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Use of Red Mud for Partial Cement Replacement

Kedar S. Shinge[1] and Sandeep S. Pendhari[2].
[1]*Structural Engineering Department, Veermata Jijabai Technological Institute, Mumbai,kedarshinge7@gmail.com*
[2]*Structural Engineering Department, Veermata Jijabai Technological Institute, Mumbai, sspendhari@vjti.org.in*

Abstract -During the Bayer process for the production of aluminum oxide from bauxite ore large amount bauxite residues is produced which is known as red mud. In this paper, effort has been put to check the effectiveness of use of red mud with some percentage of cement in cement mortar. The percentage replacement of cement by red mud adopted in this study are 5%, 10%, 15% and 20%. The parent objective of the present study is to suggest possible percentage of use of red mud along with cement which will help to reduce the cement consumption. The untreated (without any neutralization) red mud is used. The compressive, tensile and flexural strength of cement-red mud mortar have been compared with control specimens.
Keywords - Red mud, Cement mortar, Compressive strength, Partial replacement.

I. INTRODUCTION

Bauxite, is the world's main source of aluminium i.e in alumina production. India is the 5th largest country in the world to have bauxite reserves. Red mud is the solid waste residue of the digestion of bauxite ores with caustic soda for alumina (Al_2O_3) production using bayer process. A concentrated caustic soda (NaOH) solution at high pressure and elevated temperatures (~270^0C) is used to obtain alumina trihydrate ($Al_2O_3\_3H_2O$). Due to its composition, it generates highly alkaline (pH 10–13) slurries when mixed with water. Generally bauxite is composed by goethite (α- FeOOH), hematite (γ-Fe_2O_3), boehmite (α-AlO(OH)), quartz (SiO_2), sodalite ($Na_8Al_6Si_6O_{24}Cl_2$), and gypsum ($CaSO_4.2H_2O$) as major phases, and calcite ($CaCO_3$), whewellite ($CaC_2O_4.H_2O$), gibbsite ($Al(OH)_3$), and anatase (TiO_2) as minor components [1]. The exact composition of the mud depends on the origin of bauxite and on processing. Approximately 35–40% of the processed bauxite ore goes into the waste as alkaline red mud slurry.

Approximately 0.8–1.5 tons of red mud is generated per ton of alumina produced. Around 70 million tons of red mud is produced annually all over the world, with 2 million tons in India. As a solid waste, red mud is usually disposed in mud lakes in the form of stack in ponds as dry mud near alumina plants or directly discharged through a pipeline into a nearby sea. Due to its chemical and physical characteristics such as fine particle size, high alkalinity (pH 10–13) and metal content, the disposal of large quantities of red mud may be leading to the environmental problems including soil contamination, groundwater pollution and fine particles' suspension in the sea. The storage of dry red mud can also lead to dust pollution which is a can be lead to health problem for the people living near the red mud storage ponds.

World consumption of cement is forecast to continue to increasing from last 15 years, taking the annual volume up from the 2250 MT of 2005 to around 3130 MT by 2015 and 3560 MT by 2020, representing overall forward expansion of approximately 56% According to the "GLOBAL CEMENT

to 2020". There are so many estimation has done which predicts there will be massive growth of cement demand for upcoming years. So it will be economically beneficial if reduction in the amount of cement by providing some alternate material such as partial replacement of cement by industrial waste which is hazardous to the environment.

Due to chemical and physical properties of red mud, it can be used in construction and other industries. Rout *et al*. has discussed the use of red mud as an alternative embankment material based on experimental results and finite element Analysis. The geotechnical properties such as specific gravity, classification, compaction characteristics, triaxial shear strength and dispersion properties of red mud have also been discussed [2]. Dursun *et al.* [3] used the red mud for phosphate removal from waste water. Bhaskar *et al*. [4], Sawant *et al*. [5] and Chen and Luan [6] had taken efforts to use of processed red mud in the concrete construction.

In this study the untreated red mud is used for partial replacement of cement in mortar. General chemical composition of cement and red mud (HINDALCO) is given in the Table 1.

Table 1. Chemical Composition

Compounds	Red Mud (%)	Cement (%)
Al_2O_3	20.5	5.6
SiO_2	4.6	21.2
Fe_2O_3	34.3	3.4
TiO_2	8.35	
Na_2O	4.0	1.1
CaO	4.8	65
LOI	15	

II. Materials, Methods and Results

In present experimental work ordinary portland cement (OPC) [grade 43] is used for mortar preparation. The bauxite residue (red mud) from HINDALCO alumina plant Belgaum, in the state of Karnataka, India have been used for partial replacement of cement in mortar. Aggregates used in experimental work was conforming to the IS650 (1991) [Grade I sand having particle size less than 2mm and greater than 1 mm, Grade II sand having particle size less than l mm and greater than 0.5mm and Grade III sand having particle size less than 0.5mm and greater than 0.09mm].

