

Experimental Study on Partial Replacement of Cement by Neutralized Red Mud

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Abstract - Sustainable industrial development causes accumulation of heaps of waste disturbing the natural mechanism. The waste can be sometime best alternative for conventional; material like red mud. Red mud is industrial waste obtained as by product from Bayer method of aluminum extraction in this process, alkaline digestion of 2.5 T of bauxite affords alumina & 105 T of red mud. The average 4 million tons of red mud produces per annum, this amount composed of Fe & Ti oxides behaving as chemically inert material with variable percentage of nominal SiO₂, Al₂O₃ & Na₂O₃ which are partly present in cement. This paper covers significance of neutralized red mud over Portland cement by partial replacement of cement up to certain extent.

I. INTRODUCTION

Cement in the general sense of the word, can be described as a material with an adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact mass. This definition embraces a large variety of cementing material. For constructional purposes the meaning of the term cement is restricted to the bonding materials used with stones, sand, bricks blocks etc. cement is the most important material in structural constructions as it is used at different stages of construction as it is used at different stages of construction in the form of mortar or concrete.

A. Cement Production:

With 502 million tonnes per year (mtpa) of cement production capacity as of 2018, India is the second largest cement producer in the world. The cement production capacity is estimated to touch 550 MT by 2020. Of the total capacity, 98% lies with the private sector and the rest with the public sector. The top 20 companies account for around 70 % of the total production. In FY19, cement demand is expected to grow by 7-8 per cent.

A total of 210 large cement plants together account for 410 million tonnes of installed capacity in the country, while 350 mini cement plants make up the rest. Of the total 210 large cement plants in India, 77 are located in the states of Andhra Pradesh, Rajasthan and Tamil Nadu. Cement production in India increased from 230.49 million tonnes in 2011-12 to 297.56 million tonnes in 2017-18

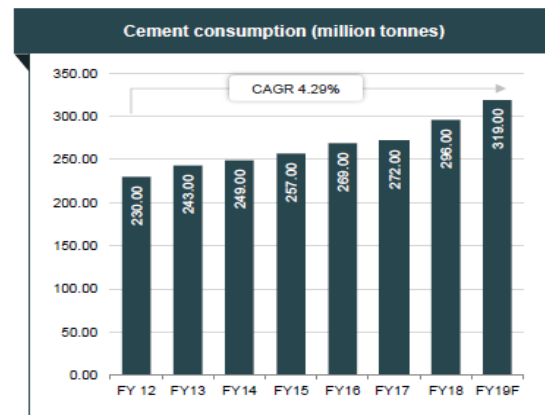


Chart 1: Cement demand in year per capita

Note: *As per CRISIL, ^CAGR is up to FY18, October 2018

Source: Media sources, Aranca Research, CRISIL, CARE Ratings, Ultratech Cement

II. INDUSTRIAL SOLID WASTE AND ITS PRODUCTS

The nation's solid wastes are increasing, posing a severe threat to the environment.

A. Red Mud

The red mud is one of the major solid wastes coming from Bayer process of alumina production. At present about 3 million tons of red mud is generated annually, which is not being disposed or recycled satisfactorily.

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.

B. Fly-ash

About 72 % of power generated in India is from Thermal Power Stations. It has been estimated that about 30 million tons of flyash is produced per year by 60 Thermal plants located in different parts of the country. The common environmental pollution problems created by disposal of flyash, besides air and water pollution are wastages of large tracts of land which otherwise could be utilized for useful purposes. It has been estimated that a one thousand-megawatt station, using coal of calorific value of 3500 kilo cal per kg and ash content of 40-50 percent for an operational period of 30 years requires about 500 acres of land.

C. Phosphogypsum

Phosphogypsum is the waste generated by the phosphoric acid, ammonium phosphate and hydrofluoric acid manufacturing plants. There is an accumulation stock of more than 10 million tons of Phosphogypsum at different at different plant sites. The fluoride content of gypsum generated is 0.7-1.5% which is the source of land and water pollution.

