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On the Experimental Investigations of Red Mud Concrete

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Abstract: ***The bauxite residue, also referred as red mud has created conflicting environmental issues associated with its disposal. Each tone of aluminium generated from Bayer's process produces nearly equal amount of highly alkaline waste, whose pH can be as high as 12 to 13. This alkaline residue is generally dumped into an open lagoon which proves to be expensive method of disposal. Also ground water contamination and soil pollution are major environmental issues associated with red mud disposal. The alkalinity is due to the presence of NaOH and Na_2O; neglecting these two other constituents of red mud are generally inactive. The presence of Fe_2O_3 and SiO_2 imparts it pozzolanic properties; hence a number of attempts have been made to use it in construction industry. Present study deals with assessment of replacement of cement by neutralized red mud on the properties of fresh and hardened M40 grade of concrete. Workability is the basic property of fresh concrete significantly affects the strength of concrete and is most demanded during the construction phase. The effect of replacement of red mud on workability was assessed by observing the variations in the slump values. The results show that, there is increase in the slump value for cement replacement up to 5% after which the slump reduces. Similar observations are recorded for compaction factor test. Also 28 days compressive strength is not much affected by replacement up to 15%. Hence present study concludes that for M40 grade of concrete 15% replacement is justified without significantly affecting necessary properties of concrete.***
Keywords: Bauxite Residue, Compressive Strength, Compaction Factor, Slump, Workability, Environmental waste.

I. INTRODUCTION

During the production of aluminium, digestion of bauxite with sodium hydroxide produces highly alkaline slurry which is generally disposed off in open lagoons. Approximately each tonne of aluminium produced generates nearly equal amount of residue. Around 70 million tons of red mud is generated all over the world, out of which India shares 2 million tons. Bauxite is formed due to decomposition of laterite which is enriched with aluminium hydroxides. The present study was carried out on the red mud generated from HINDALCO plant, situated on the outskirt of Belgaum city. The HINDALCO plant used bauxite which is extracted from mines located in Ratnagiri and Kolhapur districts of Maharashtra. Bayer's process is adopted in the cases where the bauxite contains high percentage of Fe_2O_3, this imparts red colour to the residue which is referred as Red mud. The chemical composition of red mud generally depends upon the mineralogical and geological origin of bauxite; it contains six major constituents namely Al_2O_3, Fe_2O_3, Na_2O, SiO_2, CaO and TiO_2 along with large number of trace elements. The mineral phase can extend up to 14 numbers of trace elements. Typical composition of red mud has been given in Table 1, which may vary depending upon source of bauxite.

TABLE I
Typical Composition Of Red Mud

Composition	Weight %
Fe_2O_3	30-60
Al_2O_3	10-20
SiO_2	3-50
Na_2O	2-10
CaO	2-8
TiO_2	Trace-25

A number of remedies have been proposed for environmentally sustainable disposal of red mud. Production of cement by utilizing red mud with clinker has been proposed by a number of research workers. Red mud along with fly ash, gypsum and lime has been utilized in cement production by Qui *et. al.* [1]; their study concludes that cement produced with above mentioned additives has

reduced energy consumption with improved sulphate resistance. Tsakiridis *et. al.* [2], also used red mud in cement production; 3.5% cement was replaced and modified cement was tested for 2, 7, 28 and 90 days XRD analysis. The study concluded that red mud did not negatively affect the quality of the cement produced. Other attempts of utilizing red mud in cement production and stabilization includes Kalkan [3], Barsherike [4] and Vangelatos [5]. Red mud has also been used in production of geopolymers; which are been successfully utilized in roadway construction [6]. Red mud steam cured bricks have been proposed by Xing [7], Yang [8] and Zhang [9]. MutalikDesai et. al. [10], proposed red mud fire burnt bricks as low cost housing material. Innovative application of red mud in embankment construction has been suggested by Qi [11] and Kehagia [12]. The aerated concrete blocks manufactured using red mud has been proven to be economical with enhanced thermal insulating and seismic properties as per study by Wu *et. al.* [13].