Cement mortar was prepared using cement aggregate ratio 1:3. Red mud is used against cement in the proportion of 5%, 10%, 15% and 20% of total weight of cement required in cement mortar. Standard consistency test confirming IS4031: Part 6 (1988) have been performed on cement paste to fix the appropriate water-cement (W/C) ratio and based on the test, W/C ratio 0.33 is confirmed for control specimens (pure cement mortar specimens). Similarly, standard consistency test have been performed on cement-red mud paste to fix the water-cementecious ratios (W/CM) and based on test, W/CM ratios used are 0.34, 036, 0.38 and 0.39 for 5%, 10%, 15% and 20% red mud replacement against cement. Cubes of size 70.7X70.0X70.7 mm for compression test, small beams size of 300X25X25 mm for flexural test have been prepared. Briquette moulds are used for samples preparation for tensile test. All specimens are cured for 3, 7 and 28 days. Compression and tensile testing have been done using 30T universal testing machine (UTM). Load is gradually applied at the controlled strain rate.

Figure 1 shows the comparison of compressive strength of cement-red mud mortar specimens for 3, 7 and 28 days with cement mortar specimens. The compressive strength at 28 days have been tabulated in Table 2. The compressive strength of control specimen on 28 days from casting is 36.72 MPa. The cement-red mud mortar specimens showed compressive strength on 28 days from casting

are 36.10 MPa, 34.33MPa, 30.33 MPa and 25.25 MPa for 5%, 10%, 15% and 20% cement replacement with red mud, respectively. It is observed that as red mud percentage goes on increase, compressive strength of mortar cubes goes on reducing due to probably less content of calcium oxide (CaO) and silica (SiO2) in red mud as compared to OPC cement which are responsible for strength gain. However, in the literature, it is mentioned that rate of strength gain is slow in case of red mud use along with cement [1].

Table 2. Compressive Strength (MPa)

Mix Design	Curing Age	Avg. Weight	Sample 1	Sample 2	Sample 3	Average
Control	28 Days	806gm	35.91	37.34	36.92	36.72
5 % RM	28 Days	788gm	36.12	33.87	38.53	36.10
10% RM	28 Days	798gm	30.55	37.14	35.30	34.33
15% RM	28 Days	802gm	29.23	31.23	30.53	30.33
20 % RM	28 Days	800gm	28.23	22.26	25.26	25.25

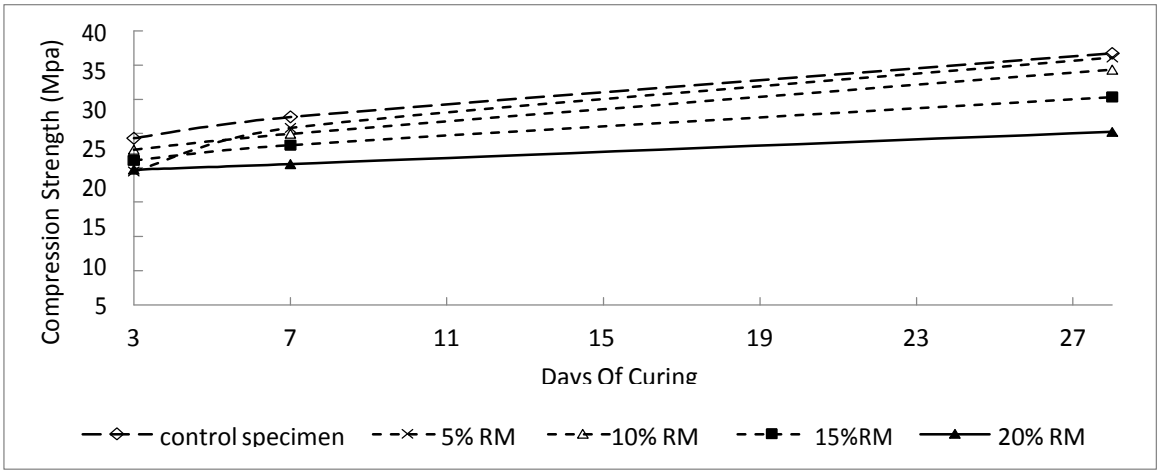

Fig. 1 Variation in Compressive Strength

Figure 2 and Figure 3 shows the comparison of tensile and flexure strength of cement-red mud mortar specimens for 3, 7 and 28 days with cement mortar specimens. The tensile and flexure strength at 28 days have been tabulated in Table 3 and 4, respectively. The tensile and flexural strength of control specimen on 28 days is 3.0 MPa and 7.15 MPa, respectively. It is observed that as red mud percentage goes on increase, both tensile and flexural strength of mortar cubes goes on increase.

