Utilization of Neutralized Red Mud (Industrial Waste) in Concrete

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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 alluminium extraction in this process, alkaline digestion of 2.5 T of bauxite affords alumina & 105 T of red mud. The average 4 million tones 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 red mud over Portland cement by partial replacement of cement up to certain extent.

Keywords: industrial development, industrial waste, red mud

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 mortor or concrete.

A. Cement Production

Production of cement during December 1992, at 43.3 lakh tones was 3.1 percent higher than that in December 1991. Cumulative production during April-December 1992 at 398.55 lakh tones also showed an increase of 3.4 percent over the 385.29 lakh tones produced during the corresponding period of 1991.

B. Demand

India's annual cement consumption is about 53 million tones and the demand by the end of Eighth Five year plan (end of 1994-95) is expected to reach 68 million tones. The objectives before the cement industry are to reach a level of 90 million tones in 1996-97 and also to export 5 million tones from the level of one million tones in 1992-93.

As forecasted by 'International Cement Review', the per capita cement consumption by 2000, in India will be 74 kg.

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Table 1 Cement demand

Year	Cement Demand	Per Capita
1910	30 MT/Y	20kg
1925	150 MT/Y	75kg
1940	400 MT/Y	180kg
1955	600 MT/Y	220kg
1974	1,000 MT/Y	250kg
2000	1,500 MT/Y	250kg

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 tones 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 tones 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 mega watt 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 or more than 10 million tones 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 tones 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 & 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 & calciumcarbide industries
8	Mica Scraper waste	0.005	Mica Mining areas
9	Phospogypsum	4.5	Phospheric 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, institure 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/cm^3.
- 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 note worthy 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 RED MUD AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE (CASE STUDY)

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.

B. *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.

C. *Design Mix Concrete of Grade M50:-*

1	Grade of Concrete	:	M 50
2	Cement	:	Vasavadatta 43 Grade
3	Target Strength	:	f_{ck} + 1.65 (s) = 50 + 8.25 = 58.25 N/mm^2
4	Cement Content (For Design)	:	380 Kg/m^3
5	Water/Cement ratio	:	0.36
6	Sand Content	:	846.524 Kg/m^3
7	Coarse Aggregate Content	:	1358.894 Kg/m^3
8	Admixture	:	Parma Plast EX (1 % of Cement by Weight)

Table 3 *final concrete design mix proportion*

Cement	Sand	Coarse Aggregate	Water	Chemical
1	**2.228**	**3.576**	**0.360**	**1 % of Cement by Weight**

D. *Discussion on Effect of Partial Replacement of Cement by Red Mud (Experimental Work):-*

Pozzolana cements are obtained by blending or intergrading a mixture of ordinary Portland cement and a Portland pozzolana confirming 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.

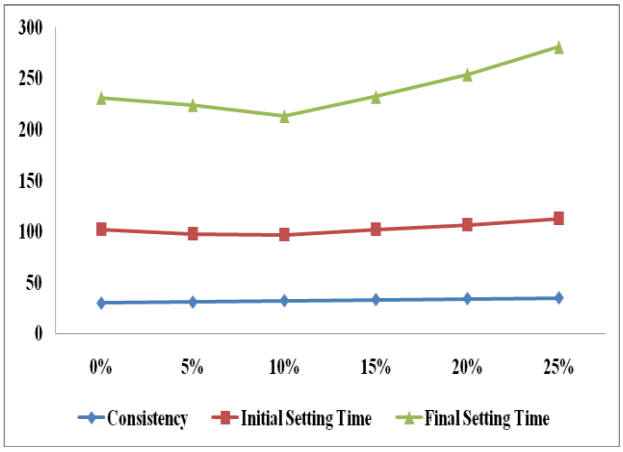
First the physical and chemical analysis of a red mud is carried out. Then the effect of the presence of different percentages of neutralized red mud in cement and cement concrete were studied with respect to following properties.

