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Study on Properties of Geopolymer Concrete

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ABSTRACT: Concrete is the most widely used building material in the world due to its versatility, low cost and durability. Currently geopolymer concrete is increasingly used in modern concrete technology, particularly in the construction of high rise buildings. This study has been conducted to investigate the possibility of using fly ash and ground granulated blast furnace slag (GGBS) for replacement of cement for different molarities (8M, 10M and 12M) in geopolymer concrete. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution have been used as alkaline activators. The utilization of fly ash obtained from power plant reduces the environmental problems. Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. The waste generated from industries cause environmental and health problems. This report contained the main topic that gives brief information regarding the generation deposition and utilization of fly ash and GGBS. To solve such major problems the waste make from industries can be used for replacement of cement in geopolymer concrete. In the present investigation, it is proposed to study the properties of low calcium fly ash and GGBS based geopolymer concrete. These properties have been determined at different curing periods like 7, 14 and 28 days and at ambient room temperature.

KEYWORDS: Geo-polymer Concrete, Fly ash, GGBS, Molarities, Sodium silicate, Sodium hydroxide, Properties.

I.INTRODUCTION

The production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO_2 to the atmosphere. The climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere. However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials. Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and the development of alternative binders to Portland cement. One possible alternative is the use of alkali-activated binder using industrial by-products containing silicate materials. In 1978, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash, GGBS and rice husk ash. He termed these binders as geopolymer. The most common industrial by-products used as binder materials are fly ash (FA) and ground granulated blast furnace slag (GGBS). In 2001, when this research began, several publications were available describing geopolymer pastes and geopolymer coating materials. However, very little was available in the published literature regarding the use of geopolymer technology to make low-calcium (ASTM Class-F) fly ash and GGBS based geopolymer concrete. The research reported in this paper was dedicated to investigate the process of making fly ash and GGBS based geopolymer concrete and the short-term engineering properties of the hardened concrete. The objective of this project is to develop and study the compressive strength, split

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tensile strength, flexural strength test, Modulus of elasticity, chloride attack and RCPT test of fly ash and GGBS based GPC mixes with different molarity at various curing period at ambient room temperature curing.

1.2 Origin of Term ‘Geopolymer’

The term “Geopolymer” was first introduced to the world by Davidovits of France resulting in a new field of research and technology. Geopolymer also known as ‘inorganic polymer’ has emerged as a ‘green’ binder with wide potentials for manufacturing sustainable materials for environmental, refractory and construction applications.

Geopolymer concrete (gpc):

Ingredients required for creation of geopolymer binders are:

- Geopolymer source materials such as fly ash, ggbs, metakaolin, and rice husk ash, etc
- Aggregate system consisting of fine and coarse aggregate - Alkaline Activator Solution.

Applications of Geopolymers:

- Used in industrial floor repairs.
- Airfield repairs (in war zones).
- Fireproof composite panels.
- External repair and structural retrofit for aging infrastructure.
- For storage of toxic and radioactive wastes.
- Potential utilizations in Art and Decoration.

1.3 Properties of Geo-Polymer Concrete

Geopolymer are inorganic binders, which are identified by the following basic properties,

- Compressive strength depends on curing time and curing temperature. As the curing time and temperature increases, the compressive strength increases.
- Resistance to corrosion, since no limestone is used as a material, Geopolymer cement has excellent properties within both acid and salt environments. It is especially suitable for tough environmental conditions.
- Geopolymer specimens are possessing better durability and thermal stability characteristics.

1.4 Salient Features of Geo-Polymer Concrete

- Reduced CO₂ emissions of geopolymer cements make a good alternative to ordinary Portland cement.
- The mechanical behavior and durability property of Geo-polymer concrete is higher than nominal concrete mix.
- Geo-polymer Concrete is Eco-Friendly.
- Water absorption property is lesser than the nominal concrete.

1.5. Need for the Study

- To find an alternative for the ordinary Portland cement.
- To reduce CO₂ emission and produce eco-friendly concrete.
- To develop a cost efficient product.
- To provide high strength concrete than ordinary Portland concrete.

