INFLUENCE OF GGBS ON STRENGTH OF RED MUD STABILIZED BY ALKALINATION PROCESS

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ABSTRACT: Industrial process generates huge amounts of industrial by-products which occupy large stretches of land surface causing environmental pollution. Red mud is the by-product of aluminium industries, generated through the Bayer process for extraction of aluminium by digesting with high concentration of sodium hydroxide. Its properties make it extremely difficult to work with and to dispose it off. The major constituents of red mud are Fe_2O_3, Al_2O_3, TiO_2, SiO_2 and Na_2O. Red mud is a highly alkaline waste. Thus, by adding small amount of alumino-silicate rich material, it can be solidified. With a view of the above, this research is aimed to stabilize the red mud by activating it by addition of ground granular blast furnace slag (GGBS). Additionally, the effect of addition of higher doses of alkali that is NaOH has been studied. The compaction characteristics have been studied for each combination of GGBS and NaOH content to the red mud. Moreover, the mechanical strength of the same has been studied for different curing periods. Simply addition of GGBS to the red mud without any alkali results in an increase of compressive strength. The unconfined compressive strength test result reveals that GGBS and NaOH content are the major influencing parameters.

KEYWORDS: industrial solid wastes, red mud, GGBS, alkaline activation, compressive strength

1 INTRODUCTION

With the tremendous growth of industrialization, the production of by-products (such as coal ash, red mud, slag etc.) from the industries also increases. Disposal of waste product is the biggest problem as it requires big expanse of land. Waste products may pollute the surrounding land by leaching toxic ingredients as well as the underground water. Also these may pollute the air due to the presence of fine particles in the so called waste products. Hence, these wastes require proper treatment to avoid pollution hazards.

Geopolymerization is the technology which can transform waste materials containing silica and alumina into useful products with excellent physical and chemical properties. The main principle involved in geopolymerization is the chemical reaction between alumino silicate materials and highly alkaline solution to form amorphous to semi crystalline inorganic polymers.

2 LITERATURE REVIEW

Researches have been made to stabilize red mud either by addition of admixtures or by suitable chemicals. Satayanarayana et al. (2012) observed that adding10% lime and curing period of 28 days is effective for the stabilization of red mud. He et al. (2013) has developed a new kind of geopolymer from red mud with rice husk ash and compressive strength ranging from 3.2 to 20.5 MPa was obtained. Hajjaji (2013) has developed a new geopolymer from metakaolin and red mud by sodium silicate solution as alkali activator and concluded that lesser amount of red mud with longer curing period gave more compressive strength. Rai et al. (2013) studied feasibility of reducing the alkaline nature of red mud by sintering using fly ash as an additive via Taguchi methodology. A pH of 8.9 was obtained at 25–50% of red mud and 50–75% fly ash with water and temperature of 1100^oC. Deelwal (2014) studied the effectiveness of red mud stabilized by lime with gypsum. The results showed that 12% lime and 1% gypsum gave more UCS value at 7 days curing. Singh (2014) stated addition of higher percentage of CKD has shown higher values up to 8% addition further addition of CKD does not play any vital role in increasing the strength of Red mud CKD mix. Zhang et al. (2014) derived geopolymers from red mud and class F fly ash and found 28 days unconfined compressive strength of about 11.3 to 21.3 MPa. Lakshmi (2015) has taken attempts to investigate the stabilization process with cement. High strength values obtained at 28 days for all percentages of cement i.e. at 10% it is $110 kg/cm^2$

and at 20% it is 175kg/cm^2. Kaya et al. (2016) investigated the behavior of red mud and metakaolin based geopolymers. Red mud is added in the range of 0 to 40% by weight of red mud-metakaolin mixture. 51.5 MPa was the maximum compressive strength for metakaolin based geopolymer.

3 MATERIALS

3.1 Red Mud

Red mud (RM) was collected from National Aluminium Company (NALCO), Damanjodi. The material was oven dried and the fineness of the material was increased by putting it in a ball mill. The red mud use in this project work had pH of 11.2.

3.2 Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBFS) was collected from Rourkela steel plant. The material was dried in oven to remove the water present in raw material and put in a ball mill to increase the fineness. The material has been sieved through 75 µm was used for the project work.

3.3 Sodium Hydroxide

The sodium hydroxide pellets used for this project were Fisher Scientific brand with 98% purity. The NaOH solution was prepared before 24 hours to ensure proper dissolution of the sodium hydroxide pellets.

4 METHODOLOGY

The mechanical properties of the waste materials are determined as per relevant Indian Standard specifications. GGBS is added with different percentages (i.e. 0, 10, 20, 40, 60 and 80%) of the total solid, i.e. mixture of red mud and GGBS. The maximum dry densities (MDD) and optimum moisture contents (OMC) for all the mixes are obtained by light compaction test as per IS 2720 (Part VII) 1980. The unconfined compressive strength (UCS) of all the mixes, compacted to their respective MDD at OMC are determined as per IS 2720 (Part X) 1991.The cylindrical test specimens were of 5cm diameter and 10cm height and were tested after curing periods of 0, 3, 15, 30 and 60 days. Further, the effect of additional alkali on compressive strength of the red mud-GGBS mixture has been studied. For this various percentages of NaOH i.e. 0, 2, 4, 8 and 12% of solid have been added. Physical and chemical properties of both RM and GGBS are presented in Table 1.