- Standard consistency, Initial setting time and Final setting time of cement: tests on cement
- Compressive strength: test on hardened concrete

E. *Effect on Consistency and Setting Time:-*

Table 4 Variations in Standard Consistency, Initial Setting and Final Setting Time with Neutralized Red Mud in cement

Sr. No.	% Replacement	Standard Consistency	Initial Setting time	Final Setting Time
01	0 %	30.00	103 mins	231 mins
02	5 %	31.00	98 mins	224 mins
03	10 %	32.50	97 mins	213 mins
04	15 %	33.50	102 mins	232mins
05	20 %	34.50	107 mins	254 mins
06	25 %	35.25	113 mins	281 mins



Graph 1 *Variation in Standard Consistency, Setting Time*

F. 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 more finer particles and occupies more volume which needs more water for the same consistency.

G. Effect of Neutralized Red Mud on Initial Setting Time of Cement:

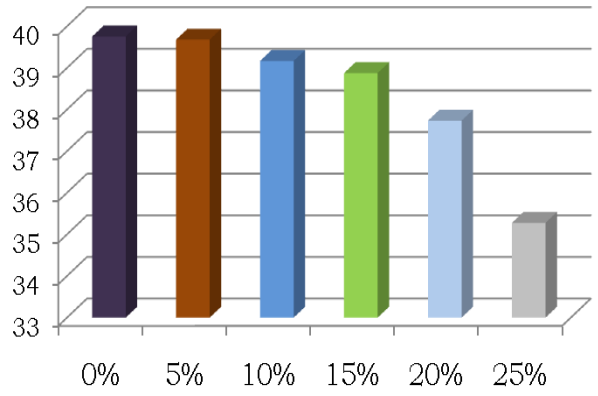
The fig shows the variation of the initial setting time with different percentage replacement of cement by neutralized red mud in cement and the values can be observed from the table

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.

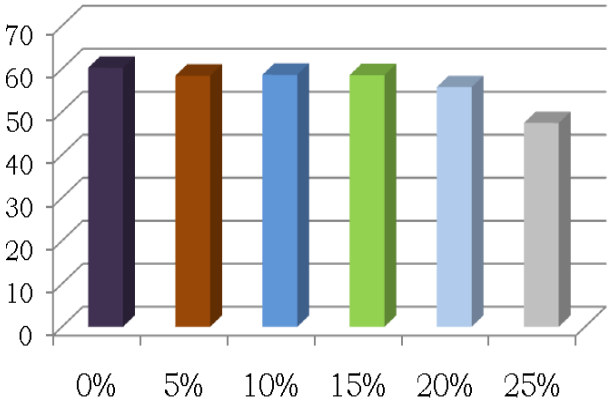
H. Effect on Compressive Strength:-

Table 5 Compressive Strength of different amount of replacement of Cement by Red Mud

ID Mark	7 Days Compressive Strength in N/mm^2	28 Days Compressive Strength in N/mm^2
C1	39.755	60.238
C2	39.681	58.395
C3	39.168	58.624
C4	38.876	58.541
C5	37.734	55.753
C6	35.278	47.407



Graph 2 *Variations in 7 Days Compressive Strength*



Graph 3 *Variations in 28 Days Compressive Strength*

V. 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 M50. The water-cement ratio 0.36 is kept constant for different percentage replacement of cement by neutralized red mud.

It is observed from the table no. 7 that the rate of gain in strength decreases with increases in neutralized red mud content at 7 days curing period compared to 7 days strength of pure cement concrete.

For M 50 concrete mix the optimum replacement is 15 %. Referring to fig. no. 2 & 3 it is interesting to note that the particular variation in average compressive strength of cement concrete with different proportions of neutralized red mud in place of cement.

It is observation that the average compressive strength decreases with increase in neutralized red mud content except for few percentage of replacement.

It is observed from table no. 7, which shows that the average compressive strength values for M 50 grade concrete with constant water-cement ratio. The maximum compressive strength obtained is 60.238 N/mm2, for pure cement concrete i.e. for 0% of replacement and minimum of 47.407 N/mm2 with 25% of neutralized red mud at 28 days of curing period.

For M50 grade concrete (0% replacement) the 28 days target strength is 58.25 N/mm2. So with reference to table no. we are able to partially replace cement by neutralized red mud up to 15 %.

From economical point of view the conventional concrete costing around 13.7 % more than the costing of neutralized red mud concrete (15 % replacement) with the nominal decrease in the compressive strength of 2.97 % than the actual 28 days compressive strength of M 50 grade concrete.

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