Red mud has also been widely used in concrete by a group of researchers. Sawant *et. al.* [14], Vandhiyan [15] and Ashok [16] studied the effect of replacement of cement by red on the properties of cement and compressive strength of concrete. Rudraswamy [17], Pujar [18]; additionally studied the effect of replacement on the workability of concrete along with compressive strength.

In work deals with assessment of partial replacement of cement by red mud on the workability and hardened concrete. Experimental study indicates that compressive strength is not much affected by replacement of cement by red mud. Hence for economical environmentally sustainable concrete production; red mud can be effectively replaced for cement up to 15%.

II. EXPERIMENTAL WORK

A. Material Properties

The test specimens were cast using cement (53 grade OPC) confirming to IS 12269:1987, fine aggregate (confirming to zone II), coarse aggregate, water, admixture and neutralized red mud. The materials, in general, confirmed to the specifications laid down in the relevant Indian Standard codes. Sieve analysis was carried out was carried out for grading of aggregates and it was found to confirm zone II. 20 mm along with 12.5 mm, coarse aggregates of same parent rock in 60-40 % fraction were used in casting cubes. Locally available river sand was used as fine aggregate. The specific gravity of sand was 2.605 and fineness modulus was 2.68. The red mud available from HINDALCO plant situated at the outskirt of Belgaum was used. The red mud was neutralized by using hydrochloric acid, and pH was brought down from 11.5 to 7.3. it becomes necessary to analyze the chemical composition after the neutralization. The general properties and specifications for materials used are tabulated in Table 2.

TABLE II
Stipulations For Proportioning

Max. Aggregate Size	20 mm
Exposure Condition	Normal
Type of Aggregate	Crushed Angular
Chemical Admixture	IS-9103
Cement Used	OPC 53 Grade
Sp. Gravity of Cement	3.15
Sp. Gravity of Water	1.00
Sp. Gravity of 20 mm Aggregate	2.884
Sp. Gravity of 10 mm Aggregate	2.878
Sp. Gravity of Sand	2.605
Water Absorption of 20 mm Aggregate	0.97%
Water Absorption of 10 mm Aggregate	0.83%
Water Absorption of Sand	1.23%
Free (Surface) Moisture of 20 mm Aggregate	nil
Free (Surface) Moisture of Sand	nil
Sp.Gravity of Combined Coarse Aggregates	2.882

B. Concrete Mix Design

Concrete mix design was carried out IS: 10262-2009 method of concrete mix design. To assess the effect of replacement of cement by neutralized red mud on the properties of concrete M30 and M40 grade of concrete was adopted as reference mix. The mix proportions are given in Table 3.

Table III
Mix Proportions

	Quantity (Kg/m^3)			
Material	Cement	Sand	Aggregate	Water
M30	386	711	1283	174
M40	402	660	1168	160

C. Effect of Replacement of Cement by Red Mud on Workability and Compressive Strength of Concrete

In order to justify the replacement of cement by red; properties of fresh and hardened concrete were assessed for which M30 and M40 grades of concrete were chosen as reference mixes. Concrete cubes of size 150x150x150 mm were prepared in accordance with IS: 10262-2009. The compressive testing was carried out with the aid of IS: 516-1959. The test specimens were prepared with red mud replacing cement content (by weight) from 0% to 20%. The effect of replacement on workability was severely assessed which are tabulated in Table 5 and are plotted in Figure 1.

TABLE V
Effect Of Replacement Of Cement By Red Mud On Slump Value Of Fresh Concrete

Sr. No.	% Replacement	Slump Value	
		M30	M40
1	0	74	68
2	2.5	76	69
3	5	77	72
4	7.5	74	70
5	10	71	67
6	12.5	68	66
7	15	66	63
8	17.5	64	61
9	20	61	58

Compressive strength of concrete is one of the most important parameter that significantly matters in the design of structures and needs a through attention in any of the experimental analysis concerning concrete. Hence seven days and twenty eight days compressive strength were recorded but only the twenty eight days strength is presented in the paper. The results in tabulated form are given below in Table 6 and are graphical presented in Figure 2 and 3. The horizontal line shows the reference mix design strength.

