Characterization of GGBS-Based Geopolymer Blended with RED MUD Using EDAX and XRD

Tanya Lairikyengbam, Chungkham Jinita Devi, Nirmala Thoudam, and Suresh Thokchom

1 Introduction

The solid waste produced during the manufacture of alumina is known as red mud. It is the most highly desirable industrial waste require for utilization [1, 2]. Iron oxides, which give red mud its colour, are among the many oxides that make up the substance. Red mud is a form of industrial waste created when alumina is generated from bauxite ore using Bayer's process [3]. Because of its high alkalinity of red mud [4], it poses a risk to both the environment and human health [5]. The largest difficulty in reducing its impact is finding an efficient, inexpensive disposal method for alumina. Currently, hazardous waste is dumped into deep ocean or into waterbodies like rivers or the sea via pipelines or barrages [6–8]. However, red mud waste discharge into aquatic bodies was discontinued starting in 2016. Disposal of red mud residue into the environmental needs to be control. Massive efforts have been undertaken by today's researchers to treat, recycle, and use red mud [9–13]. Geopolymer was first proposed by davidovites in the year 1978. Geopolymer is becoming more popular as an alternative binder in experimentation and development. Geopolymer is a highly cementitious material prepared by rich aluminosilicates [1, 3] raw material like ground granulated blast furnace slag, fly ash, coal gangue, etc. [14, 15], which can replace ordinary Portland cement.

The current paper presents the ground granulated blast furnace-based geopolymer incorporated partially by red mud at a ratio of 5% and 10% and then compared with the control specimen. The geopolymeric specimen was measured microscopically using X-ray diffraction (XRD), Scanning electron microscope (SEM), and Energy dispersive X-ray analysis (EDAX/EDX).

Present Address:
T. Lairikyengbam (✉) · C. J. Devi · N. Thoudam · S. Thokchom
Department of Civil Engineering, Manipur Institute of Technology, Manipur University, Imphal, India
e-mail: tanya.lairikyengbam@gmail.com

B. P. Swain (ed.), *Recent Advances in Materials*, Springer Proceedings in Materials 25,
https://doi.org/10.1007/978-981-99-3844-5_4

2 Materials and Methods

2.1 Materials

Ground granulated blast furnace slag (GGBS), Red mud (RM), Sodium hydroxide, Sodium silicate, and tap water were the main constituent of the geopolymer paste specimen. GGBS is a by-product of iron and steel making from blast furnace. It mainly consists of silicates, aluminosilicates, and calcium-alumina-silicates. It exhibits hydraulic cementitious properties in finely ground form GGBS was collected from Quality Polytech, Mangalore, India. Bauxite residue is termed as red mud. It is a waste generated in production of alumina from bauxite in Bayer process. It contains minerals of bauxite residue. Red mud was collected from nature and greens, Gujarat. Combination of sodium hydroxide solution and sodium silicates solution is used as an alkaline solution. Both sodium hydroxide and sodium silicate were collected from Bharat Trading Cooperation, Guwahati, Assam.

2.2 Samples Preparation

By dissolving a NaOH flask in distilled water and letting it cool to room temperature, sodium hydroxide solution (9M) was prepared. In order to create the final alkaline solution, Na_2SiO_3 and NaOH solutions were combined and stirred until the solution was obtained uniformly. The solution is used after one day to allow the exothermically heated solution to cool down at ambient temperature.

Geopolymer paste specimen were prepared by mixing GGBS and RM and alkaline solution until a homogenous slurry is obtained. A vibrating table was used to remove entrapped air from slurry before it was casted. The cube mould size is 50 mm × 50 mm × 50 mm. The samples are cured at ambient temperature. The sample were maintained at ambient temperature after casting until they were mechanically tested. One mixture was produced using only GGBS as control specimen name as 'G' while other two mixtures were produced by replacing GGBS by weight in 5% (G + 5R) and 10%(G + 10R) with red mud as in Table 1.