D. Steel and furnace slags

About 35 million tons of steel and blast furnace slags are produced in the country during manufacture of iron and steel. It has been estimated that the quantity of slags will increase to about 60 million tones around 2000. The large quantity of slags generated in plants is dumped on land nearby, which not only results in wastages of land but also causes surface and ground water pollution.

Table 2: Sources and Quantum of Generation of some Major Industrial wastes (As in 1992)

Sr. No.	Name	Quantity (MT/A)	Source/origin
1	Steel & blast Furnace slag	35.0	Conversion of pig iron to steel and Manufacturing of iron
2	Red Mud / Bauxite	3.0	Mining and Extraction of alumina from Bauxite
3	Brine mud	0.02	Caustic soda industry
4	Copper slag	0.0164	Bye-Product from smelting of copper
5	Fly ash	30.0	Coal-based thermal power plants
6	Kiln dust	1.6	Cement plants
7	Lime sludge	3.0	Sugar, paper, fertilizer, tanneries, soda ash & calcium carbide industries
8	Mica Scraper waste	0.005	Mica Mining areas
9	Phosphogypsum	4.5	Phosphoric acid plant, Ammonium phosphate

III. REVIEW OF BAUXITE WASTE IN CONSTRUCTION

A. Geotechnical Properties Of Red Mud

Dr. K. K. Jain, S. K. Singh & Laljee Sahu, Institute of Technology, B. H. U. Varanasi, have studied geotechnical properties of Red mud and red mud lime mixtures. Red mud obtained from Hindalco Industries Limited, Renukoot, U. P. has been used for their study. The properties of which were – as under:-

- Grain size distribution has 12 % of clay, 80 % of silt and 8 % of sand sizes.
- Specific Gravity 3.15
- Optimum moisture content : 25.6 percent
- Maximum dry density: 1.619 gm/cm³.
- Chemical composition shown that Fe₂O₃ - 35%, Al₂O₃ – 19%, TiO₂ – 20%, SiO₂ – 8 %, Na₂O – 5%, CaO – 3 %, and loss of ignition 10 %.

B. Use of Red Mud in mortar for masonry and plastering

Dr. R. P. Joshi, V. G. M. Desai and B. S. Setty, Gogate Institute of Technology, Belgaum, Karnataka, in their paper on “The use of locally available materials for low cost housing” has studied the use of red mud as mortar and as a plastering material and its suitability for bricks.

a). Suitability As Mortar

The plasticity characteristics with cohesion suggested that the red mud could be suitable for use as mortar for plastering as well as for binding brick work. To check this, following tests were evolved and conducted.

b). Shear Test

The test of shear strength was carried out by arranging the three bricks with the central one protruding. The bricks were held as shown in fig. 2.7.1 and the set up was tested on a universal testing machine, with the force applied on the central protruded brick till the mortar sheared off.

c). Tension Test

To measure induced tension the mortar could withstand, the bricks were jointed with mortar. The bricks were connected to the spring balance and loaded, until failure due to tension occurred. The specimens tested with plain soil and cement stabilized soil. (With cement up to 6 %) showed very poor shear strength. However, the results of shear strength and tensile strength in the case of soil stabilized with sand resulted in a good mortar.

The rate analysis of sand stabilized soil mortar and its comparison with the cement mortar rates showed that a large economy to the extent of 80% would be achieved in using the stabilized soil as mortar. The study showed that the mortar could safely be used for load bearing and partition walls which are not directly exposed to rain water.

d). Suitability As A 'Plastering Material

The adhesiveness of clayey soil in presence of water led to the investigation.

An adequate quantity of water was added to the plain red mud soil and mixed thoroughly to obtain a uniform mix. The plaster was applied on a set of three

bricks. After obtaining a smooth surface the set up was left to dry outside. Thus subjecting, it to the action of heat and wind. The resistance to rain water was tested by simulating a water shower to rain water.