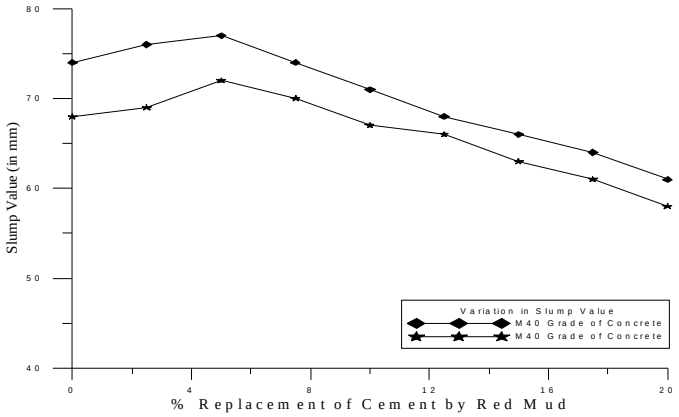

Fig. 1 Effect of Replacement of Cement by Red Mud on Slump Value of M30 and M40 Grade of Concrete.

TABLE V
Effect Of Replacement Of Cement By Red Mud On 28 Days Compressive Strength Of Concrete

Sr. No.	% Replacement	M30	M40
1	0	33.555	46.625
2	2.5	33.605	46.9
3	5	33.405	46.325
4	7.5	32.743	45.25
5	10	32.104	45.015
6	12.5	31.425	43.12
7	15	30.582	41.402
8	17.5	29.665	39.975
9	20	28.085	36.82

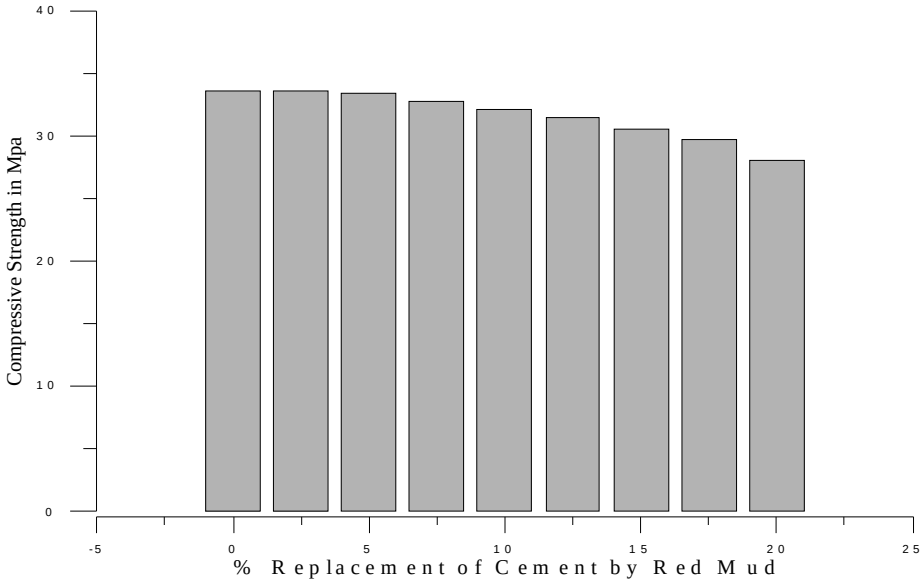

Fig. 2 Effect of Replacement of Cement by Red Mud on the 28 days Compressive Strength of Concrete M30 grade.

