Fresh And Hardened Properties Of Fly Ash Based Geopolymer Concrete With Copper Slag

H. Hanio Merinkline *, S. Manjula Devi**, Dr. C. Freeda Christy ***

*Department of Civil Engineering, Karunya University, Coimbatore-641114

** Department of Civil Engineering, Karunya University, Coimbatore-641114

*** Department of Civil Engineering, Karunya University, Coimbatore-641114

ABSTRACT

Concrete is a widely used as a construction material in civil Engineering field for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental factors are known significantly the durability of reinforced concrete structures.

The climate change due to global warming, one of non Portland cements the greatest environmental issues has become a major concern during the past decade. Main reason of global warming is because of caused by the emission of greenhouse gases, such as CO2, to the atmosphere by more human activities. Among the greenhouse gases, CO2 is responsible for contributes about 65% of global warming. The cement manufacturing industry is responsible for nearly 6% of all CO2 emissions, because the production of one ton ordinary of Portland cement approximately emits one ton of CO2 into the atmosphere.

Fly ash based Geopolymer is prepared from low calcium fly ash by activation with a mixture of alkaline liquids (Sodium Hydroxide and Sodium Silicate solution). Fly ash is a byproduct of Thermal Power Plant. A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Sodium-based alkaline solutions were chosen because they were cheaper than Potassium-based solutions. The use of Copper Slag (CS) in concrete provides environmental as well as economic benefits for all industries, mainly in areas where a large amount of CS is produced.

In this paper we deals with the fresh and hardened properties of the fly ash based geopolymer concrete with copper slag. Preliminary Investigation physical and chemical properties of various materials as cement, fine aggregate, coarse aggregate, copper slag. Fly ash is tested and the properties are compared with each other. Fresh and hardened properties of conventional concrete and blended cement concrete are tested and compared. Conclusion of this paper will be based on the test results and comparative statement.

Keywords-green house gas, global warming, Copper Slag, Sodium Hydroxide Pellets, Sodium Silicate Solution.

OBJECTIVE

- To study the experimental behaviour of Various Grades concrete in which the fine aggregate is partially replaced by Copper Slag.
- Owing to the scarcity of fine aggregate (river sand) for the preparation of mortar and concrete, partial replacement of CS with sand have been attempted.
- Making eco friendly and green concrete.
- Making modern concrete for strength effective, cost effective
- This research work is carried out to explore the effect of CS as fine aggregates on the strength and durability properties of concrete with fly ash based geopolymer concrete.

1. Introduction

Normal concrete: OPC + fine aggregate + Coarse Aggregate.

Modern concrete/Green concrete: Fly ash based Geopolymer + Fine Aggregate + Copper Slag + Coarse Aggregate + Alkaline liquid.

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable. In the recent revision of IS: 456-2000, one of the major points discussed is the durability factor of concrete. So the use of concrete is unavoidable. At the same time the scarcity of aggregates are also greatly increased nowadays.

Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes for reducing the consumption of natural raw materials as resources. For the past many years, by products such as fly ash, silica fume, ferrous and non-ferrous slag were considered as waste materials from so many industries. They have been successfully used in the construction industry for partial or full replacement for fine and coarse aggregates. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools. Recent research papers (Gorai P, Jana RK, Premchand) reviewed the potential use of copper slag as a partial substitute of cement and aggregates in concrete and asphalt mixtures.

2. Materials and Methods

Low calcium fly ash (ASTM class F) collected from Mettur Thermal Power Station was used for casting the specimens. Fine Aggregate (sand) used is clean river sand. The sand is sieved by 4.75 mm sieve for removing all the dust and impuritiesof big in size. The specific gravity, bulk density and fineness modulus of fine aggregate are 2.62, 1701.84 kg/m3 and 2.42 respectively. Preliminary test results of 20 mm size coarse aggregates are as follows: fineness modulus is 6.94, bulk density is 1679.7 kg/m3 and specific gravity is 2.87.Mixing Water quality is confirmed to satisfy the requirements of water for concreting and curing. Alkaline liquids are used in geopolymerisation. The common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate solution (Na2SiO3). In the present investigation, a combination of Sodium hydroxide solution and sodium silicate solution was used as alkaline activator solution. Commercially available Sodium hydroxide is purchased in flakes or pellets form and converted in to liquid by mixing with distilled water based on molarity.In this present study, sodium hydroxide flakes with 98% purity were used for the preparation of alkaline solution.