After subjecting it to above weathering agents, it was seen that the plaster made of plain red mud soil and with 2-6% of cement as additives failed by giving out cracks throughout. However, once again the soil stabilized with sand and straw retained with a smooth surface. The above results were confirmed by applying the plaster of all types of the wall surfaces.

The cost analysis of the sand and straw stabilized soil was made and it was seen that a saving of 60-75% could be achieved by the use of stabilized soil plaster instead of cement mortar. Another noteworthy factor observed was since, the red soil is of alkaline nature, it shows resistance to termite attack and as such it is extremely suitable for use as mortar and also as a plastering material.

C. Suitability for Bricks

The bricks of size 10 cm x 15 cm x 25 cm prepared by using a simple mould and sun dried were tested for strength. But it was found that plain red soil stabilized with cement, sand and straw failed to give the required strength. Hence, it was inferred that the waste red mud soil renders itself unsuitable for using it in the manufacture of bricks. Thus the study was useful in identifying the waste soil as an effective and economical mortar and a plaster material. However, the suitability of red mud for rammed earth wall is being studied.

IV. USE OF NEUTRALIZED RED MUD AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

A. Aim of neutralization of Red mud

It is found from digital ph meter, that the ph of red mud procured from site is alkaline with ph value ranges from 10 to 11.58. Since the alkalinity is determined to the life of cement and concrete, they propose to reduce the alkalinity of red mud (pH=10.58), so that it can be used as cement replacement material and may improve the strength characteristics of cement and concrete. Commercially

available of normality in hydrochloric acid has been used for present neutralization process, because it enriches the silicon oxide and aluminum oxide content of red mud and it also eliminates harmful sodium oxide.

a). *Neutralization of Red Mud-Experimental Procedure*

About 5 kg of red mud was mixed with 10 liters of tap water in an aluminum container and is stirred continuously for about half an hour to make the solution homogeneous. The acid was slowly mixed in the solution till pH value of solution becomes 7.0. After neutralization the container was kept at room temperature for settlement of solids for about 5 hours. The water with other dissolved materials was decanted and the settled red mud was sundried first and then oven dried. The material was cooled in oven up to room temperature then taken out from it. This material was then reduced into powder by hand.

B. *Design Mix Concrete of Grade M 45*

Table 3: M 45 Grade Concrete Mix Design

1	Grade of Concrete	:	M 45
2	Cement	:	Ultratech (M43 Grade)
3	Target Strength	:	$f_{ck} + 1.65 (s)$ = 45 + 8.25 = 53.25 N/mm ²
4	Cement Content (For Design)	:	350 Kg/m ³
5	Water/Cement ratio	:	0.41
6	Sand Content	:	781.167 Kg/m ³
7	Coarse Aggregate Content	:	1364.50 Kg/m ³

Table 4: M 45 Grade Final Mix Proportion and Ratio

Final Mix Proportion-				
Cement	Sand	Coarse Aggregate	Water	Chemical
350.000 Kg/m ³	781.167 Kg/m ³	1364.50 Kg/m ³	143.5 Kg/m ³	1 % of Cement by Weight
1	2.231	3.998	0.41	

C. *Identification marking for different % replacement of cement by Neutralized Red Mud (NRM)*

Table 5: ID Marking Neutralized Red Mud (NRM) Concrete

ID Mark	Description
C1	Conventional Concrete (0% Replacement of Cement by NRM)
C2	NRM Concrete (5% Replacement of Cement by NRM)
C3	NRM Concrete (10% Replacement of Cement by NRM)
C4	NRM Concrete (15% Replacement of Cement by NRM)
C5	NRM Concrete (20% Replacement of Cement by NRM)

V. DISCUSSION ON EFFECT OF PARTIAL REPLACEMENT OF CEMENT BY NEUTRALIZED RED MUD

Pozzolana cements are obtained by blending or intergrading a mixture of ordinary Portland cement and a Portland pozzolana conforming to IS: 1489-1976 in proportion not less than 10% and not exceeding 25% by weight of cement. Pozzolana have been defined as a natural or artificially material containing silica in reactive form a more formal definition of pozzolana is siliceous or aluminum material which in itself possesses little or no cementitious value but will in finely divide form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. First the physical and chemical analysis of a red mud is carried out. Then the effect of the presence of different percentages of neutralized red mud in cement and cement concrete were studied with respect to following properties.

