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Experimental Investigation of Strength Properties of Red Mud Concrete

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Abstract. Red mud (RM) or alumina refinery residues (ARR), is a highly alkaline waste product composed mainly of iron oxide that is generated in the industrial production of alumina (aluminum oxide, the principal raw material used in the manufacture of aluminum metal and also widely used in the manufacture of ceramics, abrasives and refractories). The scale of production of RM is in million tons per year, causing serious disposal problem in the mining industry. In order to avoid environmental hazards, every opportunity is explored to find the effective use of red mud. In this present report, an experiment was carried out to obtain the compatibility and utilization of red mud along with cement to produce a low cost green concrete. Partial replacement of cement with red mud was taken place in this experiment for the development of red mud concretes. Total five numbers of concrete developed in the laboratory to assess the fresh and hardened characteristics. This particular project work focuses on the effective use and suitability of locally available red mud for the partial replacement with cement for various civil engineering constructions. The red mud percentage for replacement of cement is varied from 0% to 20%. From the experimental work it was found that 5 to 10 percentage replacements have no significant effect on 28 days strength properties where as beyond 10% drastic drop in compressive strength was noticed.

INTRODUCTION

Red mud; a solid- waste generated at the Aluminum plants all over the world .In Western countries, about 35 million tons of red mud are produced yearly. Because of the complex physico-chemical properties of red mud it is very challenging task for the designers to find out the economical utilization and safe disposal of red mud. Disposal of this waste was the first major problem encountered by the alumina industry after the adoption of the Bayer process. The conventional method of disposal of red mud in ponds has often adverse environmental impacts as during monsoons, the waste may be carried by run-off to the surface water courses and as a result of leaching may cause contamination of ground water: Further disposal of large quantities of Red mud dumped, poses increasing problems of storage occupying a lot of space. Over the years, many attempts have been made to find a use for red mud, but none have proven to be economically satisfactory .In this paper the attempt is made to check the effectiveness of red mud at 5%, 10%, 15%, 20% over Portland cement by partial replacement of cement in concrete.

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LITERATURE REVIEW

Bala Ramudu, et al. (2013) was carried out experimental study to investigate the dry density and CBR behavior of waste plastic (PET) content on stabilized Aluminum waste, fly ash and Aluminum waste-fly ash mix. They observed that CBR values were increased up to the addition of 2.0% of PET after it is decreased.

D. Dodoo- Arhin, et al. (2013) investigated bauxite red mud clay composites for their applicability in the ceramic brick construction industry as a means of recycling the bauxite waste. Considering the physical and mechanical properties of the fabricated brick samples, the batch formulation which contained 50% each of the red mud is considered the best combination with optimal properties for the construction bricks application and it could be employed in lighter weight structural applications.

Recently interest has been focused on increasing the sorption capacity in the engineered barriers by adding other types of materials with a high sorption capacity for elements which sorbs poorly on the cement paste to the engineered barriers in the repository (Krall 2012). Although different ways to utilize red mud have been discussed in the literature (Kurdowski and Sorrentino 1996), this is still mainly considered to be industrial waste at the lowest rate of use. In the past decades, limited studies were made to investigate the adsorption of Cs-137 and Sr-90 onto red mud (Apak et al. 1995). As Krall (2012) reviewed, the study by Apak et al. (1995) concluded that red muds may be utilised for constructing natural barriers around low-level radioactive wastes. Subrat Kumar Rout et.al. (2012) had determined the physical and chemical properties of red mud and made a comparative study of red mud with the soil and fly ash. The specific gravity of Red mud is very high compared to soil, due to presence of iron compound minerals. It has low plasticity and low volumetric and linear shrinkage with 90% of particle finer than 0.075mm.

Ping Wang, et al. (2012) were investigated the Performances of two common types of red mud, Bayer red mud and Sintering red mud. Their compositions, mechanical properties and microstructure characterization were measured through XRD, TG and SEM analysis. It was concluded that, Bayer red mud has a high reuse value and also can be used as a mixing material of masonry mortar. Chuan-Sheng Wu, et al. (2012) carried out different characterizations on red mud uncalcined and samples calcined in the range of 100°C-1400°C. The obtained results provide an important base for the further studies of comprehensive utilization of red mud.