1.6. Objectives:

- To make a concrete without using cement (i.e. Geopolymer concrete).

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- To study the different strength properties of geo-polymer concrete with different molarities of alkaline solutions.
- To develop a mixture proportioning process to manufacture fly ash (ASTM Class F) and GGBS based geopolymer concrete incorporating different ranges of alkaline solutions in 8, 10 and 12 molarities at ambient room temperature curing.
- To identify and study the effect of prominent parameters that affects the properties of fly ash and GGBS based geopolymer at different molarities.

2. MATERIALS USED

- Fly ash
- Ground granulated blast furnace slag (GGBS)
- Chemicals
 - Sodium hydroxide -Sodium silicate
 - Sodium silicate
- Aggregates
 - Fine aggregate
 - Coarse aggregate

2.1 FLY ASH

Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. It is a fine grained, powdery and glassy particulate material that is collected from the exhaust gases by electrostatic precipitators or bag filters. When pulverised coal is burnt to generate heat, the residue contains 80 per cent fly ash and 20 per cent bottom ash. The size of particles is largely dependent on the type of dust collection equipment. Diameter of fly ash particles ranges from less than 1 µm–150 µm. It is generally finer than Portland cement.

Particulars	GGBS
Chemical composition	
%Silica (SiO ₂)	31.41
% Alumina (Al ₂ O ₃)	17.24
Iron oxide(Fe ₂ O ₃)	0.62
Lime(CaO)	34.48
Magnesia(MgO)	6.79
Titanium oxide(TiO ₂)	-
Sulphur trioxide(SiO ₃)	1.85
Loss on ignition	2.3
Physical composition	
Specific gravity	2.68
Fineness (m ³ / Kg)	400

Table 1.Physical and Chemical Composition of Fly Ash

2.2 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide.. The addition of G.G.B.S in Geo-Polymer Concrete increases the strength of the concrete and also curing

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of Geo-Polymer concrete at room temperature is possible. The physical and chemical composition of GGBS are shown in the Table 2.

Particulars	Class "F" fly ash
Chemical composition	
% Silica (SiO ₂)	63.4
% Alumina (Al ₂ O ₃)	30.5
Iron oxide(Fe ₂ O ₃)	3.0
Lime(CaO)	1.0
Magnesia(MgO)	1.0
Titanium oxide(TiO ₂)	0.62
Sulphur trioxide(SiO ₃)	0.1
Loss on ignition	0.24
Physical composition	
Specific gravity	2.24
Fineness (m ³ / Kg)	360

Table 2. Physical and Chemical Composition of GGBS

2.3 Alkaline Liquid

A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions.

2.4 Chemicals

In this project chemicals are the very important constituents. Sodium Silicate and Sodium Hydroxide liquid are obtained commercially from local suppliers in Chennai.

2.4.1 Sodium Hydroxide

The sodium hydroxide solids were of a laboratory grade in pellets form with 99% purity, obtained from local suppliers in Chennai. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets (a small, rounded, compressed mass of a substance of sodium hydroxide) in water. The mass of sodium hydroxide solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, sodium hydroxide solution with a concentration of 8M consisted of $8 \times 40 = 320$ grams of sodium hydroxide solids (in pellet form) per liter of the solution, where 40 is the molecular weight of sodium hydroxide.

2.4.2 Sodium Silicate

Sodium silicate solution (water glass) obtained from local suppliers in Chennai was used. The chemical composition of the sodium silicate solution was Na₂O=8%, SiO₂=28%, and water 64% by mass. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

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2.5 Aggregates

The aggregates are the main components of the concrete which greatly varies the strength, density and other properties of the concrete. Different types of aggregates used are discussed below.

