Geopolymer Concrete Using Red Mud and GGBS

Elson John[1], Kevin M. Chalapuram[2], Peter Shebin[3], Helna K. Mohan[4] , Zuman Frazana[5]

[1]*Assistant Professor, Dept. of Civil Engineering, M. A. College of Engineering, Kothamangalam, Kerala, India*
[2]*B.Tech Student, Dept. of Civil Engineering, M. A. College of Engineering, Kothamangalam, Kerala, India*
[3]*B.Tech Student, Dept. of Civil Engineering, M. A. College of Engineering, Kothamangalam, Kerala, India*
[4]*B.Tech Student, Dept. of Civil Engineering, M. A. College of Engineering, Kothamangalam, Kerala, India*
[5]*B.Tech Student, Dept. of Civil Engineering, M. A. College of Engineering, Kothamangalam, Kerala, India*

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Abstract - *Geopolymer concrete (GPC) is an inorganic polymer composite, which is a prospective concrete with the potential to form a substantial element of an environmentally sustainable construction by replacing/supplementing the conventional concretes. GPC has high strength, with good resistance to chloride penetration, acid attack, heat resistance, lower curing time etc. These are commonly formed by alkali activation of industrial aluminosilicate waste materials such as Fly Ash, Red Mud, GGBS, Metakaolin etc. and have about 22 to 27% lesser greenhouse footprint when compared to traditional concrete. In this study, red mud, a by-product of the bauxite industry is used, along with GGBS to prepare the concrete mix. Different trial mixes were prepared using varying percentage ratios of red mud and GGBS, using alkaline solution to bind the components together to obtain a suitable mix of appreciable strength. Their various properties like compressibility, flexural strength, etc. are determined and compared with that of the conventional concrete.*

Key Words: Geopolymer concrete, GPC, Red mud, GGBS, Aluminosilicate, Alkaline liquid

1. INTRODUCTION

The demand for concrete as a material of construction will increase as the demand for infrastructure development increases, especially in countries such as China and India. In order to meet this demand, the production of Portland cement must increase. However, the contribution of green house gas emission from the Portland cement production is about 1.35 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere. Furthermore, Portland cement is also among the most energy-intensive construction materials, after aluminium and steel. Hence great effort is taken to reduce the cement consumption. It includes the use of supplementary cementitious materials like fly ash, GGBS, etc. and the use of alternate binders. The geopolymer concrete (GPC) technology developed as a result of this.

The name geopolymer was formed by a French Professor Davidovits in 1978 to represent a broad range of materials characterized by networks of inorganic molecules. Geopolymers are the alkali alumino-silicate binders formed by the alkali silicate activation of alumino-silicate materials. Geopolymers have the chemical composition similar to that one of a zeolite, but have amorphous microstructure. During the process of synthesizing, silicon and aluminium atoms come together to form three dimensional polymeric chain and ring structure that consists of Si-O-Al-O bonds which are chemically and structurally similar to those that binds the natural rocks (Sumajouw et al, 2005).

$$Mn\ [-(SiO2)\ z–AlO2]\ n.\ wH2O$$

Where: M = the alkaline element or cation such as potassium, sodium or calcium;

The symbol **–** is an indication of a chemical bond,

n is the degree of polycondensation or polymerization,

z is 1,2,3 or higher up to 32.

They were mostly synthesized from silicon and aluminium materials of geological origin. However, nowadays, geopolymers are manufactured from secondary raw materials such as fly ash, slag, rice husk ash, etc.

In recent times metallurgical industries contribute significantly towards generation of industrial wastes, the production and storage of which is economically and environmentally problematic due to the risk of contamination of natural resources and living organisms. Such a type of industrial waste is bauxite residue which contains high concentration of red mud. Using red mud in GPC is an alternative as it can replace cement due to its high alumina content and also reduce the global red mud concentration. This project aims at preparing a geopolymer concrete mix using red mud having appreciable strength and comparing its various mechanical properties with the conventional M20 concrete mix.

2. MATERIALS USED

2.1. Conventional Concrete

2.1.1. Cement

Ultratech Portland Pozzolana Cement was used in this project. The specific gravity, found out using the Le Chatelier flask as per IS: 4031 is 2.80.

2.1.2. Coarse Aggregates

The specific gravity was found out using wire mesh suspended from a balance and was done according to IS: 2386 (Part 3)-1963. The specific gravity was obtained as 2.68. The sieve analysis was done as per the IS: 2386 (Part I)-1963. The results are given in chart 1.

