ASSESSMENT OF CORROSION STUDIES ON CONCRETE INCORPORATING REDMUD AS PARTIAL REPLACEMENT OF CEMENT

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***Abstract* - The main objective of the environmental protection agencies and the government is to find ways and means to minimize the problems of disposal and health hazards of the by product. Red mud is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial substitute of cement. Red mud generated out of Bayer's process for alumina from Bauxite having a high volume of solid waste. If doesn't have any wide industrial application. But MALCO has found out an innovative way for the usage of red mud as one of the raw material in the manufacture of cement. This paper presents the results of an experimental study on various corrosion tests on concrete containing red mud as partial replacement of cement. For this work, M20 grade concrete was used and the tests were conducted for various proportions of red mud replacement with cement of 0%, 5%, 10%, 15%, and 20%. The results were compared with those of control concrete made with Ordinary Portland Cement (OPC)**

***Keywords*: -** Bauxite, red mud, corrosion test, solid waste, Bayer's process.

I. INTRODUCTION

Bayer's process for Alumina production uses Caustic and Bauxite as the main raw material for Alumina production and generates Red mud which practically doesn't have wide industrial application and is generally dumped as a non-value by product in the backyards of a Alumina Refinery called as Red Mud yard. Red Mud generated in the form of mud slurry in the Bayer's process was pumped to the Red Mud pond in the form of thick concentrated slurry of red mud containing about 500 to 600gpl of solids by high energy positive displacement pumps. Right after the commissioning of Dry Mud Stacking system in 1999 the red mud slurry is dewatered in Rotary Vacuum Drum filters to yield Dry mud containing 65 to 70 % of solids and transported to the Red Mud yard using trucks for stacking in the artificially made impoundments. Over the years the red mud produced were lying in the yard not without any usage. Huge space of about 3.0 acres needed per annum to store the Red Mud and substantial expenditure incurred in maintaining the dykes. But a breakthrough was made when MALCO discovered that red mud could be tried as an alternative for the Low Grade Bauxite (LGB) which the cement industries used for its cement production. An idea struck as why not try Red Mud in cement industries instead of Bauxite as the composition of both are almost similar. It's quite possible as the cement industries were on the look out to make up for the deficiency of Alumina, in their raw materials viz - Lime stone for. Cement production.

We took a trail of using Red Mud instead of LGB with one of the renowned cement producer who was taking LGB from us. The idea worked. The Cement Company didn't have any problem in using Red Mud and the quality of Cement produced was found to be better. Also it reduced their cost of production since the Red Mud is cheaper than LGB. The successful idea of Red Mud as a substitute for LGB became a blessing in disguise as it helped MALCO conserve its mineral resources. This LGB can be beneficiated to Factory grade Bauxite there by increasing mine's life. As a step forward in its successful discovery the authors visited the Cement industry to find out the consequences arising out of using Red mud as alternative for LGB in their process of Cement production. It is understood that Red Mud besides being a cheaper substitute for low grade Bauxite,

adds value to the Cement produced by way of increased setting characteristics. It was found that the caustic in Red Mud neutralizes the Sulfur content in pet coke which is used by the cement industry for burning clinkers in the rotary kilns

II. SCOPE AND OBJECTIVES

The main scope and objective of this investigation are

- To compare the physical and chemical properties of red mud for similar to add the raw materials for manufacturing of cement.
- To measure the mechanical properties like compressive and tensile strength on red mud admixed concrete.
- To assessment of corrosion rate per year by weight loss method on REDMUD admixed concrete.
- To monitor the corrosion potential on concrete surface by OPEN CIRCUIT POTENTIAL METHOD.

III. MATERIALS

For casting the specimens and their properties are given in the **Table 1**.

