An Experimental Study on Behavior of Geopolymer Concrete using Red Mud with Recycled Aggregates

Adinath Patil[1], Meghashree M[2]

[1]Student, Dept. of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru, 560078, India
[2]Assistant Professor, Dept. of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru, 560078, India

---

Abstract - *It is well known factor that, the hazardous carbon dioxide emission during the manufacture of cement is the biggest global problem. Which led to the usage of geopolymer concrete or green concrete instead of conventional concrete. This paper studies the impact of geo-materials like red mud on its properties like durability, strength, and workability. Also the microstructural analysis is studied. The geo materials are used with a varying mix ratios for the synthesis of concrete and observed under ambient type of curing. It shown that the extended period of curing influences the increase of compressive strength and young's modulus but reduces the ductility. And red mud can be used as a replacement material up to certain percentage with GGBS for high strength concrete.*

Key Words: Red Mud Geopolymer, GGBS, Workability, Recycled Aggregate…

1. INTRODUCTION

Concrete is the widely used material for the construction. Ordinary Portland cement is the basic primary binder material for the production of cement. As through the researches and studies it is well known that the manufacturing of 1ton ordinary Portland cement results in the emission of 0.8ton of carbon dioxide which causes the environmental problems. And on the other hand the amount of energy required for the production of clinker (OPC) is too high. From the recent studies it is noted that 1.5 billion tons of ordinary Portland cement is manufacturing per year. So this huge amount of manufacturing would led to the high quantity of toxic pollutant gases emission, to reduce these kind of problems now a days researchers working on the non-toxic materials which can be used as binding agent

Past studies showed that the production of fly ash per year is one billion ton and the production of ground granulated blast furnace per year is 360 billion ton have used as an supplementary cementitious material around the world. Addition to this pozzolonic group some more materials have acquired the attraction of researchers for the study. Like Red mud, rice husk ash, silica fume, metakaolin etc. so these can be adopted as a replacement materials for the cement after the proper study and experiments.

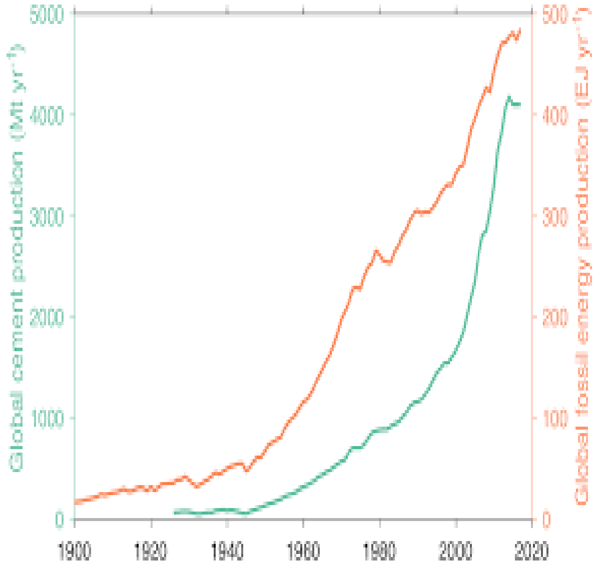

Chart 1; global CO_2 emission from 1900 to 2017

Geopolymerisation has initiated the new road for utilization of the industrial inorganic wastes. Any material which is rich in aluminosilicate can be used as source of raw materials for the Geopolymerisation. The geopolymer synthesis with the fly ash has been in new trend. But from recent studies it showed that the reaction between alkaline activators and fly ash is integrally low at ambient temperature. Hence it initiated into the study of other pozzolonic materials, which are industrial wastes of aluminosilicates. Red mud is another such material which is rich in aluminislicate property and it is the inorganic non-toxic waste produced during the extraction of alumina from bauxite. In India about 14 million tons of red mud is produced per annaum and it is dumped in red mud ponds which creates some environmental issues and also occupation of land.

1.1 Red mud

Red mud is the inorganic waste material produced during the extraction of alumina from Bayer's process which is non-toxic in nature. Around the world about 2.7 billion tons of red must is dumped as waste and about 120 million tons is generated every year. The presence of alkalinity makes it as a hazardous material and creates the environmental issues. Even though the main constituent material present in red mud is iron, it also have good degree of alumina and silica which are essential materials for the synthesis of geopolymer concrete.

