STUDY AND ANALYSIS OF CONCRETE STRENGTH PARAMETERS USING RED MUD AS A PARTIAL REPLACEMENT OF BINDER CONTENT WITH AND WITHOUT HYDRATED LIME

ABSTRACT: ***The research was conducted to study the properties of concrete by using red mud as replacement of cement in concrete. The Bayer Process for the production of alumina from Bauxite ore is characterized by low energy efficiency and it results in the production of significant amounts of dust-like, high alkalinity bauxite residues known as red mud. Currently red mud is produced almost at equal mass ratio to metallurgical alumina and is disposed into sealed or unsealed artificial impoundments (landfills), leading to important environmental issues.***

It comprises of oxides of iron, titanium, aluminum and silica along with some other minor constituents. 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. 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 enrooted cement production and adds to the cement's setting characteristics. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud management issues i.e. of utilization, storage and disposal. Different avenues of red mud utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible.

Experiments have been conducted under laboratory condition to assess the strength characteristics of the aluminum red mud. The project work focuses on the suitability of red mud obtained for construction. Seven test groups were constituted with the replacement percentages 0%, 10%, 20%, 30%, 40%, 50%, 60% of red mud and 5% of hydrated lime with cement in each series in M_{40} ***grade concrete. To achieve Pozzolanic property of red mud, hydrated lime was added. This paper points out another promising direction for the proper utilization of red mud.***

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. 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 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.

Properties of red mud: ([1] Ping Wang, and Dong-Yan Liu)

Physical properties of red mud:

The following are the physical properties of the mud powder.

- Generally fineness of red mud is varies between 1000-3000cm^2/gm.
- Its PH is varies in between 10.5 to 12.5 hence alkaline in nature
- Specific gravity of red mud is found to be 2.51

Chemical properties of red mud:

Chemical properties of red mud are shown in below table it indicates that percentage of Cao is vary less hence it has no cementitious properties but when it reacts with water and cements it starts gaining cementitious properties. And also to improve this property we adding the optimized percentage of lime (5%).

Composition of Red Mud and its Properties

Red Mud as such containing about 65% to 70% Solids with the remaining as moisture is a thixotropic substance which exhibits shear thinning behavior i.e., when the shear rate is increased, the apparent viscosity decreases. The following is the composition of the Dry Red Mud of MALCO.

COMPONENTS	WEIGHT %
Al_2O_3	20 – 22
Fe_2O_3	40 – 45
SiO_2	12 – 15
TiO_2	1.8 – 2.0
CaO	1.0 – 2.0
Na_2O	4 – 5

Utilization of iron values in Red mud: ([2] Harekrushna sutar, Subash Chandra Misra, Santhosh Kumar Sahoo et.al(2014))

(a) As an independent raw material to recover iron alone or along with other valuable constituents such as AL2O3, TiO, etc;

(b) Use as an additive to the feed in conventional iron making blast furnace (BF) - mostly after sintering with iron ore;

(c) Other miscellaneous applications in the iron and steel industry.

Two main approaches which have been generally investigated to recover iron values are based on: (a) Solid state reduction of red mud followed by magnetic separation to recover iron; and (b) Reduction smelting in a blast/electric/low shaft furnace (with or without pre reduction) to produce pig iron.

Red mud location:

The red mud used for the project is collected from the NILA EXPORTERS (TAMIL NADU)

ADDRESS: No. 25, NCV Street,

Thoothukudi, 6139, Tamil Nadu, India.

Having the following specifications

1. Non-soluble material:90.47%
2. Iron:3.61%
3. Aluminium:2.92%
4. Organic matter:1.01%
5. Magnesium:0.70%
6. Lime:0.56%
7. Carbon-Di-oxide:0.36%
8. Potash:0.24%
9. Soda:0.12%
10. Phosphorus:0.09%
11. Nitrogen:0.08%

Objectives of the study:

The major objectives of this study were:

1. To identify various industrial wastes suitable for utilization in cement manufacture.
2. Physico-chemical and mineralogical characterization of industrial wastes.
3. To assess the compatibility of industrial solid waste as raw material/ blending material/ admixture.
4. To examine the constraints related to utilization of industrial waste.
5. To make recommendations to promote utilization of industrial waste.