MATERIALS	PROPERTIES
Cement	OPC(43 grade), Specific gravity is **3.12**
Fine aggregate	River sand (Madurai) conforming to grading zone II of IS:383, Specific gravity is **2.56.**
Coarse aggregate	Blue granite crushed stone aggregates of 20 mm as maximum size. Specific gravity is **2.904**
Water	The potable water, available in the campus, is used for Casting and curing process.
Steel	12 mm dia Fe 415 TMT bars.
Hydrated lime powder	Available in market at Madurai
Red mud (cement replacement)	Passing from 600µ sieve (IS2720-PartIV)
Red mud	Purchasing from MALCO industries in Mettur, Tamilnadu

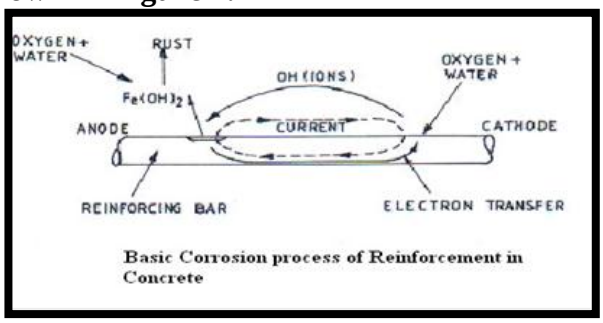
Figure - 1: Appearance of Red Mud

Table 2: Chemical Compositions of Dry Red mud

S .No	Chemical compositions	Granulated DRY Red mud
1	SIO_2	15%
2	Fe_2O_3	45%
3	Al_2O_3	22%
4	CaO	1%
5	MgO	0.04%
6	Na_2O	5%
7	TiO_2	2%
8	LOI	7.2%

IV. CORROSION

Corrosion is defined as the destruction of a material because of reaction with its environment Most of the concrete structures are subjected to corrosion due to various reasons. The basic corrosion process of reinforcement in concrete is shown in **Figure 2.**



Basic Corrosion process of Reinforcement in Concrete

a)Causes of corrosion

The deterioration of reinforced concrete structures is mainly due to the reinforcing steel in concrete among several degradation processes. Aggressive chloride ions, carbon dioxide, moisture and oxygen can easily diffuse into concrete through pores and cracks presents in concrete and thus lower the pH of the pore solution from high alkalinity. This reduction in pH destroys the passive oxide film formed on the embedded steel.

b)Corrosion prevention methods

Following are the few effective corrosion prevention of methods applicable to reinforced concrete structures:

- Improved quality of concrete
- Coating to the concrete surface.
- Coating to the reinforcement
- Using corrosion inhibitors in concrete.
- Providing rich cover concrete
- Use of (CRS) Corrosion Resistant Steel.

V. REVIEW OF LITERATURE

Investigations are going on throughout the world to study the effect of partial replacement of cement with red mud.

"WASTE INTO WEALTH", S.Balasubramaniam, R.Vasantha Kumar,

MALCO has found out an innovative way for the usage of Red mud as one of the raw material in the manufacturing of Cement. Presence of Alumina and Iron oxide in red mud compensates the deficiency of the same components in Limestone which is the primary raw material for Cement production. Besides what makes red mud special in cement manufacturing is the presence of soda in the red mud which when used in Clinker production neutralizes the sulfur content in the pet coke that is used for burning clinker enroute cement production and adds to the cement's setting characteristics.

VI. MIX PROPORTIONS

With the available materials mix proportion for **M20**, control concrete was designed and the same was progressively corrected by trial mixes. The mix adopted for all specimens were **1: 1.67:3.7**6 by weight of cement: fine aggregate: coarse aggregate and water cement ratio of **0.5**.

The actual material required for each specimen was weighed and mechanically mixed and hand vibrated for compaction.

Table-3. Description Of Test Specimens

Specimens	**Size(mm)**	**No of Specimens**
Cube	150×150×150	20
Cylinders	150Ø:ht-300mm	20

VII. CASTING OF SPECIMENS

The actual quantity of materials were weighed and kept ready before mixing. The moulds were kept ready on tamping by hand action. The concrete was mixed by manually and filled in the mould by three layers and compacted well by hand

action. After 24 hours the cube and cylinder specimens were removed from the moulds and placed out side and cured by putting the specimens in curing tank for 28 days**.**

VIII. COMPRESSIVE AND SPLIT TENSILE TEST

The casted concrete cubes and cylinders were cured in the curing tank. After a curing period of 28 days, the compressive strength and splitting tensile strength were found out.[2]

a)Specifications details

MIX ID	
C.C	Control Concrete (0%)
R5	5% Red mud replacement for cement
R10	10% Red mud replacement for cement
R15	15% Red mud replacement for cement
R20	20% Red mud replacement for cement