2.1.3. Fine Aggregate

Manufacturer's sand (M sand) was used as fine aggregate. The specific gravity was found out using pycnometer and was done according to IS: 2386 (Part 3)-1963. It was obtained as 2.65. The sieve analysis results are given in the chart 2.

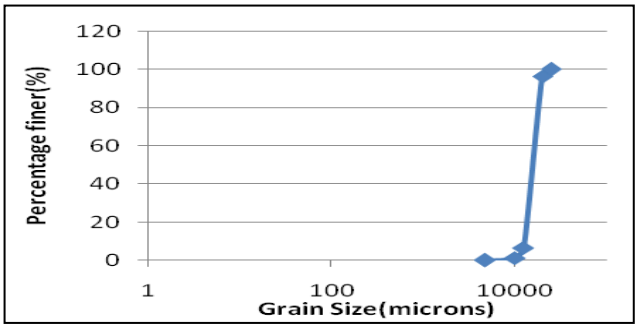

Chart -1: Particle Size Distribution Graph for Coarse Aggregates

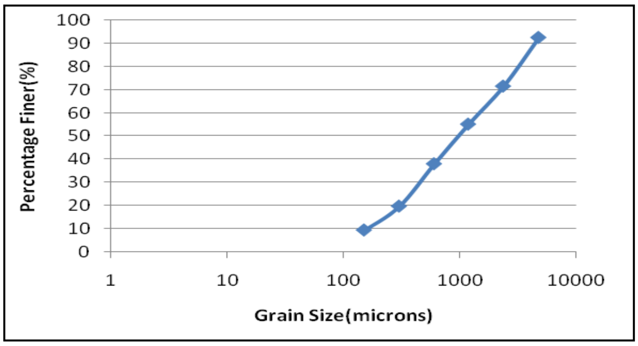

Chart -2: Particle Size Distribution Graph for Fine Aggregates

2.2. Geopolymer Concrete

2.2.1. Red Mud

The specific gravity of red mud was found out using pycnometer. It was found to be 2.64.

2.2.2. GGBS

The specific gravity of red mud was found out using pycnometer. It was found to be 2.85.

2.2.3. Alkaline Liquids

The alkaline liquid used is a combination of sodium hydroxide and sodium silicate. Sodium hydroxide (NaOH) of 10 M was used.

3. METHODOLOGY

The conventional concrete of M20 grade was designed and casted. The mix proportion used was: 1:1.88:2.85:0.5. The geopolymer concrete mixes were made by varying the proportion of red mud and GGBS (80%:20%; 70%:30%; 60%:40%). The alkaline liquids, sodium hydroxide and sodium silicate were taken in the required proportion. The concrete cubes were casted and their compressive strengths were tested after 28 days. Flexural strength and split tensile strength tests were conducted on the conventional concrete and the geopolymer concrete having similar compressive strength to that of the conventional M20 mix. The mixes made are given in tables 1 and 2.

Table -1: Trial Mix 1

MATERIALS	QUANTITY
C.A	1294
F.A	554
Red mud	407
NaOH	41
Na_2SiO_3	103

Table -2: Other Trial Mixes

MATERIALS	M1	M2	M3	M4
C.A	1294	1294	1294	1294
F.A	554	554	554	554
Red mud	81	81	122	163
GGBS	326	326	285	244
NaOH	86	91	98	98
Na_2SiO_3	85	95	100	123

3. RESULTS AND DISCUSSIONS

3.1. Workability

The workability of concrete was found out using the slump test. The slump values obtained for the various mixes are given in table 3.

Table -3: Slump Values

MIX DESIGNATION	SLUMP IN mm
M1	50
M2	48
M3	30
M4	28

The workability of the GPC mixes was very low. They were very dense. It was found that the workability decreases with increase in the red mud content.

3.2. Compressive Strength

The compressive strength after 28 days was obtained by testing the cube specimens of size 150x150x150mm in the compression testing machine. The results are given in chart 3.