2.1 Fly ash

Fly ash is a thermal industrial by-product, generated in the stage of combustion of coal in the power plants. The increasing scarcity requirement or demand of raw materials and an urgent need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power station which creates unmanageable disposal problems due to its potential to pollute the environment. Fly ash when used as a mineral admixture in concrete improves its strength and durability. Fly ash can be used either as mineral admixture or as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.

Fig1: fly ash dumped yard

Table: 1
Chemical composition of Fly ash, Copper slag and Cement

Component	Fly ash	Copper slag	Cement
SiO_2	61.16	33.05	21.1
Al_2O_3	30.08	2.79	4.7
Fe_2O_3	4.62	13.6	2.8
CaO	1.75	6.06	63.8
Na_2O	0.76	0.36	0.5
MgO	0.18	1.44	2
K_2O	0.36	0.55	0
SO_3	0.19	1.84	2.5
LOI	0.6	0.54	2.1

2.2 Copper slag

Copper slag used in this work was brought from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India. SIL is producing CS during the manufacture of copper metal. Currently, about 2600 tons of CS is produced per day and a total accumulation of around 1.5 million tons. This slag is currently being used for many purposes ranging from land-filling to grit blasting. These applications utilize only about 15% to 20% and the remaining dumped as a waste material.Surrounding environment may pollute because of this dumped waste material. The microscopic view of CS tells that it is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. In order to reduce the accumulation of CS and also to provide an alternate material for sand, the Sterlite Industries Ltd, proposed to study the potential of CS as replacement material for sand in cement concrete.

Fig2: copper slag in dumped yard

2.3 Geopolymer

The term "geopolymer" was coined by Davidovits in 1978. This inorganic alumina silicate polymer is synthesized from predominantly silicon and aluminium material of geological origin or by-product materials such as fly ash. Geopolymer results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. Fully cement free concrete. This material is being studied extensively and shows promise as a greener substitute for Ordinary Portland cement concrete in particular situations. Now the research is mainly concentrated for commercial production of this geopolymer concrete for its specific engineering applications. It has been found that fly ash based geopolymer concrete has good engineering properties with a reduced global warming potential resulting from the total replacement of ordinary Portland cement. Fly ash-based geopolymer cements reduce CO2 emissions by 90% when compared to Portland cement.

2.4 Sodium Hydroxide (NaOH)

The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The type and concentration of alkali solution affect the dissolution of fly ash. Leaching of Al3+ and Si4+ ions are generally high with sodium hydroxide solution compared to potassium hydroxide solution. Alkali concentration is a significant factor for controlling the leaching of alumina and silica from fly ash particles, geopolymerization process and mechanical properties of hardened geopolymer.Duchesneetal confirmed that in presence of NaOH in the alkaline activating solution, the reaction takes place more rapidly and the gel is less smooth.

Fig3: Sodium Hydroxide pellet

2.5 Sodium Silicate solution

Sodium silicate is the common name for a compound sodium metasilicate, Na_2SiO_3, also known as water glass or liquid glass. It is available in both aqueous solution and solid form and is used in cements, passive fire protection, refractories, textile and lumber processing, and automobiles.

Sodium carbonate and silicon dioxide react in molten state to form sodium silicate as well as carbon dioxide.

$$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$$

2.6 Alkaline Liquids

- Alkaline liquid is prepared by mixing sodium silicate solution and sodium hydroxide solution with proper proportion.
- Sodium-based solutions were selected because they were cheaper than Potassium based Solutions.
- The sodium hydroxide solids were either a technical grade in flakes form (3 mm), with a specific gravity of 2.130, 98% purity, or a commercial grade in pellets form with 97% purity, obtained from Lomb Scientific, Australia.

Fig4: Alkaline Liquids

2.7 Preparation of Geopolymer concrete

Sodium hydroxide solution of 8M is prepared by dissolving sodium hydroxide pellets with distilled water. The mass of NaOH pellets was taken depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was taken as 320 g per kg of NaOH solution of 8 M concentration. To get desired alkaline solution the sodium hydroxide solution which is prepared already is mixed with sodium silicate solution one day before of the geopolymer concrete preparation. After mixing the constituents of concrete, wet mixing was done for 4 min.Required numbers of cubes of size 150 mm x 150 mm x 150 mm and cylinder of size 150 dia 300 depth were cast and compaction was done by mechanical vibration using a table vibrator.