Table -4, Mix ID

Table-5,COMPRESSIVE TEST & SPLITTING TENSILE TEST

MIX ID	Compressive strength (N/mm^2) at 28 days(FIG-3)	Tensile strength (N/mm^2) at 28 days(FIG-4)
C.C	26	1.65
R05	27.1	1.82
R10	28.8	1.93
R15	25.1	1.83
R20	24.4	1.78

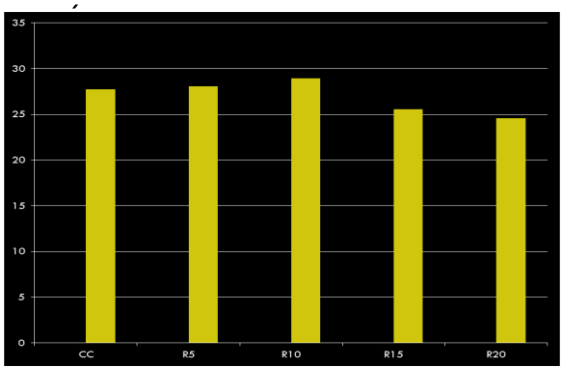


Figure - 3

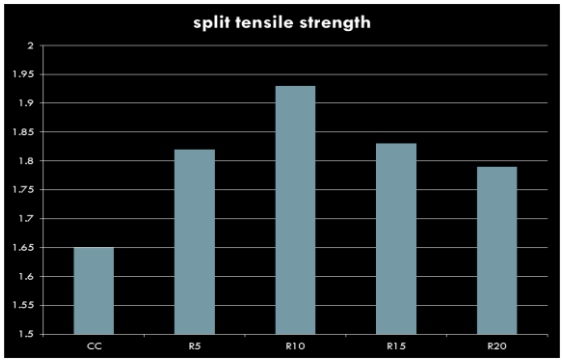


Figure - 4

Figure - 5 Compressive test setup

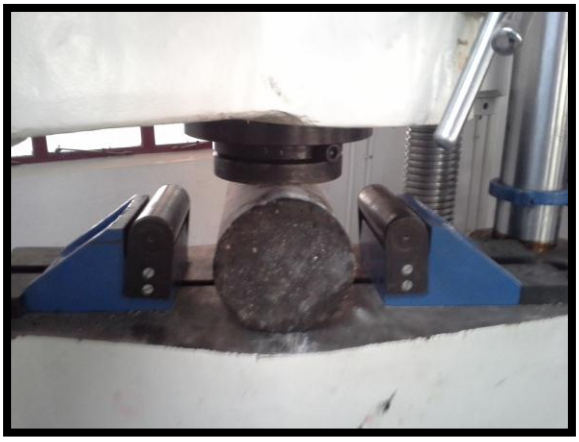


Figure – 6 split tensile test setup

IX. ACCELERATION OF CORROSION PROCESS[13].

The corrosion process is to be accelerated by using galvano static method. Regular D.C power supply of 10V is supplied continuously throughout the corrosion period of 15 days. + ve terminal of voltmeter is connected with soldered wires and –ve terminal is connected with copper plate (cathode).The Galvano static cell was created in Reinforced concrete tank. After the process of accelerated corrosion was over, all the specimens were disconnected and removed from tank. After the corrosion period, the rod was taken out and weighed. The loss of weight of the reinforcement due to corrosion in M20 grade of concrete with and without Red mud admixed concrete. Then the corrosion rate is calculated using the formulae,

$$CorrosionRate = \frac{(K * W)}{(A * T * D)} \quad (\text{mm/yr})$$

Where K is a constant, K =87.6 in case of expressing Corrosion rate in mm/yr

T is the exposure time expressed in hours,

A is the surface area in cm^2, W is the mass loss in gram, and

D is the density of the corroding metal ($7.85 g/cm^3$)

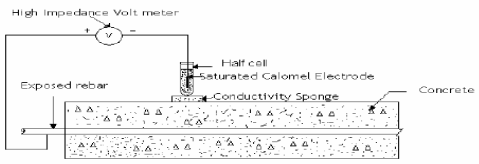
Figure – 7 placing of reinforcement

Figure – 8 initial rod weight

Figure – 9 curing process

X. OPEN CIRCUIT POTENTIAL (OCP) TEST[14].

The tendency of any metal to react with an environment is indicated by the potential it develops in contact with the environment. In reinforced concrete cylinders, concrete acts, as an electrolyte and the reinforcement will develop a potential depending on the concrete environment, which may



vary from place to place. The schematic diagram for open circuit potential measurements is as shown in **Figure – 10.**