EXPERIMENTAL PROGRAM

An experimental program was designed to produce red mud concretes by replacing several combinations of red mud percentage with ordinary Portland cement. The materials used and the experimental procedures are described in the following sections.

(a) Dry mix of cement with red mud

(b) Moulded concretes

FIGURE 1

Dry mixing of cement with red mud and concrete casting is shown in Fig. 1(a) and (b) respectively. The cement used in all mixes was normal Ordinary Portland cement (53 grade) conforming to IS 12269. It has a specific surface area of 360 m^2/kg and a specific gravity of 3.15. As a cement substitute, waste product of the Bayer process the red mud is used as a mineral additive. Ph value ranging from 10 to 13 and specific gravity 2.7 was obtained for the used

red mud. The composition of dry red mud of locally available plant near to Bhawanipatna, Kalahandi were given in Table 1.

TABLE 1. Chemical Properties of Red mud

Composition	Weight Percentage
Fe_2O_3	30-60
Al_2O_3	10-20
SiO_2	8-15
Na_2O	2-10
CaO	2-8

Crushed granite with nominal grain size of 20 mm and well-graded river sand of maximum size 4.75 mm were used as coarse and fine aggregates, respectively. The specific gravities of aggregates were determined experimentally. The specific gravity of 20mm, 10mm coarse aggregate had specific gravity of 2.86 and 2.80, whereas the fine aggregate had specific gravity of 2.73, respectively.

MIX PROPORTIONS

Trials mixtures were prepared to obtain target strength of minimum grade of 20 MPa for the control mixture at 28 days. The details of the mixtures for the study are presented in Table 2. Five different mixtures (RM00, RM05, RM10, RM15 and RM20) were developed to examine the influence of red mud on concrete mechanical properties. The control mixture (RM00) does not contain red mud. In mixtures RM05, RM10, RM15and RM20, cement content was partially replaced with 5%, 10%, 15% and 20% red mud (by weight) respectively. The binder consists of cement and red mud.

The mixing of the concrete ingredients was carried out in a pan mixer of 40-litre capacity. Initially, the aggregates were put into the mixer, followed by the cement and mineral additives. Mixing of dry ingredients was carried out for a period of 2 min. The required amount of water was added to the concrete mixer and the mixing was continued for 3 min. The fresh concrete was placed into the steel cube moulds and compacted on a vibrating table. Finally, surface finishing was done carefully to obtain a uniform smooth surface. 100 mm and 150mm cubes, 100mm×200mm cylinders, 150×300mm cylinders were used to evaluate the compressive strength, splitting tensile strength of the concretes respectively. Tests were conducted at different test ages; 3, 7 and 28 days of age. All experiments were performed on three specimen replicates. The average values are used in the discussion of the test results. The specimens were demoulded after 24 hours of casting and were then cured in water at approximately 270C until the testing day.

TABLE 2. Mix Proportion per one cubic meter

Mix Materials (kg)	RM00	RM05	RM10	RM15	RM20
Cement	380	361	342	323	304
Red mud	00	18.05	34.20	48.45	60.80
Water	190	190	190	190	190
10mm aggregates	635.05	634.48	633.89	633.14	632.56
20mm aggregates	649.05	649.83	651.57	655.81	661.38
Sand	712.57	712.24	711.97	711.36	711.05
Density (kg/m^3)	2566.67	2565.60	2563.63	2561.76	2559.79

Earthquake parameters for the buildings were considered as per the provisions made in the Indian seismic code for earthquake zone III, computer software is used to analyze the building models.

TEST PROCEDURES

The workability of the fresh concrete is measured by using the standard slump test apparatus. The compressive strength was obtained, at a loading rate of 2.5 kN/s at the age of 3, 7 and 28days on 1000 kN machine. The average compressive strength of three specimens was considered for each age. The split tensile strength was also tested on the same machine at the age of 28 days. Fig. 2(a) shows the hardened concretes after casting and Fig. 2(b) show the compressive strength of the developed concretes.