1. Test on cement
 - a. Standard consistency of cement
 - b. Initial setting time of cement
 - c. Final setting time of cement
2. Test on Hardened Concrete
 - a. Compressive strength of neutralize

A. Effect of Neutralized Red Mud on Standard Consistency of Cement

The fig no1 shows the variation of standard consistency with different percentage of neutralized red mud in cement. The standard consistency of ordinary Portland cement is 30.00. It is observed from the table no.6, that the standard consistency increases with increase in neutralized red mud content. The affinity for water increases with increase in neutralized red mud content in cement.

The affinity of water increases by 2.50 %, 5.50 %, 8.00 %, 10.5 % & 12.75 % with 5%, 10%, 15%, 20% and 25% of replacement of cement by neutralized red mud respectively, compared with that of water required for standard consistency of ordinary Portland cement.

In general, it is observed that with the increase in neutralized red mud content in the mix the water required for standard consistency increases and this increased requirement of water shows almost a linear relationship with standard consistency. This increase may be due to the fact that the neutralized red mud being slightly lighter in weight has finer particles and occupies more volume which needs more water for the same consistency.

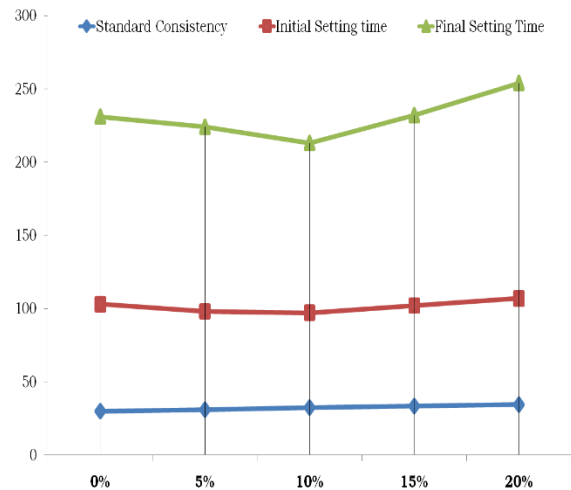
B. Effect of Neutralized Red Mud on Initial Setting Time of Cement

The fig shows the variation of the initial setting time with different percentage replacement of cement by neutralized red mud in cement and the values can be observed from the table

As per IS: 269-1976 specification the minimum initial setting time for ordinary Portland cement is 30 minutes. The initial setting time for the cement used in the present studies is 90 minutes. It is observed from the table no. The initial setting time for 5% and 10% replacement by neutralized red mud gradually reduces whereas for 15% of replacement by neutralized red mud the initial setting is nearly the same as that of ordinary Portland cement. Future increase in neutralized red mud i.e. for 20% and 25% increases the initial setting time.

Table 6: Variations in Standard Consistency, Initial Setting and Final Setting Time with Neutralized Red Mud in cement

Sr. No.	% Replacement	Standard Consistency	Initial Setting time in Mins	Final Setting Time in Mins
01	0 %	30.00	103	231
02	5 %	31.00	98	224
03	10 %	32.50	97	213
04	15 %	33.50	102	232
05	20 %	34.50	107	254



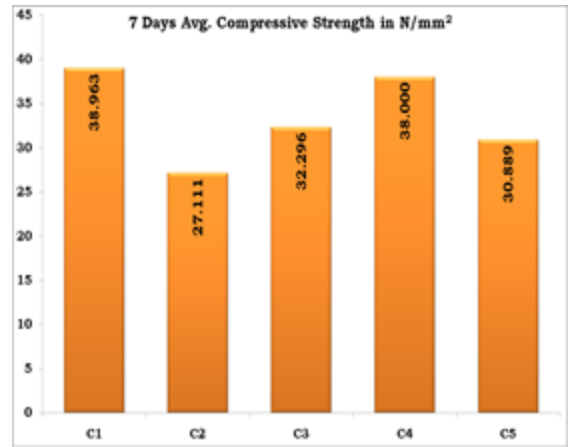
Graph 1: Variations in Standard Consistency, Setting Time.

