



AN EXPERIMENTAL CHARACTERIZATION ON MECHANICAL PROPERTIES OF ECO-FRIENDLY CONCRETE USING WATER GLASS AND LYE LIQUID AS ALKALINE SOLUTION

(zero cement concrete using red mud)

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Abstract— To reduce greenhouse gas emission and environmental pollution, efforts are needed to develop ecofriendly construction materials in India and worldwide. The industrial wastes mostly possess threat to the environment and the society living nearby. Various researches has been done on this waste material to either degrade or to utilize it in some or the other way. One such hazardous waste generated by industry is Red mud. It is the residual waste generated by Bayer's Process of aluminum extraction. Red mud is the most hazardous waste than the other waste mainly due to its high fineness and Ph. Steps have been taken to utilize this waste as partial replacement of cement in concrete without compromising the strength and economy. This paper also speaks about the future possibilities of using red mud as a replacement for cement in concrete for R.C.C work such as buildings, pavements, dams, etc after few more test is conducted and various other parameters found on this optimized concrete. This project presents the development of red mud-based geopolymer concrete. In geopolymer concrete, a by-product material rich in silicon and aluminium, red mud is chemically activated by a high-alkaline solution to form a paste that binds the loose aggregates and fine aggregates and other unreacted materials in mixture. The test results presented in this paper show the effect of various parameters on the properties of geopolymer concrete. The concrete obtained after the reaction between sodium hydroxide, sodium silicate has high strength. In this project the geopolymer mix design & experimental studies on are made on the Mechanical properties Viz, Compressive Strength, Split tensile strength, Flexure strength & Modulus of elasticity of concrete. Results of investigation indicated that there was improvement in Mechanical properties. Viz,(*Compressive strength, Modulus of elasticity, Split tensile strength, Flexural strength*) with increase in *Alkaline/Red mud ratio. (0.30 to 0.45)*. Strength also increased with increase in curing time and temperature.

INTRODUCTION

NEED FOR GEOPOLYMER CONCRETE

Portland cement (pc) production is under critical review since high amount of carbon dioxide gas is released to the atmosphere. Therefore, attempts to utilize the red mud to partially replace the portland cement in concrete are gathering momentum. Most of the red mud produced as by-product material in aluminium refining process is currently dumped in land fills, thus creating a threat to the environment. However, geopolymer concrete is a "new" material that does not need the presence of portland cement as a binder, because, the red mud, which is rich in silicon (Si) and Aluminium (Al), can be activated by alkaline liquids to produce the geopolymeric material to act itself as binder.

There are two environment- related situations in production of RED MUD and PC:

- (1) The high amount of carbon dioxide released to the atmosphere during the production of Portland cement.
- (2) The large scale availability of red mud, a by-product from aluminium extracting factories worldwide.



The rate of production of these two by-products (CO₂ and red mud) is increasing due to the escalating demand on infrastructure development, and hence there is an urgent need for proper attention and to minimize their impact on the sustainability of our living environment. De-carbonation of limestone in the kiln during manufacturing of cement is responsible for the liberation of one ton of carbon dioxide to the atmosphere for each ton of Portland cement.

ORIGIN OF TERM “GEOPOLYMER”

The term ‘geopolymers’ was first introduced to the chemical world by Davidovits in the mid 1970’s (Davidovits, 1993), and in so doing a new field of research and technology was created. He explained that “geosynthesis” is the science of manufacturing artificial rock at a temperature below 100°C (Davidovits, 1993) in order to obtain natural characteristics (hardness, longevity and heat stability). Geopolymers were thus viewed as mineral polymers resulting from geochemistry or geosynthesis.

The structural model geopolymer material is still under investigation and the exact mechanisms by which geopolymer setting and hardening occur is not yet clear (Davidovits 1999; van Jaarsveld, van Deventer & Lukey 2002). The mechanism of geopolymerisation is reported to be consisting of dissolution, transportation or orientation, and polycondensation (Xu & van Deventer 200), and takes place through an exothermic process (Palomo, Grutzeck & Blanco 1999; Davidovits 1999).

BENEFITS OF GEOPOLYMER CONCRETE

Heat-cured red mud-based geopolymer concrete offers several economic benefits over Portland cement concrete. The price of one ton of red mud is only a small fraction of one ton of Portland cement. Therefore allowing for the price of alkaline liquids needed to make the geopolymer concrete.

In addition, the appropriate usage of one ton of red mud earns approximately one carbon-credit that has significant redemption value. One ton red mud can be utilized to manufacture approximately three cubic meters of high quality red mud-based geopolymer concrete, and hence earn monetary benefits through carbon-credit trade.

Furthermore, the very little drying shrinkage, the low creep, the excellent resistance to sulfate attack, and good acid resistance offered by heat-cured red mud-based geopolymer concrete may yield additional economic benefits when it is utilized in infrastructure application.

MATERIALS

Fine aggregate

Natural river sand was used and tested as per IS:2386.1970. The fineness modulus of sand used is 2.81 with a specific gravity of 2.6.