Table 3. Tensile Strength (MPa)

Mix Design	Curing Age	Aveweight	Sample 1	Sample 2	Sample 3	Average
Control Specimen	28 Days	162gm	3.01	2.89	3.1	3.00
5 % RM	28 Days	156gm	3.4	3.1	3.09	3.19
10% RM	28 Days	161gm	3.5	3.34	3.45	3.43
15 % RM	28 Days	153gm	3.6	3.42	3.52	3.51
20% RM	28 Days	155gm	3.88	4.03	3.92	3.94

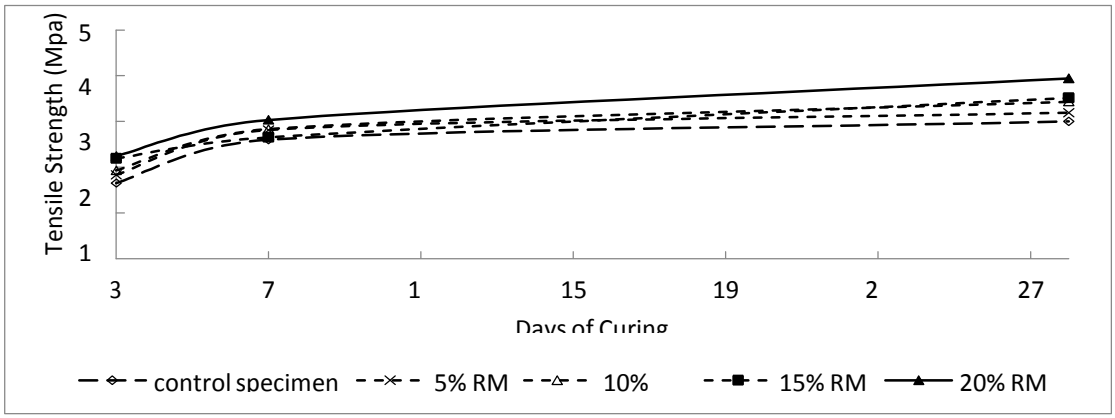

Fig. 2 Variation in Tensile Strength

Table 4. Flexural Strength (MPa)

Mix Design	Curing Age	Avg Weight	Sample 1	Sample 2	Sample 3	Average
Control Specimen	28 Days	426gm	6.89	7.34	7.23	7.15
5 % RM	28 Days	420gm	7.11	7.52	7.66	7.43
10% RM	28 Days	425gm	7.33	7.83	7.91	7.69
15% RM	28 Days	422gm	7.02	7.96	8.21	7.73
20% RM	28 Days	423gm	7.56	8.23	8.31	8.03

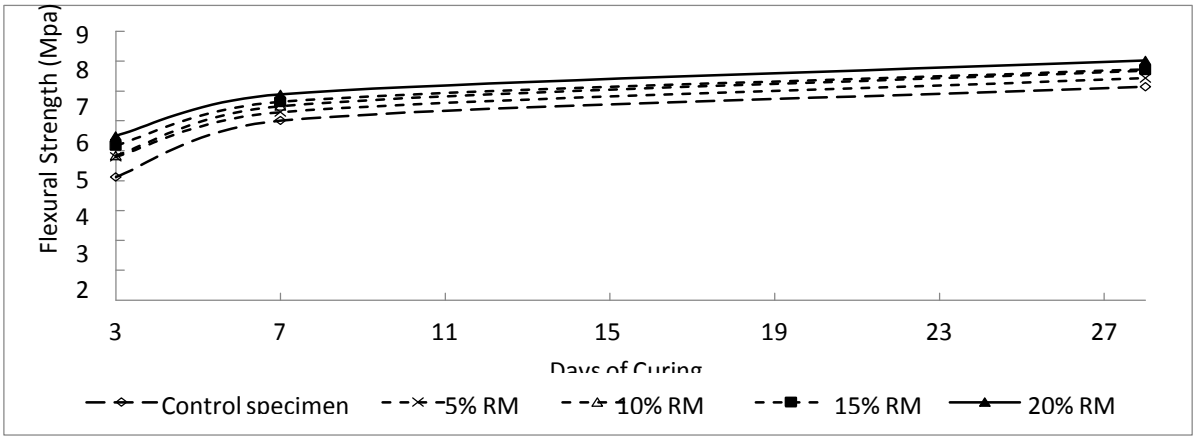

Fig. 3 Variation in Flexural Strength

From the present experimental studies on the basis of compressive, tensile and flexural strength, it is suggested that 10% red mud can be used for partial replacement of cement without compromising the compressive strength of mortar too much. However, detailed research is required in this direction to

check the feasibility of use of red mud in construction industry.

III. CONCLUSION

In the present experimental study, effort has been put to check the feasibility of red mud use in cement mortar. It is observed that 10% replacement of the red mud for cement is possible from compressive, tensile and flexural strength point of view but need to be verify by exhausts experimental studies. Research is required to address the issues like, corrosion, durability of cement product along with red mud.

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