Table 1 Details of specimen

Specimen ID	GGBS (%)	RM (%)
G	100	–
G + 5R	95	5
G + 10R	90	10

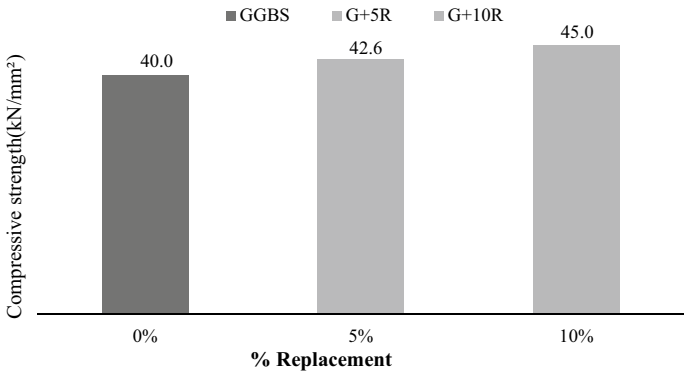

Fig. 1 Compressive strength of G, G + 5, and G + 10 paste specimen

2.3 Methods

The samples' compressive strength is evaluated. After the compressive strength test, the samples are crushed. A part of crushed samples is ground until it passes through 45 microns mesh sieve for XRD. The other part of the crushed samples was collected for SEM and EDAX.

3 Results and Discussion

3.1 Compressive Strength

The compressive strength of paste specimen sample prepared from unblended GGBS and blended GGBS with red mud is given in Fig. 1. The strength of paste specimens is tested at 28th days curing. The strength for geopolymer blended with red mud increases with increasing dosages of red mud.

3.2 Microscopic Measurements

3.2.1 Scanning Electron Microscope(SEM)

The microstructure of the specimen was examined using SEM. The microstructure of unblended GGBS paste specimen and blended GGBS with red mud are shown in Fig. 1(G), Fig. 2(G + 5R), and Fig. 3(G + 10R), respectively. The microstructure shows formation of gel along with one partially reacted particles. The microstructure indicates improvement with increasing blend with RM upto 10%, i.e. G + 10R

paste specimen is observed to form better gel among the three specimens. However, unreacted GGBS particles are noticed along with the presence of few pores.