C. Effect on Compressive Strength

Table 7: 7 Days Compressive Strength of different amount of replacement of Cement by Red Mud

Sr. No	ID Mark	Load in KN	Compressive Strength in N/mm ²	7 Days Avg. Compressive Strength in N/mm ²
1	C1	875	38.889	38.963
		885	39.333	
		870	38.667	
2	C2	610	27.111	27.111

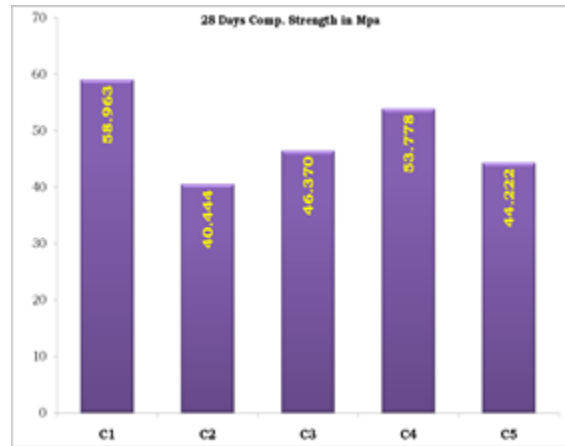
Sr. No	ID Mark	Load in KN	Compressive Strength in N/mm ²	7 Days Avg. Compressive Strength in N/mm ²
3	C3	620	27.556	32.296
		600	26.667	
		730	32.444	
		725	32.222	
		725	32.222	
4	C4	850	37.778	38.000
		860	38.222	
		855	38.000	
5	C5	710	31.556	30.889
		690	30.667	
		685	30.444	



Graph 3: Variations in 7 days Compressive Strength

Table 8: 28 Days Compressive Strength of different amount of replacement of Cement by Red Mud

Sr. No	ID Mark	Load in KN	Compressive Strength in N/mm ²	7 Days Avg. Compressive Strength in N/mm ²
1	C1	1350	60.000	59.111
		1330	59.111	
		1310	58.222	
2	C2	960	42.667	42.741
		965	42.889	
		960	42.667	
3	C3	995	44.222	44.222
		1000	44.444	
		990	44.000	
4	C4	1210	53.778	53.778
		1190	52.889	
		1230	54.667	
5	C5	970	43.111	42.741
		940	41.778	
		975	43.333	



Graph .4: Variations in 28 Days compressive strength

VI. CONCLUSION

The decrease in initial setting time at 5% and 10% may be due to the light weight of neutralized red mud and finer particles of mud which fills the voids of the cement by which there may be increase in the density of the mix. Beyond 10% of neutralized red mud cement initial setting time increases may be due to reduction in the density of mix.

The effect of replacement of cement by neutralized red mud has been studied on design mix concrete of grade M45. The water-cement ratio 0.41 is kept constant for different percentage replacement of cement by neutralized red mud.

It is interesting to note that there was a particular variation in average compressive strength of cement concrete with different % replacement of cement by

neutralized red mud. initially for 5% replacement of cement by neutralized red mud the compressive strength was decreased, for next two replacements i.e. 10% and 15% replacement of cement by neutralized red mud again the strength was increased, then after the strength was again decreased for 20% replacement of Cement by neutralized red mud.

28 days Target compressive strength of M45 grade concrete was 53.25 N/mm². With reference to table 8, the obtained 28 days compressive strength was 58.963N/mm² and 53.778N/mm² for 0% and 15% replacement of cement by neutralized red mud respectively.

So with reference to tables, graphs and nature of graphs we can conclude that, the optimized % utilization of neutralized red mud in concrete as a partially replacement of cement is 15% without much affect on 28 days compressive Strength of concrete.

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