Coarse aggregate

Crushed granite coarse aggregate of particle shape “average and cubic” was used for the present investigation. The specific gravity is 2.83 and fineness modulus is 6.4

RED MUD:

- A. Physical properties of red mud:
 - Fineness-in between 10-30 m²/g, Red mud is very fine grained material.
 - It’s pH -10.5 to 12.5.



- Specific gravity of red mud 2.51
- B. Chemical properties of red mud:
Chemical properties of red mud indicates that percentage of CaO is very less hence it has no cementitious properties but when reacts with alkanine liquid, starts gaining cementitious properties. Also silica available provides strength. Red mud concrete gains early strength compared to that of OPC.
- C. Effects of red mud on environment:
 - Ground water pollution: when the red mud get mix with surface water ,alkalinity of water increases .If service reservoirs will get polluted it may create hurdles to society.
 - Alkali seepage in to underground water-Underground water resources such as wells, aquifer may get polluted.
 - The fertility of the land gets reduced when this waste gets mixed with fertile land.
 - Huge area of land is consumed for dumping of Red mud.

CATALYTIC LIQUID SYSTEM

Analytical sodium hydroxide (NaOH with 98% purity) and sodium silicate solutions were used as the alkaline activators. In order to avoid the effect of unknown contaminants in the mixing water, the sodium hydroxide pellets were dissolved in distilled water. Even though it has been reported by several researchers that the activator solution was prepared at least one day prior to its use, in our present study, the catalytic system consisting of sodium hydroxide, sodium silicate and distilled water were mixed together approximately 24 hours before casting the specimens and kept for cooling under normal room temperature.

PREPARATION OF GEOPOLYMER CONCRETE

PREPARATION OF SOLUTION:

Separate solutions of NaOH and Na_2SiO_3 of required concentrations were prepared mixing together before 24 hours prior to casting.

MIXING:

Weighed amount of red mud, fine aggregate and coarse aggregate were dry mixed for 1 minute. After dry mixing, wet mixing was done for 2 minutes. Cubes of size 150 X150X150mm and Cylinders of size 150X300mm and Prisms of size 100X100X700 mm were cast. Compaction was done by needle vibrator as in the case of Portland cement concrete.

CURING:

After casting the specimens, they were kept in an oven. Then the specimens were demoulded at room temperature and kept at 60°C for 24 hrs and 100°C 96 hrs of the required curing time. After curing the specimens were kept at room temperature until the time of testing.

DESIGN OF GEOPOLYMER CONCRETE:

Mixture proportion of heat-cured low-calcium red mud-based geopolymer concrete mix design.



Assume that normal-density aggregates in SSD condition are to be used and the unit-weight of concrete is 2400 kg/m³. Take the mass of combined aggregates as 77% of the mass of concrete, i.e. $0.77 \times 2400 = 1848$ kg/m³. The combined aggregates may be selected to match the standard grading curves used in the design of Portland cement concrete mixtures. For instance, the aggregates may comprise 277 kg/m³ (15%) of 20mm aggregates, 370 kg/m³ (20%) of 14 mm aggregates, 647 kg/m³ (35%) of 7 mm aggregates, and 554 kg/ SiO₂ -to-Na₂O ratio by mass of approximately 2, i.e., Na₂O = 14.7%, SiO₂ = 29.4%, and water = 55.9% by mass, is selected. The sodium hydroxide solids (NaOH) with 97-98% purity is purchased from commercial sources, and mixed with water to make a solution with a concentration of 8 Molar. This solution comprises 26.2% of NaOH solids and 73.8% water, by mass.

20 mm aggregates = 277 kg/m³, 14 mm aggregates = 370 kg/m³, 7 mm aggregates = 647 kg/m³, fine sand = 554 kg/m³, red mud = 408 kg/m³, sodium silicate solution (Na₂O = 14.7%, SiO₂ = 29.4%, and water = 55.9 % by mass) = 103 kg/m³, and sodium hydroxide solution (8Molar) = 41 kg/m³ (30%) of fine sand to meet the requirements of standard grading curves. The fineness modulus of the combined aggregates is approximately 5.0.

The mass of red mud and the alkaline liquid = $2400 - 1848 = 552$ kg/m³. Take the alkaline liquid-to-red mud ratio by mass as 0.35; the mass of red mud = $552 / (1+0.35) = 408$ kg/m³ and the mass of alkaline liquid = $552 - 408 = 144$ kg/m³. Take the ratio of sodium silicate solution-to-sodium hydroxide solution by mass as 2.5; the mass of sodium hydroxide solution = $144 / (1+2.5) = 41$ kg/m³; the mass of sodium silicate solution = $144 - 41 = 103$ kg/m³.

Therefore, the trial mixture proportion is as follow: combined aggregates = 1848 kg/m³, low-calcium red mud = 408 kg/m³, sodium silicate solution = 103 kg /m³, and sodium hydroxide solution = 41 kg/m³.