2.8 Curing Of Geopolymer Concrete

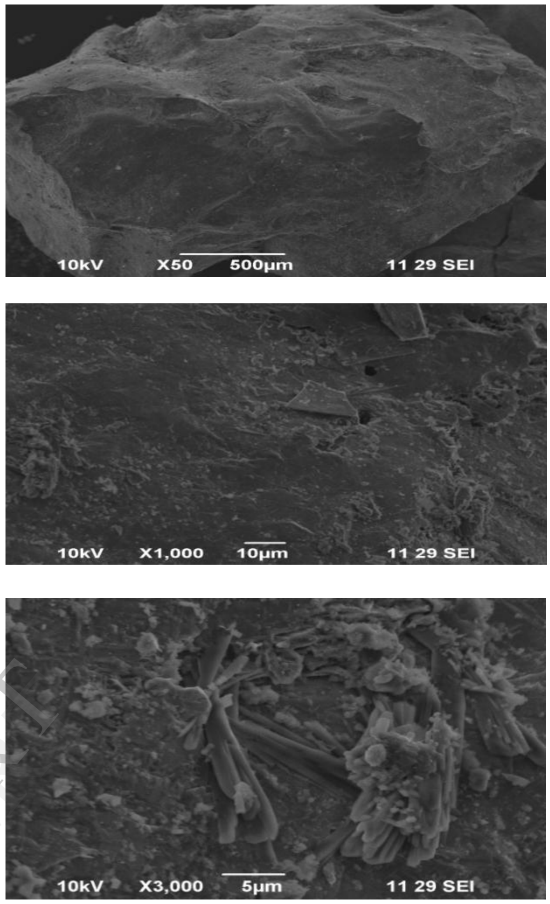
After casting the specimens, they were kept in rest period for five days and then they were remoulded. Rest period is defined as the time taken from the completion of casting of test specimens to the start of curing at an elevated temperature. To keep rest period for specimens before curing may be important in certain practical applications. When fly ash-based geopolymer concrete is used for precast concrete elements, sufficient time is available between casting of products and sending them to the curing chamber. At the end of the Rest Period, some specimens were kept under ambient conditions for curing at room temperature Remaining six specimens were kept at 90^{o}C in hot oven for 24 h The compressive strength test was conducted for h sample and the results showed that there is an increase in compressive strength with the increase in age for ambient cured specimens. For hot air cured samples the increase in compressive strength with age was very less as compared to that of specimens subjected to ambient curing. The density of geopolymer concrete was 2400 kg/m3 which is equivalent to that of conventional concrete.

Fig5: Hot curing of specimens

3. SEM ANALYSIS

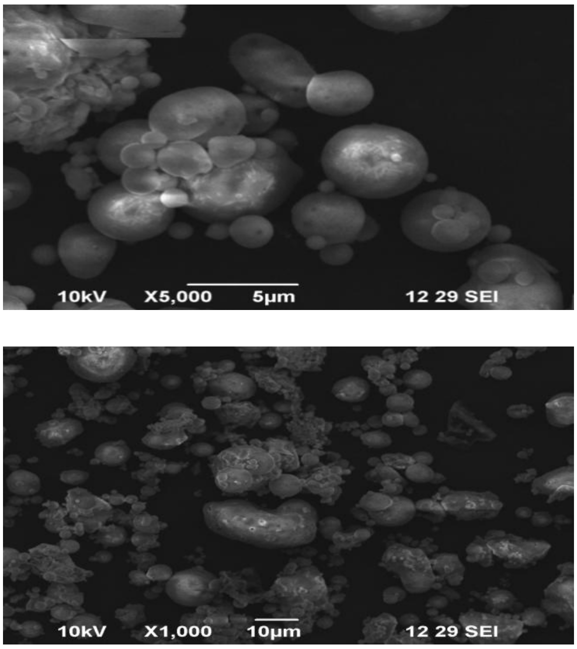
Fig 6: (SEM Images of Copper Slag)

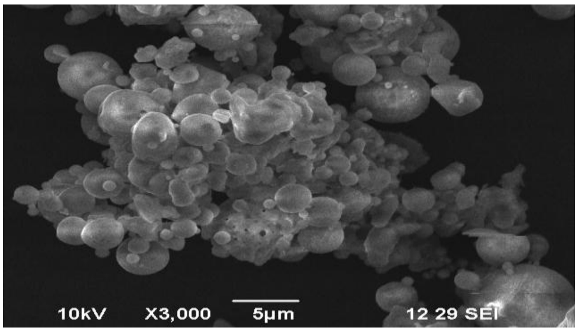
A **scanning electron microscope** (**SEM**) produces images of a sample by scanning it with a focused beam of electrons. These electrons interact with electrons in the sample, producing various signals which contain information about the sample's surface topography and composition. SEM can achieve resolution better than 1 nanometer.