5 RESULTS AND DISCUSSION

5.1 Compaction Characteristics

The compaction curve for red mud-GGBS mixtures are shown in Fig. 1. In red mud-slag mixture, as the percentage of slag increased in red mud, the maximum dry density increases up to 40% slag content and further addition of slag resulted in decrease of MDD value. Both red mud and slag possess higher specific gravities than the fly ash. Change in MDD value of the mixture mainly depends on the specific gravity of the constituent materials and gradation of the mix. A well graded material possess a high MDD value compared to poor grade material, observed changes in MDD values may be attributed to the above reason. The highest MDD value is observed for 60% red mud and 40% slag, which is 18.6kN/m^3.

Table 1 Physical and chemical properties of the materials

Sl. no.	Properties	RM	GGBS
1	pH value	11.20	10.12
2	Specific gravity	3.3	2.84
3	Coefficient of uniformity (C_u)	3	2.5
4	Coefficient of curvature (C_c)	1.33	1.36
5	Maximum dry density (MDD), kN/m^3	17.88	16.9
6	Optimum moisture content (OMC), %	23	19

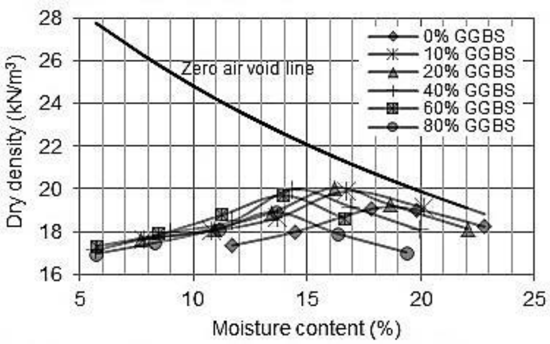

Fig. 1 Compaction curves for red mud-GGBS mixtures

Table 2 UCS values of red mud-slag mixes in (MPa)

GGBS (%)	Curing Period (days)			
	0	15	30	60
0	0.22	0.23	0.32	0.32
10	0.1	0.16	0.77	1.25
20	0.15	0.2	1.63	2.36
40	0.26	0.48	1.65	5.2
60	0.23	0.44	1.39	2.62
80	0.1	0.19	0.5	1

5.2 Unconfined Compressive Strength

For all red mud-slag mixes, compressive strength at 0 days curing is very less which increases from 0.22 MPa to 0.26 MPa with the addition of 40% slag (Table 2).

For the mix 60%RM+40% GGBS strength increased about 20 times from 0 days to 60 days curing period.

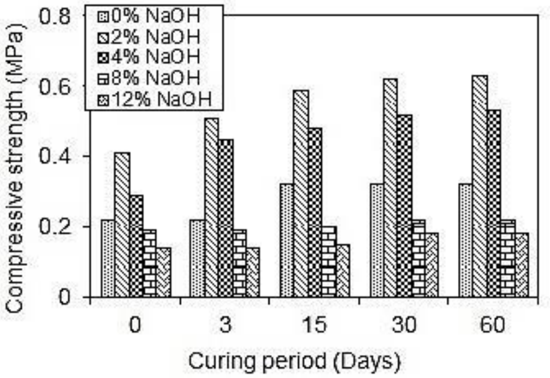

Fig. 2 UCS values of red mud with different dosages of alkali

For 2% NaOH, red mud attains maximum strength of 0.63 MPa at curing period of 60 days (Fig. 2). Further increase in NaOH content results in reduction in unconfined compressive strength. This is due to the lubricating effect of excess NaOH. As red mud is devoid of reactive silica and alumina, an addition of higher alkali to red mud does not bring about any chemical reaction and hence in increase in compressive strength.

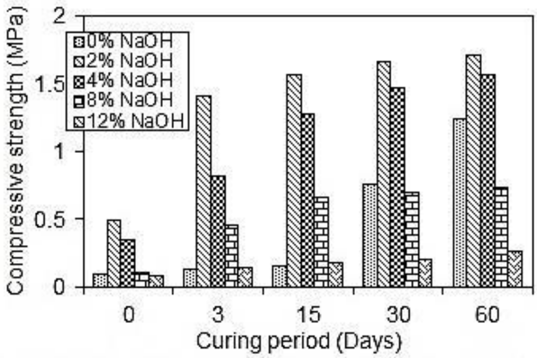

Fig. 3 UCS values of red mud, slag (90:10) mix with different dosages of alkali

For 90%RM+10% GGBS with 2% NaOH compressive strength increases from 0.52 MPa to 1.72 MPa at 60 days curing period (Fig.3). For 80%RM+20% GGBS with 2% NaOH compressive strength increases from 0.26 MPa to 4.32 MPa at 60 days curing period (Fig. 4). For 60%RM+40% GGBS with 4% NaOH compressive strength increases from 0.32 MPa to 14.02 MPa at 60 days curing period (Fig. 5). For 40%RM+60% GGBS with 4% NaOH compressive strength increases from 0.31 MPa to 18.2 MPa at 60 days curing period (Fig. 6). For 20%RM+80% GGBS with 4% NaOH compressive strength increases from 0.32 MPa to 14.02 MPa at 60 days curing period (Fig. 7). From these observations it is concluded that the improvement in strength of red mud basically depends on the availability of reactive silica and alumina in the mixture and the alkali content.