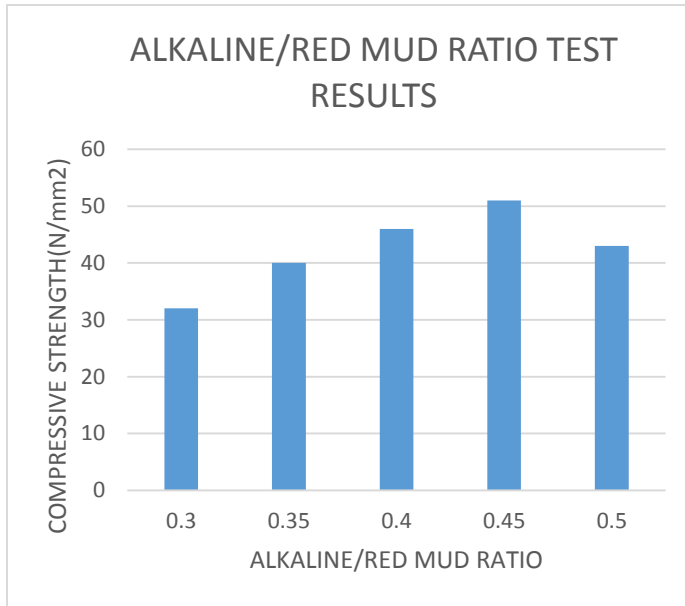
TESTS CONDUCTED:

Compressive strength, Split tensile strength, Flexure strength and Modulus of elasticity of concrete tests were conducted.

COMPRESSIVE STRENGTH:

The compressive strength test was performed taking three cubes from each set after 24hrs and 96 hrs. The results of tests at 24hrs and 96 hrs are given. Increase in compressive strength was also observed with increase in Alkaline/Red mud ratio & Curing temperature from 60 °C to 100 °C.

ALKALINE/RED MUD TEST RESULTS



Alkaline/Red mud ratio= (0.30)

Sodium silicate/Sodium hydroxide ratio= (2.5)

Curing time=24 hrs @ (60°C)

SODIUM SILICATE / SODIUM HYDROXIDE TEST RATIO:

Alkaline/Red mud ratio= 0.45

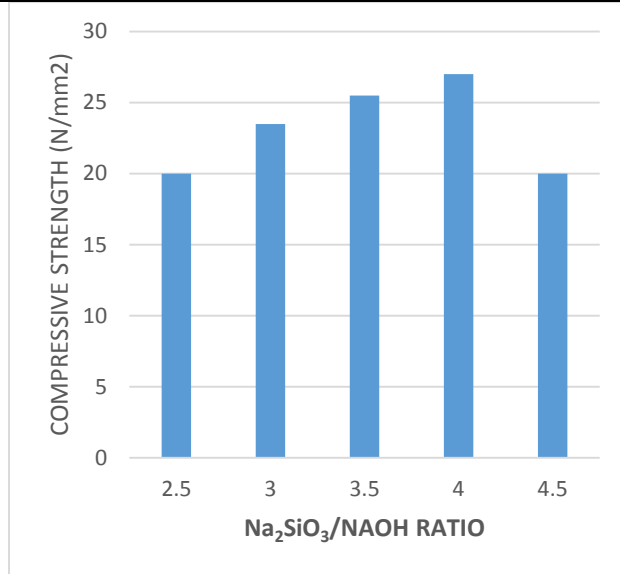
Sodium silicate/ sodium hydroxide ratio=2.5 to 4.5

Curing time= 24 hrs at 110°C

ALKALINE/RED MUD RATIO	COMPRESSIVE STRENGTH (N/mm ²)
.30	32
.35	40
.40	46
.45	51
.50	43

Na ₂ SiO ₃ /NAOH RATIO	COMPRESSIVE STRENGTH (N/mm ²)
2.5	20
3	23.5

3.5	25.5
4	27
4.5	20



SPLIT TENSILE TEST:

The split tensile strength test was performed taking cylinders from each set after 96 hrs. The results of tests at 96 hrs are given. Increase in split tensile strength was also observed with increase in Alkaline/Red mud ratio & Curing temperature from 100 degree Celsius.

CONCLUSION:

Following conclusions were drawn from the study on geopolymer concrete:

- Geopolymer concrete is more environmental friendly and has the potential to replace ordinary cement concrete in many applications such as precast units.
- Compressive strength increases with increase in concentration of NaOH from 8M to 16M. Increase in compressive strength was also observed with increase in curing time. However when curing time was increased from 24 hrs to 96 hrs, there is variation in compressive strength.
- The test results show that the compressive strength increases with increase in oven curing time from 24 hrs to 96 hrs.
- The Split Tensile strength increased with increase in Alkaline /red mud ratio and increase in Curing time.
- The Flexural Strength also increased with increased in alkaline/red mud ratio with increase in Curing time and temperature.
- The modulus of elasticity of concrete is Increasing and decreasing with the increasing alkaline/Red mud ratio.
- The Sodium silicate/Sodium Hydroxide ratio should be further investigated with the increase in molar concentration of Sodium hydroxide solution.



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