3.1 SEM ANALYSIS

Fig 7: (SEM Images of Fly ash)





4. MIX DESIGN

The details of the mix design are given in Mix Design Calculation for M25 and M30 Grade Concrete Using IS 10262:2009

Material	M25		M30	
	Quantity (Kg/m^3)	Mix ratio	Quantity (Kg/m^3)	Mix ratio
Cement	425.78	1	445	1
Fine aggregate	685	1.6	670	1.5
Coarse aggregate	1209	2.8	1186	2.6
Water	191.6	0.45	191.6	0.43

5. EXPERIMENTAL INVESTIGATIONS

Basic tests to find the physical properties of various ingredients in blended cement concrete have been conducted to continue the thesis. The results of the various tests are tabulated and the comparisons are produced in graphical form in the following session.

5.1 Properties of Fine Aggregate

Property	River Sand	Copper Slag
Specific gravity	2.68	3.86
Loose density	1.57 g/cc	2.12 g/cc
Rodded density	1.72 g/cc	2.36 g/cc
Grading Zone	II	I

5.2 Tests on Strength

5.2.1 Compressive Strength of Cement (N/mm^2)

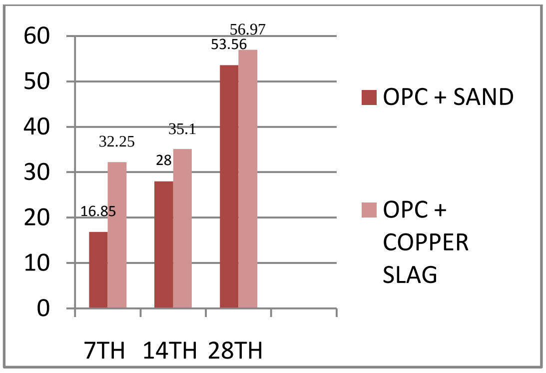


Fig8: Comparison of strength development of Cement using river sand and Copper Slag