The past investigations have declared redmud as less pozzolonic material that basically acts as filler in geopolymerised matrix due to its crystalline nature of compounds present. But the reactivity of the particles can be intensified by chemical activation, thermal activation and mechanical activation . but the chemical activation has limitations regarding its impregnation and due to the thermal activation the concrete may get earlier strength but acts inversely as a long term strength. Mechanical activation is all about its fineness nature which increases the specific surface area. Pulvarising is the most preferred method to manage the particle size distribution, decrease porosity, and to deaden the adverse effects of crystalline materials on its reactivity. The majority of research work reported the grinding of raw material gives the good reactivity of any binder material.

1.2 GGBS

Ground granulated blast furnace slag (GGBS) produced by grinding of blast furnace slag available in steel plants. To achieve better workability, it is widely used in Portland cement concrete and also for higher ultimate strength and durability, superior resistances to chloride penetration, sulphate attack, and alkali-silica reaction.

1.3 Materials and reaction:

It is investigated that the pulverized red mud gives more pozzolonic property than the unpulvarized red mud because it provides more specific surface area as the particles are grinded upto the required size (5μ). From the report [smitha singh] it is concluded that the pulverized red mud gives more strength in geopolymer concrete than the unpulvarized red mud because the pulverized redmud enhances the mechanical property of the materials for the synthesis of geopolymer.

Table 1 Particle size analysis:

Sample	D10 (μm)	D50 (μm)	D90 (μm)
Red mud	0.35	2.5	70
Pulverized red mud	0.12	0.45	2.3

The table 1 shows that particles sizes of the pulverized and unpulvarized red mud with consideration of different diameter ball mills. It can be concluded that a great variation in D90 values of red mud and pulverized red mud is observed, thus it is major step to state that pulverization guides to evolution of mesoporous particles to microporous particles. The strength of binder containing higher percentage (greater than 90%) of red mud is bit unsatisfied because it creates cracks as it undergoes for dehydration after period of time. So it is better to use red mud with other pozzolonic material having less percentage of total binder (Smitha singh).

The fig 2 shows TEM of red mud
before

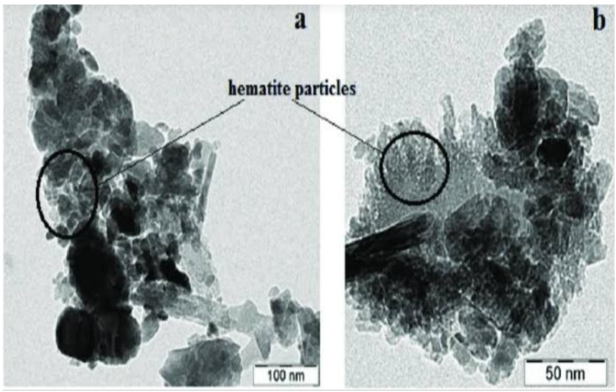

Fig 1TEM of a) unprocessed and b) processed red mud

And after the pulvarisation. It is clearly seen that the hematite particles distribute throughout the area after the grinding (pulverizing) as nano particles. Which also shows spacing of particles, narrow spacing helps to the easier reactivity of materials and also increase in lattice spacing helps in the improve the ease of protonation and disprotonation of ions thereby further it leads to increase in reactivity.

2. SCOPE:

Every year there has been huge quantity of industrial waste is generated in India and worldwide, to overcome the storage of industrial waste which creates some environmental hazards, the laborious research works are carried out to use these wastes as an alternative in construction industry. Geopolymerization is the present attraction over the world. Further into research areas, there is a need of study to develop geopolymer units making majority use of industrial wastes. In this present work, use of GGBS and Red Mud as binder along with Alkaline Solution and Red Mud based geopolymer concrete to be done with proper percentage of mix.

2.1 RESEARCH OBJECTIVES

1. The main objective of this research is to utilize the red mud and GGBS as binders in the manufacturing of geopolymer concrete,

[Geopolymer binders (red mud & GGBS) with different molarity solution (8M,12M, 14M) and with different mix ratios]

- 1. 90% GGBS and 10 % Red Mud
- 2. 80 % GGBS and 20 % Red Mud
- 3. 70 % GGBS and 30 % Red Mud
- 4. 60 % GGBS and 40 % Red Mud
- 5. 50 % GGBS and 50 % Red Mud

2. To find the compressive strength of cubes for various mix ratios of binders,
3. To find the tensile strength of cylinders,
4. To find and comapre the flexural strength of the beam with analytical strength value.

