20%).

TABLE 2 MIX PROPORTIONS OF GEOPOLYMER CONCRETE FOR 1 M^3 OF CONCRETE

Mix ID	Fly Ash kg/m3	Fine Aggregate kg/m3	Coarse Aggregate kg/m3	NaOH Solution kg/m3	Na_2SiO_3 Solution kg/m3	Water kg/m3
GPC1	394.3	554.4	1293.4	45.1	112.6	59.14
GPC2	394.3	554.4	1293.4	45.1	112.6	59.14
GPC3	394.3	554.4	1293.4	45.1	112.6	59.14

IV EXPERIMENTAL INVESTIGATION

Different specimens such as cubes, cylinders, prisms were cast for a mix proportion to find the mechanical properties of specimens.

Compression test

The cube specimen is of the size 15 x 15 x 15 cm.

Split tensile test

Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long.

Flexure Test

A beam specimen should be casted for determining the flexural strength of concrete. The standard specimen size is 15cm×15cm×70cm and 10cm×10cm×50cm

V RESULTS AND DISCUSSIONS

The result and discussion based on the experimental investigation carried out on the density of concrete, workability, compressive, split tensile and flexural strength.

TABLE 3 DENSITY OF CONCRETE AT 28 DAYS

MIX ID	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Compaction Factor
GPC1	7.745	$1x10^{-3}$	2290	0.900
GPC2	7.634	$1x10^{-3}$	2425	0.864
GPC3	7.435	$1x10^{-3}$	2375	0.858

TABLE 4 TEST RESULTS OF COMPRESSIVE STRENGTH

Specimen	Compressive strength, N/mm^2

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	7 Days	*14 Days*	*28 Days*
GPC1	18.45	21.6	23.4
GPC2	18.25	19.56	25.8
GPC3	17	18.85	24.5

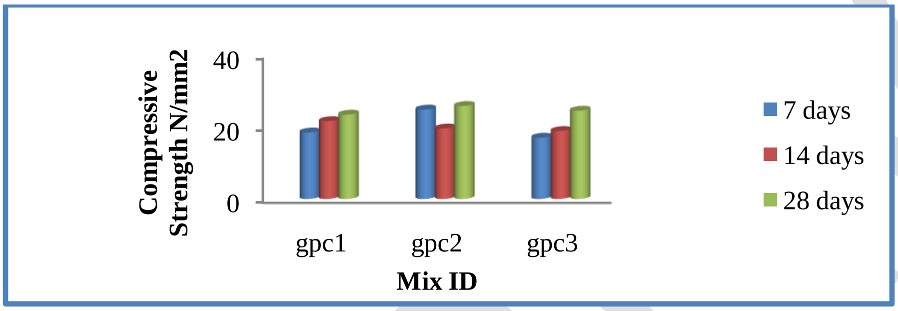

Fig 1 Compressive strength

TABLE 4 TEST RESULTS OF SPLIT TENSILE STRENGTH

Specimen	**Split tensile strength, N/mm^2**		
	7 Days	*14 Days*	*28 Days*
GPC1	1.8	2.5	3.8
GPC2	2	3	4.2
GPC3	2.3	2.8	4

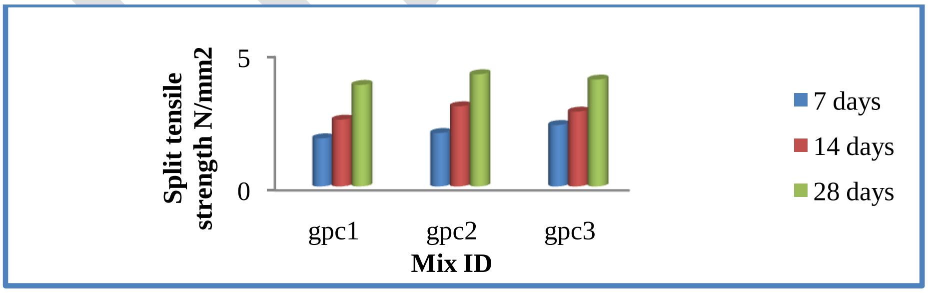

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Fig 2 split tensile strength

TABLE 4 TEST RESULTS OF FLEXURAL STRENGTH

Specimen	**Flexural strength, N/mm^2**		
	7 Days	***14 Days***	***28 Days***
GPC1	2	3	3.5
GPC2	2.2	2.9	3.8
GPC3	1.9	2.5	3.4

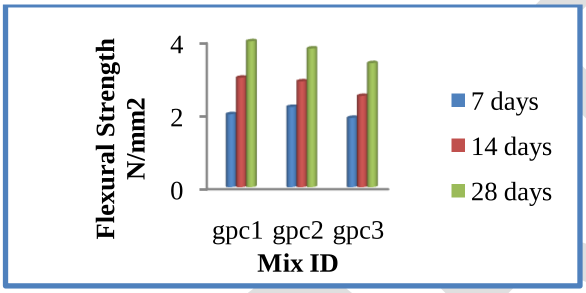

Fig 3 flexural strength

Addition of hyposludge resulted in enhanced compressive strength. As the age of concrete from 7 days to 28 days, compressive strength, split tensile strength and flexural strength increases for all mixes. From the test results it can be seen that, average flexural strength of geopolymer concrete gives the higher values compared to conventional concrete.

VI – CONCLUSION

1. Addition of hyposludge in geopolymer concretes enhanced its mechanical properties.

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2. The compressive strength of the geopolymer concrete increases with increase in the curing time.
3. The compressive strength of GPC2 is 5% high compared to GPC3 in 28 days.
4. In 14 days compressive strength of GPC3 is 3.7% low compared to GPC2.
5. The split tensile strength of GPC2 is 4% high compared to GPC3 in 28 days.
6. In 14 days split tensile strength of GPC3 is 7.14% low compared to GPC2.
7. The flexural strength of GPC2 is 10% high compared to GPC3 in 28 days.
8. In 14 days flexural strength of GPC3 is 16% low compared to GPC2.
9. This project work emphasis the usage of geopolymer concrete in construction to save our environment by reducing global warming.

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