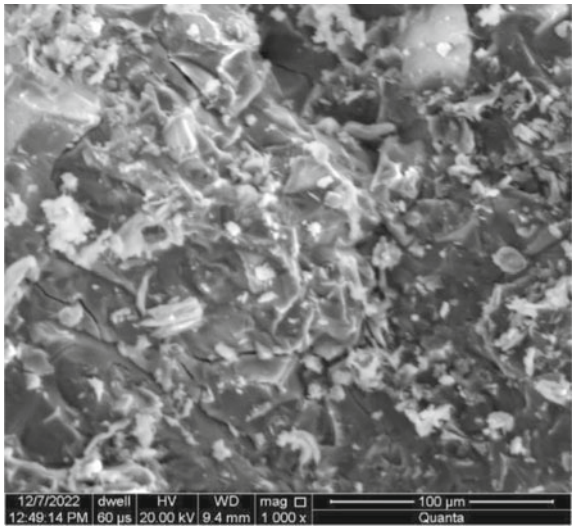

Fig. 2 G paste specimen

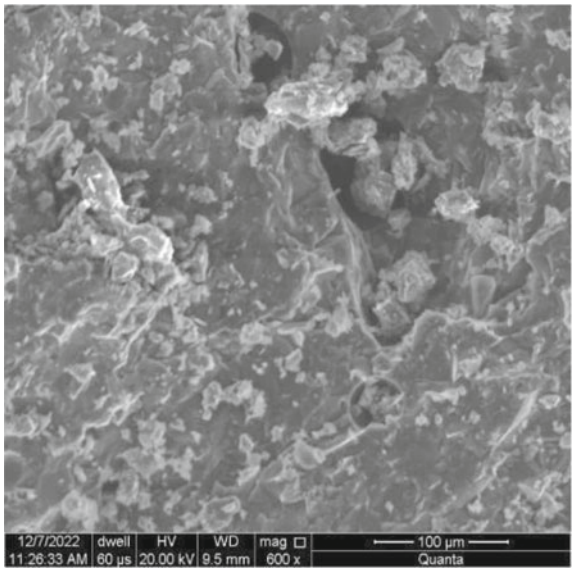

Fig. 3 G + 5R paste specimen

3.2.2 Energy Dispersive X-Ray Analysis (EDAX)

EDAX was used to evaluate the chemical composition of the specimens. Figures 4, 5 and 6 shows the EDAX spectra of G, G + 5R, and G + 10R specimen, respectively. In all the spectra, the major elements identified are Oxygen, Sodium, Aluminium, Silica, Calcium, etc. while traces of other elements like carbon, magnesium, phosphorous, sulphur, chlorine, potassium, titanium, manganese, iron, cobalt, copper were also observed. The weight % of the major elements identified in EDAX spectra are presented in Tables 2, 3, 4. The weight % of silica increased with blending RM with GGBS. However, weight % of calcium remain approximately equal in all the geopolymer blended specimen (Fig. 7).