2.2 MIX DESIGN PROCEDURE

The primary difference between geopolymer concrete and Portland cement concrete is the binder. The silicon and aluminum oxides in the solids reacts with the alkaline liquid to form the geopolymer paste that binds the loose coarse aggregates, fine aggregates, and other un-reacted materials together to form the geopolymer concrete.

As in the case of Portland cement concrete, the coarse and fine aggregates occupy about 75% to 80% of the mass of geopolymer concrete. This component of geopolymer concrete mixtures can be designed using the tools currently available for Portland cement concrete. Several trial mixtures were manufactured and tested in order to ensure consistency of results prior to casting of the beam specimens.

Following ranges were selected for the constituents of the mixture

- The total water content in the mixture is assumed based on previous researches.
- Total water content = water in Na_2SiO_3 + water in NaOH solution.
- Water present in Na_2SiO_3 is obtained as per the test results obtained.
- Ratio of sodium silicate solution-to-sodium hydroxide solution, by mass, of 0.4 to 2.5. This ratio was fixed at 2.5 for most of the mixtures because the sodium silicate solution is considerably cheaper than the sodium hydroxide solution.
- Molarity of sodium hydroxide (NaOH) solution was taken as 8M.12M, 16M.
- Coarse and fine aggregates, approximately 75% to 80% of the entire mixture by mass. This value is similar to that used in OPC concrete and 75% is adopted for this experiment.
- Super plasticizer is taken as 2% of binder material (cementitious particles).

2.3 Material property:

- Red mud – pulverized red mud.
- Water content – 140 kg/m^3
- Void content = C.A: F.A = 55:44

Table 2 Specific Gravity of Aggregates

	Fine aggregate	Course aggregate
Specific gravity	2.62	2.67

3. Results and discussions

Table 3 Test results for the specimens

Molarity	R-red mud G-GGBS (%)	Compressive strength (N/mm^2)	Flexural strength (N/mm^2)
8M	R10G90	35.77	--
	R20G80	34.59	--
	R30G70	32.96	--
12M	R10G90	55.34	5.207
	R20G80	52.11	5.053
	R30G70	52.07	5.051
16M	R10G90	56.33	--
	R20G80	52.78	--
	R30G70	54.56	--

Geopolymer concrete prepared using 10% red mud and 90% GGBS achieved maximum strength of 56.33 MPa for 16M. But 30% of red mud and 70% GGBS showed strength of 52.07 MPa for 12M. So economically, strength having lesser molarity is preferred i.e. 12M is selected for the suitable replacement.

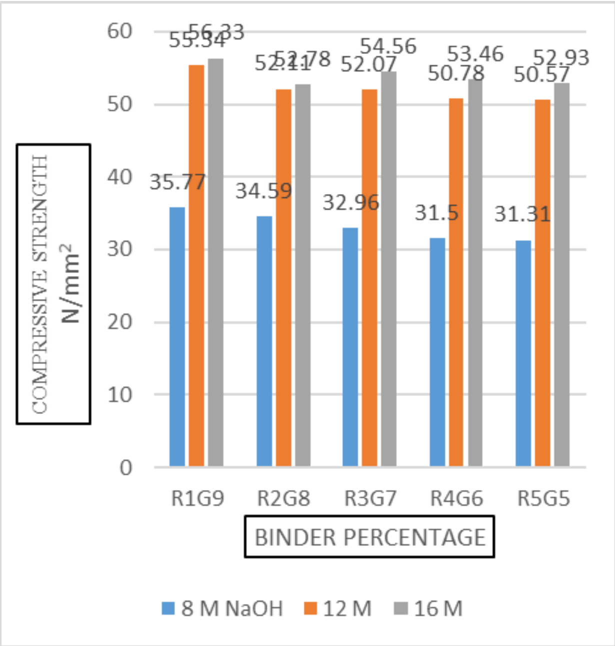

Chart 2 Effect of molarity of NaOH solution on compressive strength.