FIGURE 2(**a):** Hardened concrete

FIGURE 2(**b):** Comp. Strength test

Results and Discussions

Compressive Strength

The compressive and split tensile strength results of samples presented in Table 3. And the comparison between red mud mix percentages with compressive strength is given in Fig. 3

TABLE 3. Mechanical Properties of the Concretes Developed.

Mixes	Compressive Strength (MPa)			Tensile Strength (MPa)
	3days	7days	28days	28days
RM00	10.23	14.73	26.31	2.82
RM05	12.11	15.40	27.65	2.95
RM10	13.73	17.67	29.05	3.32
RM15	10.02	15.20	25.38	2.79
RM20	8.95	12.68	21.09	2.14

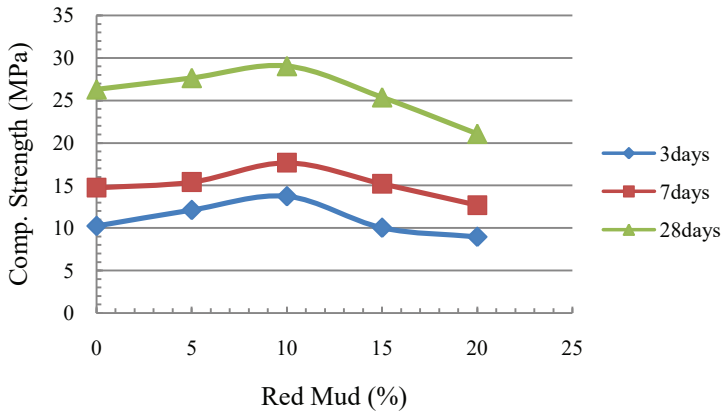

FIGURE 3 Comparison between Red mud percentages with Compressive strength

All the 3 day test results show a similar trend. The 28-day strength varied between 21.09 to 29.05MPa, and the 7 day strength varied between 12.68 and 17.67 MPa. The 10% replacement RM10 mixture showed higher strengths comparatively than the other red mud percentages. Fig. 4 plotted between changes in duration with compressive strength of red mud concretes

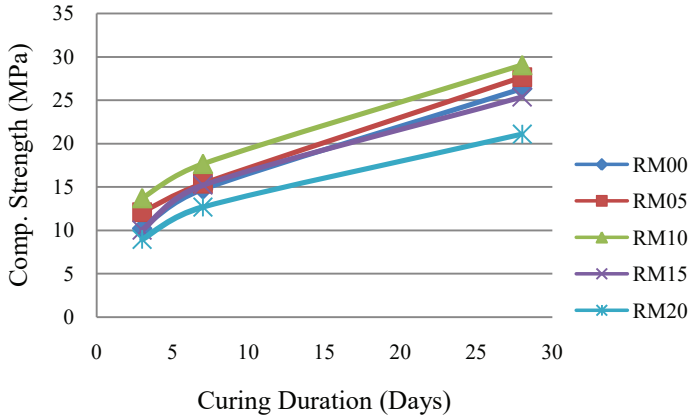

FIGURE 4 Change in compressive strength with duration

CONCLUSIONS

The following are conclusions drawn from the present work are given as follows:

1. For each percentage replacement up to 10% the compressive strength values of the red mud concrete showing greater strength value than conventional concrete. But beyond 10% there is reduction in the strength of conventional concrete.
2. Replacement up to 15% the compressive strength values of the red mud concrete coincides with that of conventional concrete. But beyond 10% there is a reduction in the strength value of the concrete.
3. Optimum percentage of the replacement of cement by weight is found to be 10%. By this replacement results got are greater than to the results of conventional concrete.
4. From the experimental work it was found that increase in red mud content (greater than 10%) decreases the compressive strength as well as tensile strength of concrete.
5. The compressive strength of the red mud concretes increases with the increase in curing period.

The above results show that the optimum utilization of Red mud in concrete is 10% as a partial replacement of cement. This study concludes that red mud can be innovative supplementary cementitious material but judicious decision must be taken by expert engineers.

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