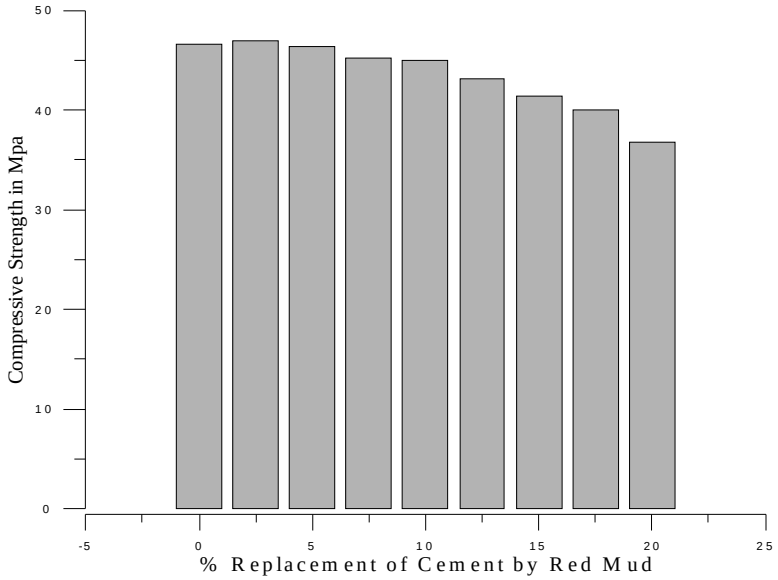

Fig. 3 Effect of Replacement of Cement by Red Mud on the 28 days Compressive Strength of Concrete M40 grade.

III. RESULT ANALYSIS

Possible discussion on the effect of replacement of cement by red mud on various properties of cement and concrete are mentioned below.

1) *Effect of Partial Replacement of Cement by Neutralised Red Mud on Various Properties of Cement:* The addition of neutralized red mud in cement significantly affects some of its basic properties. Standard consistency of the cement reflects its affinity towards the water. Generally for OPC it needs to be in the range of 30 or below. From the graph it is evident that the standard consistency increases with increase in percentage of red mud due to the fact that red mud being finer in nature has less mass which results in increased surface area thereby demanding more amount of water. Also it can be observed that the variation of standard consistency with addition of red mud follows linear relationship. From the figure 1 it can be seen for the replacement of cement by red mud, below 5% there is slight reduction in initial setting time but a significant difference is not observed after that. Also for final setting time in the initial replacements there is slight reduction but after 7.5% replacement not much deviation is observed to that from OPC.
2) *Effect of Partial Replacement of Cement by Neutralised Red Mud on slump value of Concrete:* It is observed that the slump value of fresh concrete for initial replacements increases but later on deceases as the percentage of replacement is increased the slump value rapidly comes down but again it is within the acceptable limits to be adopted for onsite conditions. Hence the replacement of cement by red mud does not negatively affect the workability of concrete and is justified as per workability requirements.
3) *Effect of Partial Replacement of Cement by Neutralised Red Mud on slump value of Concrete:* The study on compressive strength of M30 and M40 grades of concrete shows that the replacement of cement by red mud does not affect much on the compressive strength of concrete. To assess the effect of partial replacement of red mud on the compressive strength of concrete, M30 and M40 grades of concrete were kept as reference mixes and were tested for 7 days and 28 days. The replacement of cement by red mud although reduces the strength of concrete but the reduction still lies below 5% (i.e. between acceptable limits). From the figure 2 it can be observed that the for M30 and M40 grades of concrete, cement can be replaced by red mud by approximately 15% such a high amount of replacement will result into much economy.

IV. CONCLUSIONS

From the experimental studies some of the important aspects of red mud on the properties of cement and concrete were observed. The consistency of cement continuously increases as the percentage of replacement for cement goes on increase. Similarly there are large variations observed in initial and final setting time of cement. Initially there is increase in initial and final setting time which drops down immediately but for next replacement again there is increase in the value; this can be attributed to the fineness of red mud. Red mud also plays a important role on the workability of concrete due to its greater surface area to weight ratio but the value remains in acceptable limits. Finally discussing about compressive strength; the 15% replacement of cement by red mud is justified as observed from the graphs. Hence from environmental concerns and economical issues it suggested that the red mud can be effectively used in concrete production.