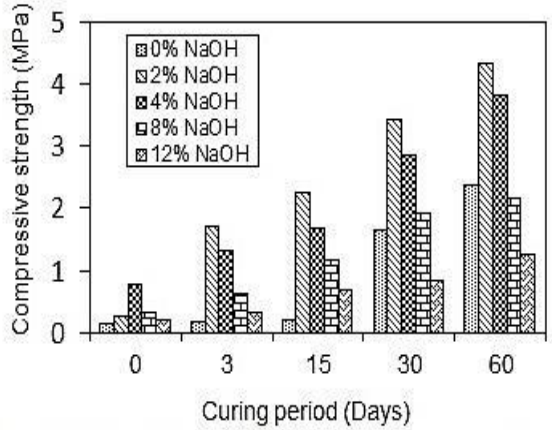

Fig. 4 UCS values of red mud, slag (80:20) mix with different dosages of alkali

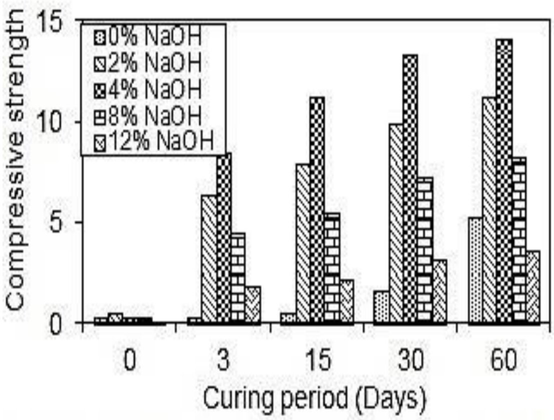

Fig. 5 UCS values of red mud, slag (60:40) mix with different dosages of alkali

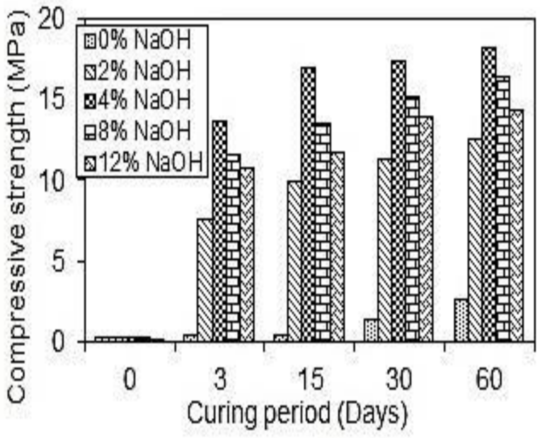

Fig. 6 UCS values of red mud, slag (40:60) mix with different dosages of alkali

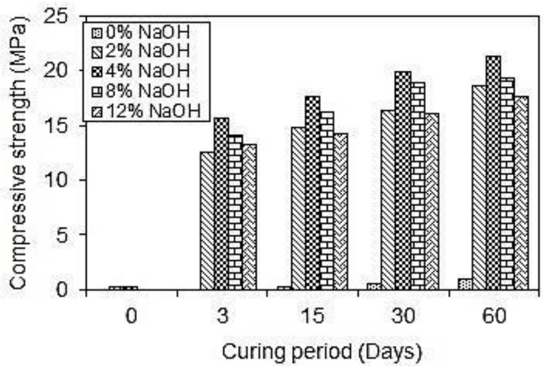

Fig. 7 UCS values of red mud, slag (20:80) mix with different dosages of alkali

6 CONCLUSIONS

Based on the experimental investigation the following conclusions can be drawn:

1. Addition of slag to red mud increases the maximum dry density up to 40% slag content thereafter the same decreases by further addition of slag. The highest MDD value of 18.6kN/$m^3$is observed for 40% slag content in the red mud.
2. Addition of slag to red mud without any additional alkali increases the UCS value up to 40% slag content. Further addition of slag results in reduction in unconfined compressive strength. Virgin red mud possesses UCS value of 0.22 MPa which is increased to 5.2MPa with the addition of 40% slag after a curing period of 60 days.
3. Addition of alkali i.e. NaOH solution enhances the strength remarkably for red mud-slag mixes. With the addition of 40% slag and 4% NaOH, red mud attains an unconfined compressive strength of 14.02 MPa after 60 days curing. Only addition of alkali to red mud without any addition of slag does not improve the strength.
4. The improvement in strength is due to availability of reactive silica and alumina in the slag which is activated by alkali. In addition to that the presence of high content of CaO in slag brings about the pozzolanic reaction in the specimen.

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