Fig9: compressive strength of cement testing setup

5.2.2 Compressive Strength of Concrete (N/mm^2)

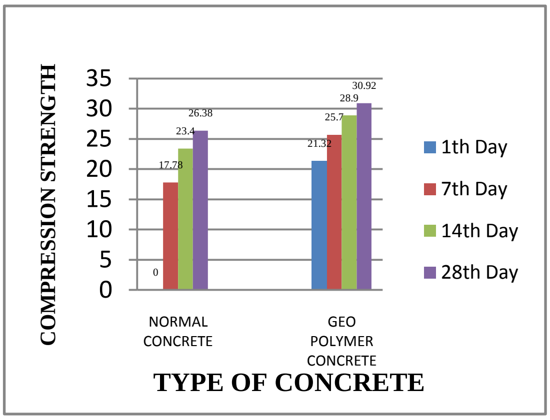


Fig10: Cube compressive strength for M25Grade concrete

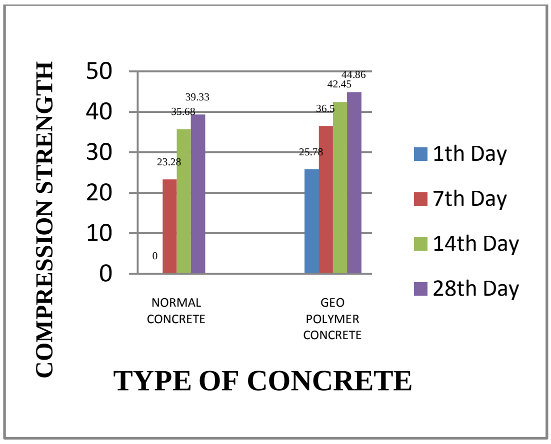


Fig11: Cube compressive strength for M30 Grade concrete

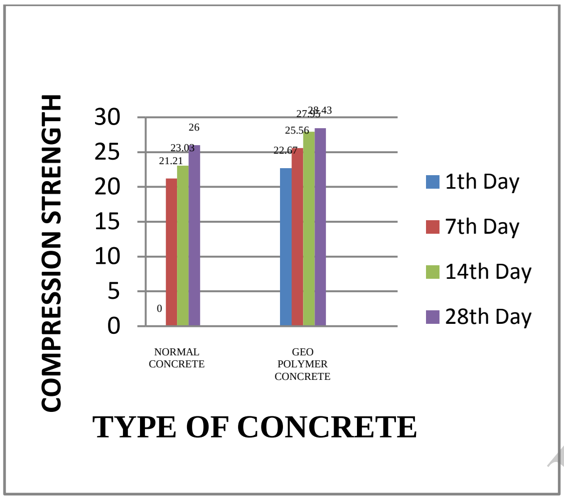


Fig12: Cylinder compressive strength for M25 Grade concrete

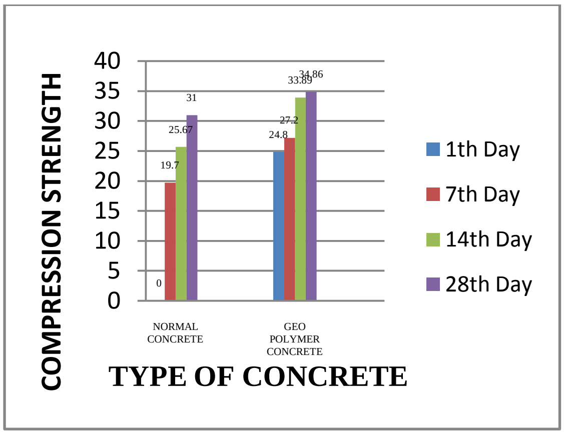


Fig13: Cylinder compressive strength for M30 Grade concrete

5.2.3 Split tensile Strength of Concrete (N/mm^2)

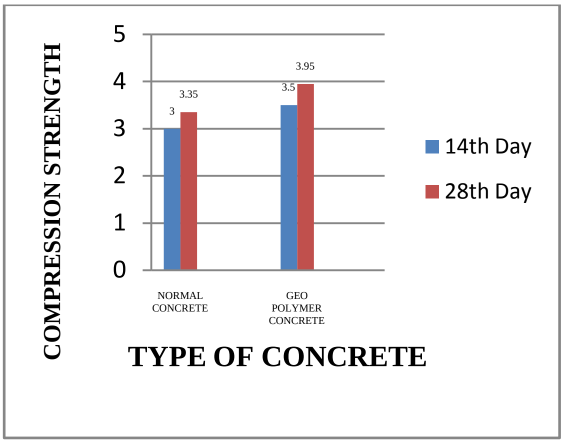


Fig14: Cylinder split tensile strength for M25 Grade concrete

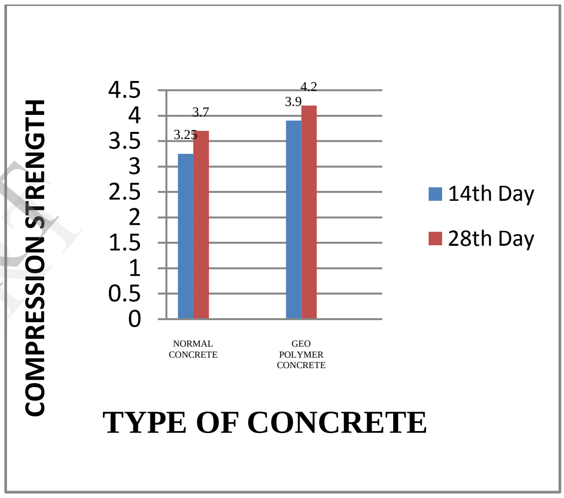


Fig15: Cylinder split tensile strength for M30 Grade concrete

Fig16: split tensile testing setup

Fig17: Comparison of Cylindrical compressive Strength development of normal concrete

Test on Durability – Alkalinity Test

pH value of concrete

Concrete grade	pH value(normal concrete)	pH value (geopolymer concrete)
M25	11.2	10.08
M30	11.7	10.17

6. Conclusion

- A detailed review of literature has been done for copper slag, geopolymer concrete and fly ash.
- Physical and chemical properties of individual (fly ash, copper slag, coarse aggregate and fine aggregate) components of geopolymer concrete are found in laboratory tests and SEM Analysis is also done.
- Experiment investigation of strength (Compressive strength, split tension strength) for geopolymer concrete are found and listed.
- Test of alkalinity for conventional concrete and geopolymer are found.
- Test on durability of geopolymer concrete will be done.

7. References:

[1]. **K. Vijai1, R. Kumutha1 and B. G. Vishnuram** *" Effect of types of curing on strength of geopolymer concrete"* July, 2010.

[2]. **M. M. A. Abdullah1, K. Hussin1, M. Bnhussain, and K. N. Ismail"** *Mechanism and Chemical Reaction of Fly Ash Geo polymer Cement- A Review".*

[3]. **D. Brindha and S.Nagan**"*Durability Studies on Copper Slag Admixed Concrete"* March 2011.

[4]. **Menasha Sudarvizhi .S,Ilangovan. R** *" Performance of Copper slag and ferrous slag as partial replacement of sand in Concrete"* 2011.

[5]. **D.Brindha,Baskaran.T, Nagan.S** *"Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete"2010.*