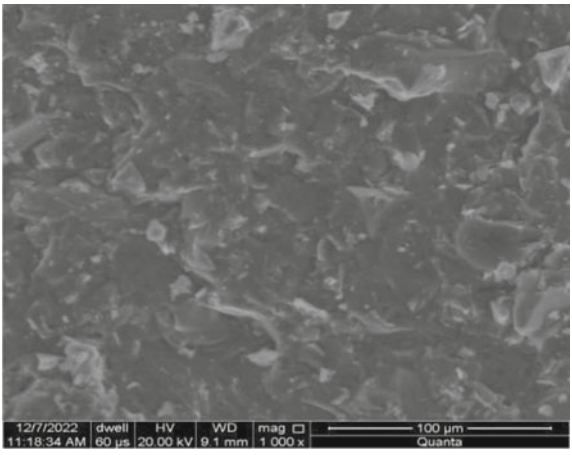

Fig. 4 G + 10R paste specimen

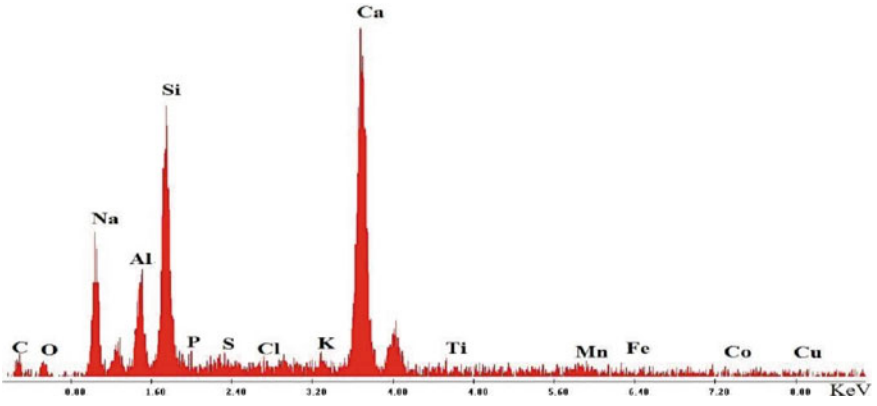

Fig. 5 EDAX diagram of G paste geopolymer specimen

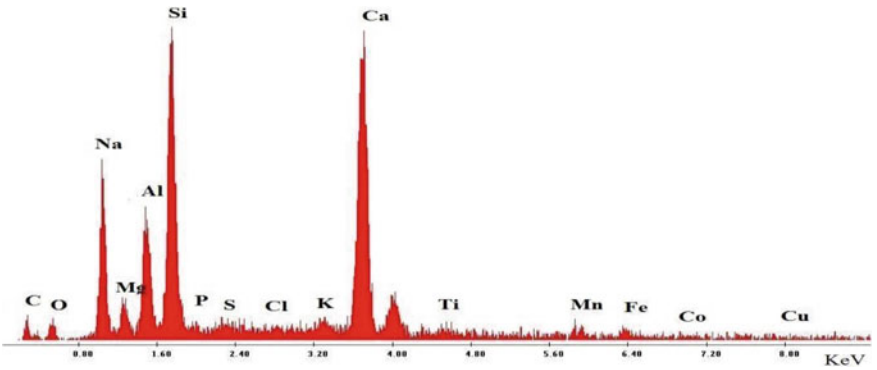

Fig. 6 EDAX diagram of G + 5R paste geopolymer specimen

Table 2 Major component of G paste specimen

Elements	Wt %	At %
O K	4.26	6.99
Na K	13.02	14.87
Al K	7.20	7.01
Si K	20.08	18.78
Ca K	31.14	20.41

Table 3 Major component of G + 5R paste specimen

Elements	Wt %	At %
O K	4.97	8.00
Na K	14.22	15.93
Al K	8.49	8.11
Si K	21.70	19.90
Ca K	26.83	17.25

Table 4 Major component of G + 10R paste specimen

Elements	Wt %	At %
O K	3.96	7.03
Na K	5.52	6.81
Al K	10.39	10.93
Si K	26.55	26.82
Ca K	30.52	21.61

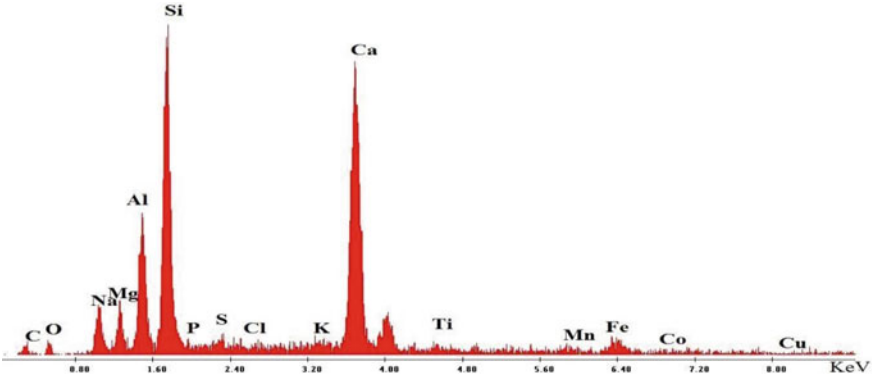

Fig. 7 EDAX diagram of G + 10R paste geopolymer specimen

3.2.3 X-Ray Diffraction

Figure 8 shows the XRD patterns of GGBS unblended paste specimen and GGBS blended specimen with red mud. Patterns in the range of 10–70° are shown in Fig. 8. It is observed that GGBS unblended paste specimen peaks of quartz and calcite, respectively, at 2Θ. In GGBS blended with red mud paste specimen peaks of quartz, hematite, and calcite were noticed at 2Θ approximately. All the XRD patterns indicates amorphous nature. Blending GGBS with red mud produces peaks of hematite peaks of quartz and calcite. However, the hematite present in blended geopolymer paste specimen was not observed in unblended GGBS paste specimen.