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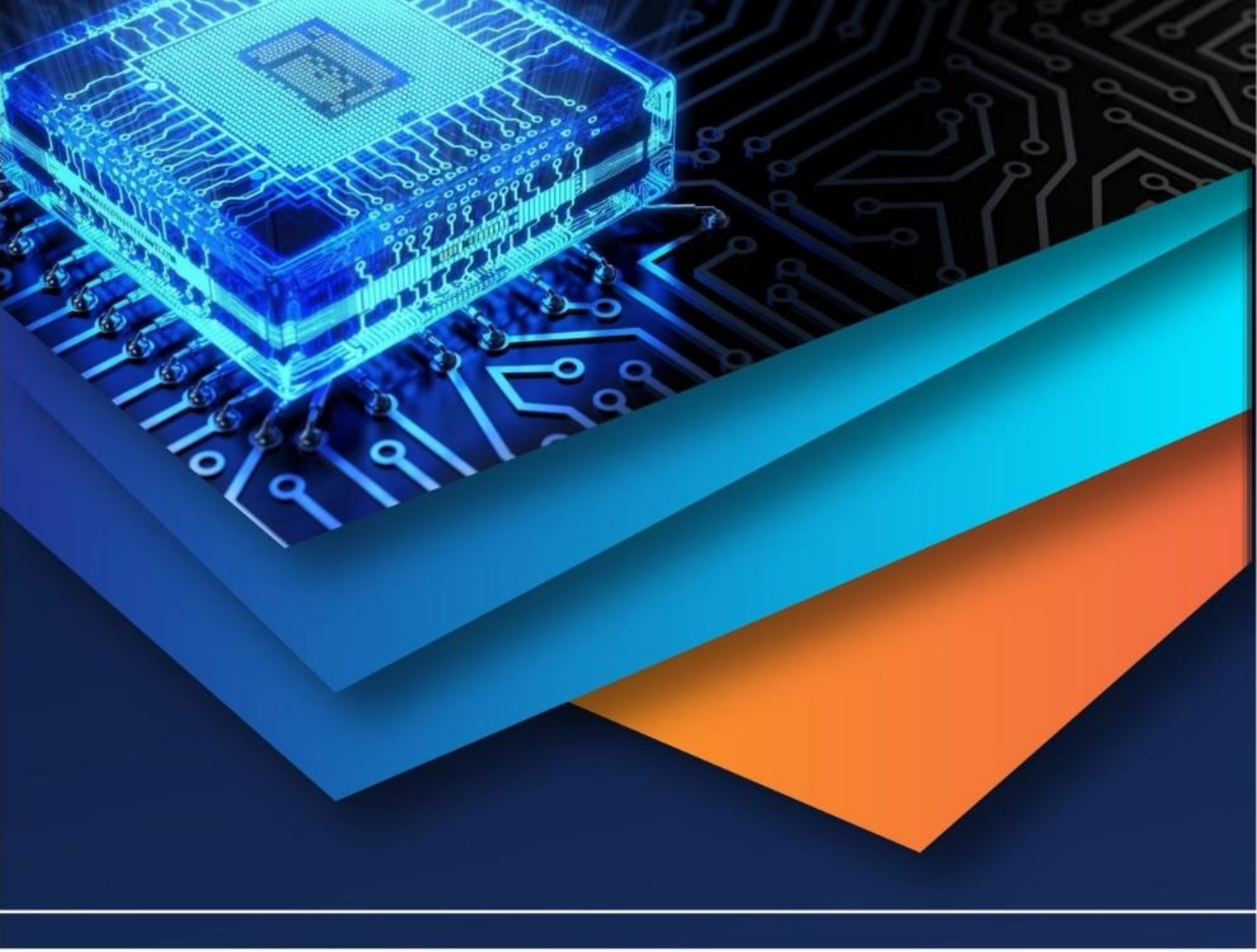

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