Setup for O.C.P test

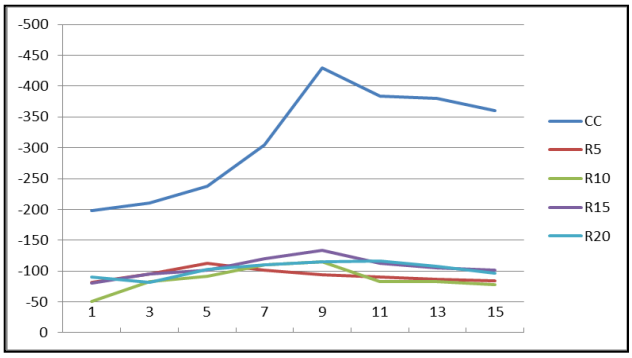
a)Measurement of corrosion parameter

Half –cell potential measurements [14] were taken daily. Half-cell potential (HCP) values were used for measuring corrosion parameters. Saturated calomel electrode (SCE) was used to measure the HCP at the concrete surface of the cylinders. The HCP is to be measured at both ends and middle sections of the specimens.

b)corrosion potential-time result

Table-6 corrosion potential-time result

Mix	1 DAY mV	3 DAYS mV	5 DAYS mV	7 DAYS mV	9 DAYS mV	11 DAYS mV	13 DAYS mV	15 DAYS mV
CC	-198	-210	-238	-304	-429	-384	-380	-360
R05	-81	-95	-113	-102	-94	-90	-87	-84
R10	-50	-83	-92	-110	-115	-83	-83	-78
R15	-80	-95	-101	-120	-134	-112	-105	-101
R20	-90	-82	-103	-110	-115	-116	-107	-97



Graph – 1

XI. CARBONATION DEPTH

Experiments were to be conducted to study the effect of Carbonation depth on the Red mud Admixed Concrete at 50 days.

XII. CONCLUSION

a)Effect of Red mud on compressive strength of concrete

The average 28 days compressive strength for different proportions of concrete mixes as show in fig-1. The results show that the compressive strength of concrete is increased as Red mud quantity increases up to 10% addition, beyond that the Red mud was reduced significant increase in free water content in the mixes. The excessive free water content in the mixes with Red mud content causes the bleeding and segregation in concrete. Therefore leads reduction in the concrete strength.

The highest compressive strength was achieved with 10% replacement of red mud, which was found about 28.8 N/mm^2 .This means that there is an increase of compressive strength of more than 12% compared to the control mix. However mix with 20% replacement of Red mud gave the low compressive strength when compare to 10% but still less than 8% compared to the control mix. The results showed that the uses of Red mud as a replacement of cement in concrete mixes resulted high compressive strength of about 10%.

b)Effect of Red mud on split tensile strength of concrete

Totally 15 cylindrical specimens were tested for finding split tensile strength in accordance with ASTM C 496-96 .the splitting tensile strength was determined by using the following formulae

$$F_t=2P/\pi LD$$

The results from the splitting tensile test at 28 days are presented in fig 2. The tensile strength of concrete showed similar behavior to the compressive strength. The results show that the split tensile strength is increased as Red mud quantity increases up to 10% addition, beyond that the split tensile strength value slightly reduces but still more than 16% compared with control mix. The results showed that the use of Red mud in concrete resulted an increase tensile strength of about 20% with that of control mixture.

c)Corrosion potential vs time

From the table 6.It was found that all the systems are showing high negative potentials than (-270 mV) Vs SCE indicating the active condition of the rebar both the control and Red mud concrete showed very high negative potential value are not more than -200 mV initially at 7 – 10 days. This shows the active condition of rebar's at the end of 15 days SCE indicating the slight passive condition of rebar. After that potential, value of all specimens decreases simultaneously with increasing no. of days. The trend in reduction in the passivity of various systems was shown by graph in fig 10

XIII. ACKNOWLEDGEMENT

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