LITERATURE REVIEW

P. Ashok, M.P. Suresh kumar, et., al. (2010) were explained the Bayer Process for the production of alumina from Bauxite ore is characterized by low energy efficiency and it results in the production of significant amounts of dust-like, high alkalinity bauxite residues known as red mud. Currently red mud is produced almost at equal mass ratio to metallurgical alumina and is disposed into sealed or unsealed artificial impoundments (landfills), leading to important environmental issues. It comprises of oxides of iron, titanium, aluminum and silica along with some other minor constituents. 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. 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 enrooted cement production and adds to the cement's setting characteristics. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud management issues i.e., of utilization, storage and disposal. Different avenues of red mud utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible. Experiments have been conducted under laboratory condition to assess the strength characteristics of the aluminum red mud. The project work focuses on the suitability of red mud obtained for construction. ([3] P. E. Tsakiridis, S. Agatzini-Leonardou, and P. Oustadakis,)Five test groups were constituted with the replacement percentages 0%, 5%, 10%, 15%, 20% of red mud and 5% of hydrated lime with cement in each series. To achieve Pozzolanic property of red mud, hydrated lime was added. This paper points out another promising direction for the proper utilization of red mud.

D.V. RIBEIROJ, A. LABRINCHA, M.R.MORELLI, et., al. (2012) were presented the red mud is a solid waste produced in the alumina production process and, due to its high pH, is classified as hazardous. Its incorporation in concrete mixtures, acting as filler due to the particles fineness, might be an interesting reuse alternative. The focus of this paper is to study the chloride diffusivity of concrete mixtures containing red-mud. The concentration of chlorides was monitored by measuring the conductivity of the anolyte, which was distilled water initially. In addition, the estimation of the chloride ions diffusion coefficients in steady and non-steady conditions, Ds and Dns, was obtained from the ‘‘time-lag’’ and ‘‘equivalent time’’ between diffusion and migration experiments. Due to superfine particle-size distribution and the “filler” effect, the red mud addition seems to assure lower chloride diffusivity.

The time lag increases with increasing red mud content as a result of the reduction in the relative amount of capillary pores. The decrease in the interconnectivity between capillary pores in samples containing red mud and the presence of typical mineralogical phases such as sodium alumino silicates, known as sodalities, are responsible for reducing the flow of chloride ions, and hence, the steady-state and non steady state diffusion coefficients; he chloride migration tests of samples of concrete containing red mud showed a longer service life, reaching more than double that of the reference samples (16.5 versus 35 years).

R.Vandhiyan, K. Ramkumar et. al. (2014)

This study aims at utilization of industrial by product for value added application. Red mud is a main waste generated in aluminum production by the Bayer process. Concrete cubes and mortars cubes were made by replacing cement with red mud in concrete 5%, 10% &15% respectively. The compressive strength, consistency and setting time tests were conducted for the above replacements. The study indicates that red mud can be used in mortars and concretes for nonstructural application.

The results in this study recommend that red mud is an appealing material for use in mortars and concretes for nonstructural application. The mechanical strength diminishes with increasing proportions of red mud in place of cement, up to 10%, substitution still show suitable strength for non-structural applications. The concrete cubes made with cement replacements showed decrease in strength. The colour of the concrete changes to red with increase in replacement. Further investigation can be done by calcinating the red mud as the properties of the material change at high temperature.

MATERIALS AND METHODOLOGY

MATERIALS USED

CEMENT:

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete which is a combination of cement and an aggregate to form a strong building material.

Physical properties of 53 grade cement:

Sl No	Characteristics	Values
1	Standard consistency	53
2	Fineness of cement as retained on 90 micron sieve	3%
3	Initial setting time	30 minutes
4	Specific gravity	315
5	7 days compressive strength	37 Mpa

FINE AGGREGATES:

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to source fine aggregate may be described as:

- Natural sand-it is the aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.
- Crushed stone sand-it is the fine aggregate produced by crushing hard stone.
- Crushed gravel sand-it is the fine aggregate produced by crushing natural gravel.