2.5.1 Fine aggregate

M-sand is used as fine aggregates in this mix. Fine aggregate are tested for specific gravity, sieve analysis and moisture content. The properties of fine aggregates are given below,

1. Specific Gravity - 2.63
2. Moisture content - 0.65
3. Fineness Modulus - 2.2
4. Grading (IS 383-1970) Zone 4.

2.5.2 Coarse aggregate

Locally available coarse aggregate having the maximum size of (10 - 20mm) were used in this project. The aggregates were tested as per Indian Standard Specifications IS: 383-1970. Properties of the coarse aggregate are given below,

1. Specific gravity - 2.6
2. Bulk Density - 1765 kg/m³
3. Fineness modulus - 6.45
4. Maximum size - 20mm.

III.DESIGN MIX

A mix M30 grade was designed as per Indian Standard method (IS 10262-1982) and the same was used to prepare the test samples. The design mix ratio is 1:0.35:1.82:3.37:0.211.

IV.RESULTS AND DISCUSSION

The various tests that have done are given as follows,

1. Compressive strength test
2. Split tensile strength test
3. Flexural tensile strength test.
4. Modulus of Elasticity of concrete.
5. RCPT test.

4.1 Compressive Strength Test

Compressive strength was tested for the mixes with the different molarities levels of 8M, 10M and 12M. The samples were tested after curing periods of 7, 14 and 28 days. Figure-1 shows the compressive strength of geopolymers for different curing periods.

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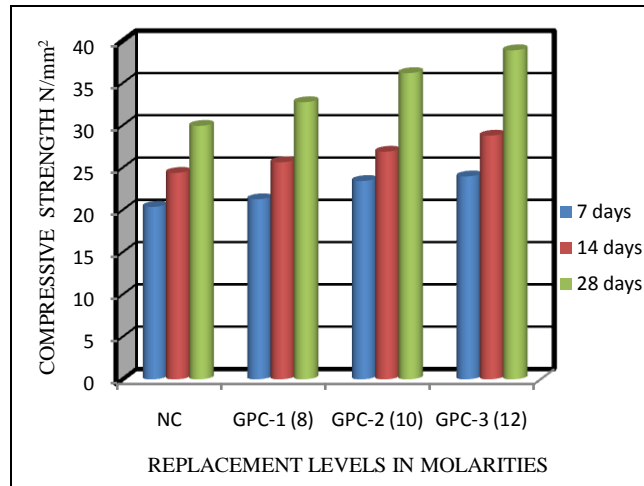


Fig: 1 Variation of Compressive Strength for various trail mixes

4.2 Split Tensile Strength Test

Split tensile strength was tested for the mixes with the different molarities levels of 8M, 10M and 12M. The samples were tested after curing periods of 7, 14 and 28 days. Figure-2 shows the Split tensile strength of geopolymer for different curing periods.

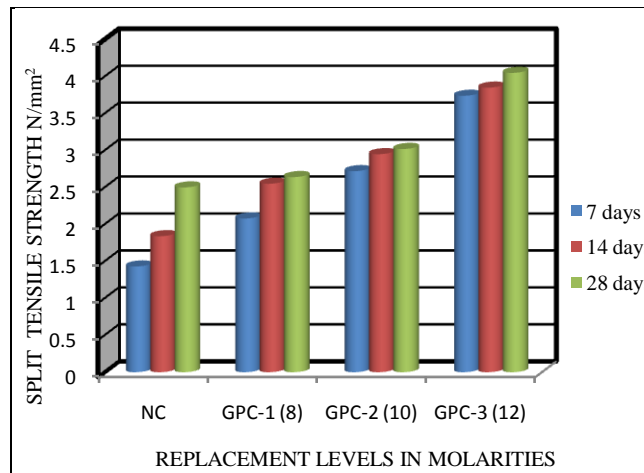


Fig: 2 Variation of Split Tensile Strength for various trail mixes

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4.3 Flexural Tensile Strength Test

Flexural tensile strength was tested for the mixes with the different molarities levels of 8M, 10M and 12M. The samples were tested after curing periods of 7, 14 and 28 days. Figure-3 shows the Flexural tensile strength of geopolymer for different curing periods.