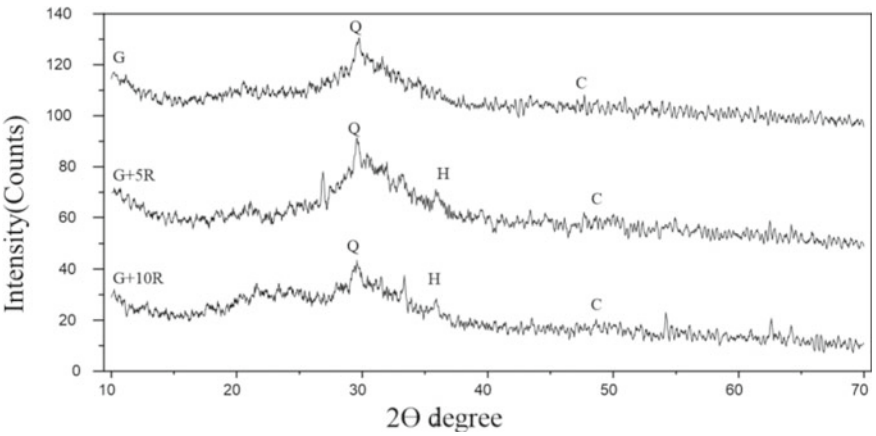

Fig. 8 XRD patterns of ambient cured specimens (Q-Quartz; HHematite; C- Calcite)

4 Conclusion

The study examined the strength of the specimen cured at ambient temperature. Further findings include the fact that the compressive strength of blended paste geopolymer by 10% weight red mud has higher strength as compared blended paste geopolymer by 5% weight red mud and unblended paste specimen. Using XRD and SEM analysis, it was determined that an amorphous paste geopolymer gel had formed, while the blended paste specimen had less pores than the unblended GGBS paste specimen. The microstructure analysis showed red mud as filling material during geopolymerization process.

References

1. Davidovits J (1994) Properties of geopolymer cements. In: First International Conference on Alkaline Cement and Concrete
2. Davidovits J (1994) Chemistry of geopolymeric systems, Terminology Geopolymer, International Conference
3. Zhang G, He JA, Gambrell RP (2010) Synthesis, characterization and mechanical properties of red mud-based geopolymer. Trans Res Record 2167:1–9
4. Xu B, Smith P, Wingate C, Siva L De (2010) The effect of calcium and temperature on the transformation of sodalite to cancrinite in Bayer digestion. Hydrometallurgy 105:75–81
5. Joseph CG, Taufiq-Yap YH, Krishnan V, Puma GL (2019) Application of modified red mud in environmentally-benign applications-a review paper. Environ Eng Res 25:795–806
6. Alp A, Goral MS (2003) The influence of soda additive on the thermal properties of red mud. J Therm Anal Calorim 73:201
7. Atasoy A (2005) An investigation of characterization and thermal analysis of the Aughinish red mud. J Therm Anal Calorim 81:357–361
8. Gelencser A, Kovts N, Turoczi B, Rostsi A, Hoffer A, Imre K, et al (2011) The red mud accident in Ajka (Hungary): characterization and potential health effects of fugitive dust. Environ Sci Tech 45:1608–1615
9. Ayres RU, Holmberg J, Andersson B (2001) Materials and the global environment: waste mining in the 21st century. MRS Bull 26(6):477–480
10. Marabini AM, Plescia P, Maccari D, Burragato F, Pelino M (1998) New materials from industrial and mining wastes: glass-ceramics and glass- and rock-wool fibre. Int J Miner Process 53(1–2):121–134
11. Singh M, Upadhayay SN, Prasad PM (1996) Preparation of special cements from red mud. Waste Manage 16(8):665–670
12. Singh M, Upadhayay SN, Prasad PM (1997) Preparation of iron rich cements using red mud. Cement Concrete Res 27(7):1037–1046
13. Yalcin N, Sevinc V (2000) Utilization of bauxite waste in ceramic glazes. Ceram Int 26(5):485–493
14. Asim N, Alghoul M, Mohammad M, Amin MH, Akhtaruzzaman M, Amin N, Sopian K (2019) Emerging sustainable solutions for depollution. Const Building Mat 199:540–548
15. Chen S, Wu C, Yan D (2019) Binder-scale creep behaviour of metakaoline based geopolymer. Cement Const Res, 12