Property	River sand
Specific gravity	26
Sieve analysis	Zone II

COARSE AGGREGATES:

It is the aggregate most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification. According to source, coarse aggregate may be described as:

- Uncrushed Gravel or Stone– it results from natural disintegration of rock
- Crushed Gravel or Stone– it results from crushing of gravel or hard stone.
- Partially Crushed Gravel or Stone– it is a product of the blending of the above two aggregate.

WATER:

Fresh and clean water is used for casting and curing of specimen. The water is relatively free from organic matters, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard. Combining water with a cementitious material forms a cement paste by the process of hydration. A cement paste glues the aggregate together fills voids within it, and makes floor freely.

Final Quantities of all materials:

Material	Cement	FA	CA	Water	Admixture
Proportion	1	1.60	2.34	0.4	1% of cement
Quantities	4.5 bags	515 kgs	754 kgs	129 liters	3.2 liters

Tests on materials

Cement

i. Density
ii. Determination setting time
iii. Standard consistency test
iv. Specific gravity of cement
v. Fineness of cement

Fine aggregate

i. Bulking of fine aggregates
ii. Determination of bulk density and voids
iii. Specific gravity

Coarse aggregate

i. Specific gravity
ii. Crushing value test
iii. Impact test

Tests on concrete

i. Slump cone test
ii. Compaction factor test
iii. Compressive strength of concrete
iv. Split tensile strength
v. Flexural strength test

TEST RESULTS AND ANALYSIS

MATERIAL PROPERTIES:

CEMENT:

Sl.No	Test	Results	IS code used	Acceptable limit
1	Specific gravity of cement	3.150	IS:2386: 1963	3 to 3.2
2	Standard consistency of cement	6mm at 34% w/c	IS:4031: 1996	w/c ratio 28%-35%
3	Initial and final setting time	50mins and 10 hours	IS:4031: 1988	Minimum 30mins and should not more than 10 hours
4	Fineness of cement	3.48%	IS:4031: 1988	<10%

COARSE AGGREGATES:

Sl.No	Test	Results	Is code used	Acceptable limit
1	Fineness modulus	6.5	IS:2386:1963	6.0 to 8.0mm
2	Specific gravity	2.90	IS:2386:1963	2 to 3.1mm
3	Porosity	46.83%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.8855	IS:2386:1963	Any value
5	Bulk density	1.50g/cc	IS:2386:1963	-
6	Aggregate impact value	37.5	IS:2386:1963	Less than 45%
7	Aggregate crushing value	26.6%	IS:2386:1963	Less than 45%

FINE AGGREGATES:

Sl.No	Test	Results	Is code used	Acceptable limit
1	Fineness modulus	4.30 5	IS:2386:1963	Not more than 3.2 mm
2	Specific gravity	2.43	IS:2386:1963	2.0 to 3.1
3	Porosity	36.6 %	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.57 7	IS:2386:1963	Any value
5	Bulk density	1.54 24	IS:2386:1963	-
6	Bulking of sand	3.0%	IS:2386:1963	Less than 10%

TESTS ON CONCRETE:

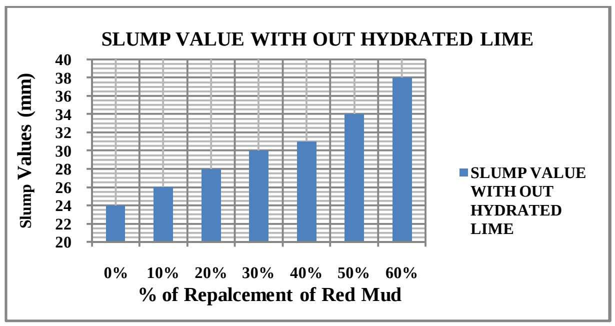
FREST CONCRETE TESTS:

Slump cone test:

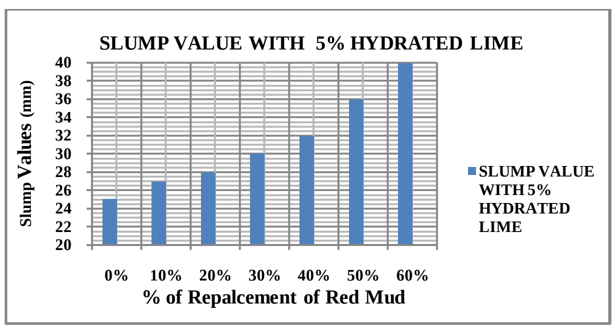
FOR M40 GRADE CONCRERTE

SI.NO	% REPLACEMENT	SLUMP VALUE WITH OUT HYDRATED LIME	SLUMP VALUE WITH 5% HYDRATED LIME
1	0%	24	25
2	10%	26	27
3	20%	28	28
4	30%	30	30
5	40%	31	32
6	50%	34	36
7	60%	38	40

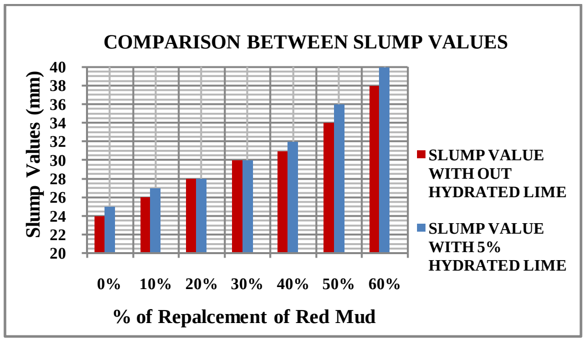
Slump cone test without hydrated lime



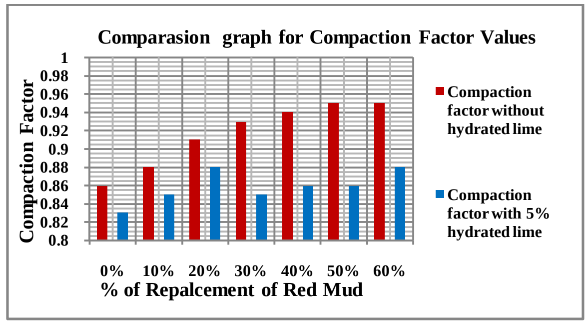
Slump cone test with 5% hydrated lime



Comparison between slump values



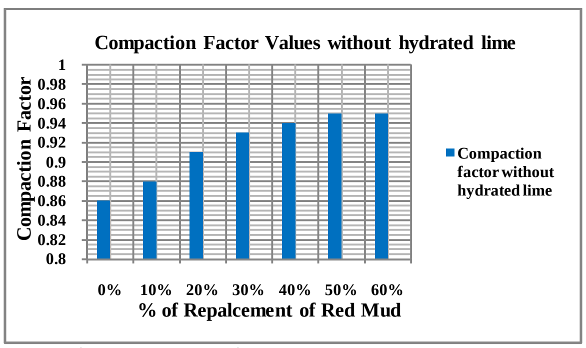
Comparison between compaction factor values



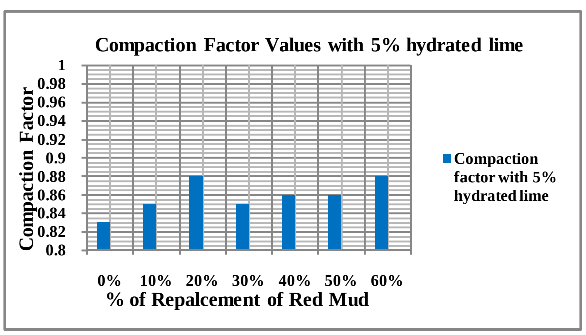
Compaction factor test

Sl.NO	% Replacement	Compaction factor without hydrated lime	Compaction factor with hydrated lime
1	0%	0.86	0.83
2	10%	0.88	0.85
3	20%	0.91	0.88
4	30%	0.93	0.85
5	40%	0.94	0.86
6	50%	0.95	0.86
7	60%	0.95	0.88