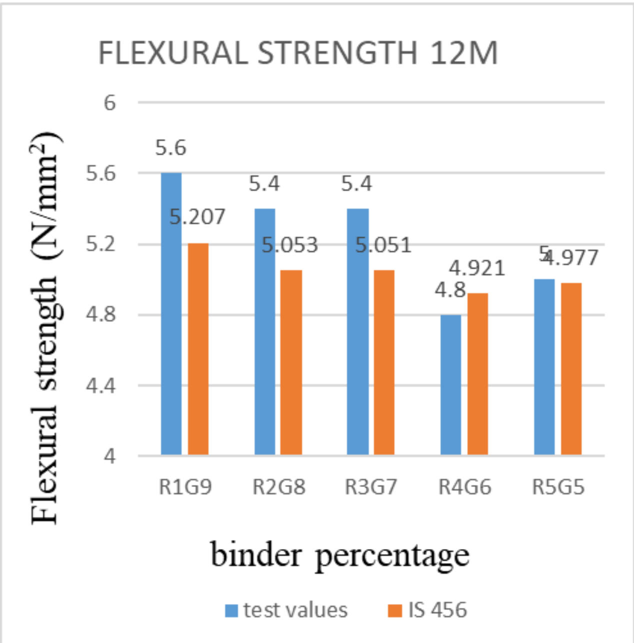

Chart 3 Effect of binder percentage content on flexural strength

4. CONCLUSIONS

The following conclusions can be drawn from the above experimental work.

- The geopolymer concrete, which contains less quantity of red mud and more GGBS is hard to handle.
- The workability of geopolymer concrete is mainly depends on the total water content, Red mud content and molarity. The workability increases with increase in red mud content and molarity up to certain limit.
- The compressive strength of cube specimens increases with increase in molarity of NaOH from 8M to 16M. And the strength decreases with increase in red mud content.
- Geopolymer concrete prepared using 10% red mud and 90% GGBS achieved maximum strength of 56.33 MPa for 16M. But 30% of red mud and 70% GGBS showed strength of 52.07 MPa for 12M. So economically strength having lesser molarity is preferred i.e. 12M is selected for the suitable replacement.
- Geopolymer concrete having 30% or less than 30% of red mud showed the good strength. But for 10% and 20% of red mud geopolymer concrete, it is very difficult to handle as it starts setting early compare to OPC. Therefore, concrete containing 30% red mud and 70% GGBS preferred is preferred as a suitable replacement.
- The test values of flexural strength and tensile strength are slight higher than the calculated strength values (IS 456).

REFERENCES

[1] Smita Singh., Dr. M. U.Aswath., & Dr. R.V. Ranganath. Effect of pulverization and curing methods on the strength of red mud-fly ash geopolymer. 1–18.

[2] Jian He, Yuxin Jie, Jianhong Zhang, Yuzhen Yu, Guoping Zhang. (2013). Synthesis and characterization of red mud and rice husk ash-based geopolymer composites. Cement and Concrete Composites, 37(1), 108 118. https://doi.org/10.1016/j.cemconcomp.20

[3] Narasimha Raj, Suresh G Patil, and B. Bhattacharjee. (2014). Concrete Mix Design By Packing Density Method. IOSR Journal of Mechanical and Civil Engineering, 11(2), 34–46. https://doi.org/10.9790/1684- 11213446

[4] Singh. Smitha. (2016). Flexure and Shear Bond Strength of Red Mud – Fly Ash Based Geopolymer Mortars. International Journal of Research in Engineering and Technology, 05(32), 251–259. https://doi.org/10.15623/ijret.2016.05320

[5] Sanjay, Dr Aswath, M. U., (2017). An Experimental Study on Flexural Behaviour of Reinforced Geopolymer Concrete Beams with Recycled Aggregates.International Journal of Civil Engineering and Technology, 8(10), 1481–1489.

[6] Mónica A. Villaquirán-Caicedo (2019). Studying different silica sources for preparation of alternative waterglass used in preparation of binary geopolymer binders from metakaolin/boiler slag. Construction and Building

Materials, 227, 1–13. https://doi.org/10.1016/j.conbuildmat.2019.08.02

[7] Shamshad Alam, Sarat Kumar Das, B. Hanumantha Rao. (2019). Strength and durability characteristic of alkali activated GGBS stabilized red mud as geo-material. Construction and Building Materials, 211, 932–942. https://doi.org/10.1016/j.conbuildmat.2019.03.21

[8] Ankur Mehtaa, Deepankar Kumar Ashish. (2020). Silica fume and waste glass in cement concrete production: A review. Journal of Building Engineering, 29(March), 100888. https://doi.org/10.1016/j.jobe.2019.100888

[9] Singh, S., Aswath, M. U., Das Biswas, R., Ranganath, R. V., Choudhary, H. K., Kumar, R., & Sahoo, B. (2019). Role of iron in the enhanced reactivity of pulverized Red mud: Analysis by Mössbauer spectroscopy and FTIR.