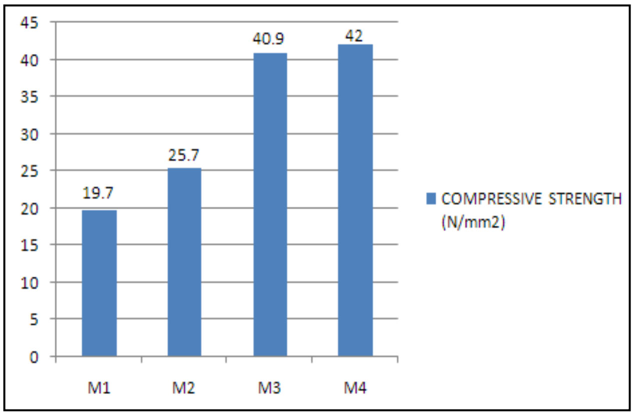

Chart -3: Compressive Strength

3.3. Flexural Strength

The flexural strength test was carried out on the universal testing machine on the conventional concrete specimen and the GPC specimen M1, as they have comparable compressive strengths. The results are given in chart 4.

3.4. Split Tensile Strength

The split tensile strength values of the conventional concrete specimen and the GPS specimen M1 were found by testing on the compression testing machine. The results are shown in chart 4.

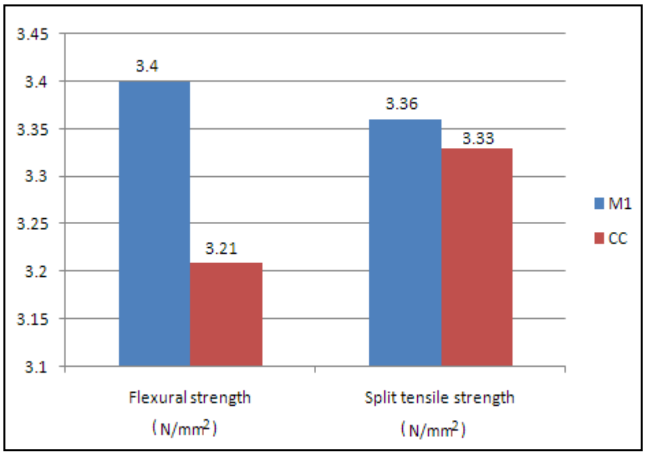

Chart -4: Flexural Strength and Split Tensile Strength

4. CONCLUSIONS

1. The workability of GPC with red mud is very low. The workability decreases with increase in the red mud content.
2. The compressive strength increases with increase in the red mud content, but with addition of more than 30%red mud, no significant rise in strength is obtained.
3. The compressive strength also increases with the increase in the alkaline liquid content.
4. Out of all the trial mixes prepared, M1 was found to have compressive strength similar to that of the conventional M20 concrete mix.
5. The mechanical properties of the GPC mix (M1) with red mud and GGBS, like flexural strength and split tensile strength, when compared with that of the conventional concrete mix having the same compressive strength, are similar.

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REFERENCES

[1] Abhishek H. N. and Dr. M.U. Aswath, “Strength studies of red mud based geopolymer concrete,” International Journal of Emerging Trends in Engineering and Devolopment, Vol. 6, September 2012.

[2] Nan Ye, Jiakuan Yang, Sha Liang, Yong Hu, Jingping Hu, Bo Xiao and Qifei Huang, “Synthesis and strength optimisation of one-part geoplymer based on red mud”, Construction and Building Materials III, 2016, pp. 317-325.

[3] Jian He, Yuxin Jie, Jianhong Zhang, Yuzhen Yu and Guoping Zhang, “Synthesis and characterisation of red mud an drice husk ash-based geopolymer composites”, Cemnt and Concrete Composites, Vol. 37, March 2013, pp. 108-118.

[4] Mira Vukčević, Danka Turović, Milun Krgović, Ivana Bošković, Mileta Ivanović and Radomir Zejak, “Utilisation of geopolymerisation for obtaining construction materials based on red mud”, Professional article, ISSN 1580-2949, 2013, pp. 99-104.

[5] Supraja V. and Kanta Rao M., “Experimental study on Geopolymer concrete incorporating GGBS”, International Journal of Electronics, Communication & Soft Computing Science and Ennginееring, ISSN: 2277-9477, Vol. 2, pp. 11-15.

[6] Anuj Kumar and Sanjay Kumar, “Development of paving blocks from synergistic use of red mud and fly ash using geopolymerization”, Construction and Building Materials, Vol. 38, pp. 865-871.

[7] S. Kumar, “The properties and performance of red mud-based geopolymeric masonry blocks”, Eco-Efficient Masonry Bricks and Blocks, 2015, pp. 311-328.

[8] Madheswaran C. K., Gnanasundar G., Gopalakrishnan N., “Effect of molarity in geopolymer concrete”, International Journal of Civil and Structural Engineering, Volume 4, No 2, 2013.

[9] Prof.More Pratap Kishanrao, “Design of Geopolymer Concrete” , International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 5, May 2013.