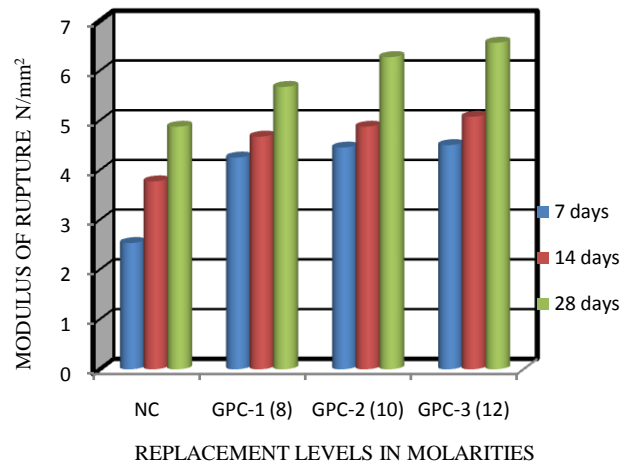


Fig. 3 Variation of Flexural Tensile Strength for various trail mixes

4.4 Modulus of Elasticity of Concrete:

Modulus of elasticity (also known as **elastic modulus**, the coefficient of **elasticity**) of a material is a number which is **defined** by the ratio of the applied stress to the corresponding strain within the **elastic** limit. The modulus of elasticity of concrete lies between 15 to 40. The modulus of elasticity of concrete is given by the formula, For Normal concrete,

$$E_c = 5000 \sqrt{f_{ck}}$$

For Geopolymer concrete,

$$E_c = 4600 \sqrt{f_{ck}}$$

Mean Compressive Strength N/mm ²	Modulus of Elasticity
24.93	24.96
26.58	23.71
28.46	24.54
30.58	25.43

Table.3. Modulus of Elasticity of concrete

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4.5 Rapid Chloride Permeability Test:

The Rapid Chloride Permeability test was developed in a FHWA research program. The program was created to develop techniques to non-destructively measure the chloride permeability of in-place concrete. The test method involves obtaining a 100 mm (4 in.) diameter core or cylinder sample from the concrete being tested. A 50 mm (2 in.) specimen is cut from the sample. The side of the cylindrical specimen is coated with epoxy, and after the epoxy is dried, it is put in a vacuum chamber for 3 hours. The specimen is vacuum saturated for 1 hour and allowed to soak for 18 hours. It is then placed in the test device (see test method for schematic of device). The left-hand side (–) of the test cell is filled with a 3% NaCl solution. The right-hand side (+) of the test cell is filled with 0.3N NaOH solution. The system is then connected and a 60-volt potential is applied for 6 hours. Readings are taken every 30 minutes. At the end of 6 hours the sample is removed from the cell and the amount of coulombs passed through the specimen is calculated. The test results are compared to the values in AASHTO T277-83 and ASTM C1202 specifications. The test results are given in below table,

Samples	Chloride permeability (in Coulomb's)			
	7 days	Remark	28 days	Remark
Normal concrete	6800	H	4600	H
GPC-1	6077	H	3850	M
GPC-2	5126	H	3269	M
GPC-3	3752	M	2552	M

Table-4 Rapid Chloride Permeability Test Results

V.CONCLUSION

Based on the investigation, the following conclusions have been drawn,

1. The strength properties i.e., Compressive, Split tensile and Flexural strength of geopolymer concrete increases with increasing alkaline solution of molarity 12M.
2. For a given proportion of a mix, the Compressive strength, Split tensile strength and Flexural strength slightly increase with age.
3. The Strength properties increase by increasing the GGBS percentage.
4. The rate of gain in strength of geopolymer concrete is very fast at 7 days curing period and the rate gets reduces with age.
5. Geopolymer concrete can be recommended as an innovative construction material for the use of Construction.
6. Reduces environmental Hazards by use of industrial waste product.
7. Waste utilization making it more environmentally friends.
8. Utilization of fly ash and GGBS and its application are used for the development of the construction industry, Material sciences.

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