Graph for Compaction factor without hydrated lime



Graph for Compaction factor with 5% hydrated lime



HARDENED CONCRETE TESTS:

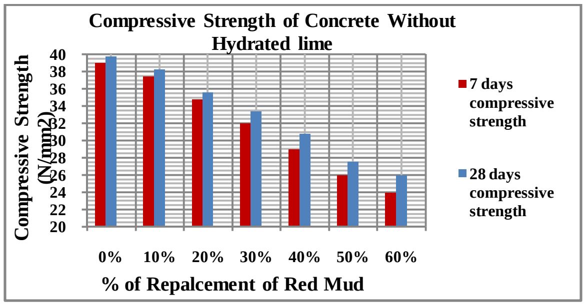
Compressive strength of concrete:

Sl.No	% replacement	7 days compressive strength N/mm^2	28 days compressive strength N/mm^2
1	0%	39	39.8
2	10%	37.5	38.3
3	20%	34.8	35.6
4	30%	32	33.4
5	40%	29	30.8
6	50%	26	27.5
7	60%	24	26

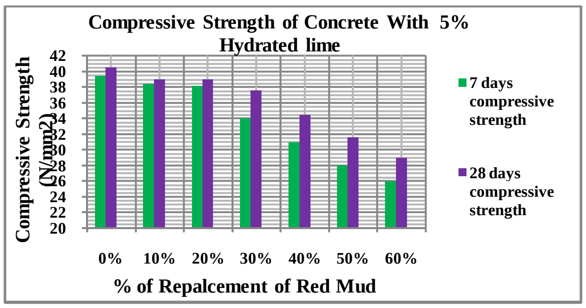
Compressive strength of concrete with 5% hydrated lime:

Sl. No	% replacement	7 days compressive strength N/mm^2	28 days compressive strength N/mm^2
1	0%	39.5	40.5
2	10%	38.4	39
3	20%	38.2	39
4	30%	34	37.6
5	40%	31	34.5
6	50%	28	31.6
7	60%	26	29

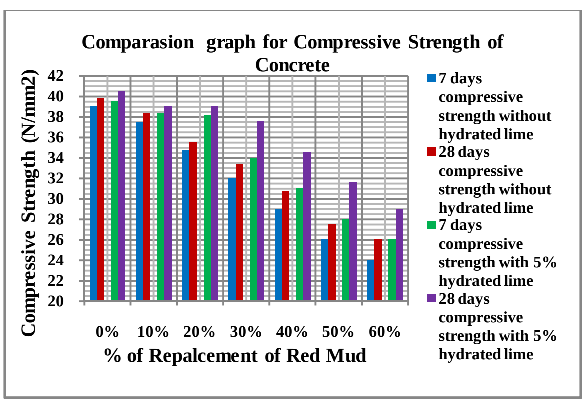
Graph for Compressive strength of concrete without hydrated lime



Graph for Compressive strength of concrete with 5% hydrated lime



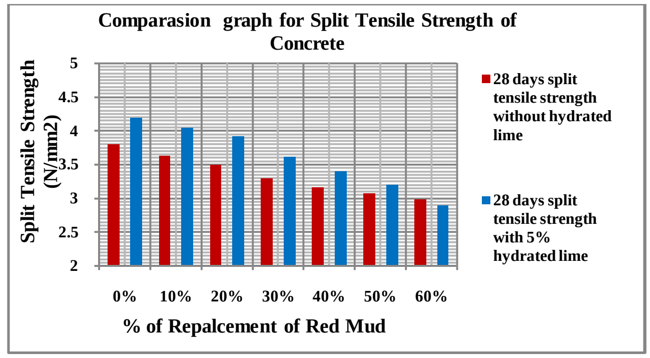
Comparison graph



Split tensile strength of concrete:

Sl.No	% Replacement of red mud	28 days split tensile strength without hydrated lime N/mm^2	28 days split tensile strength with hydrated lime N/mm^2
1	0%	3.8	4.2
2	10%	3.63	4.05
3	20%	3.5	3.92
4	30%	3.3	3.62
5	40%	3.16	3.4
6	50%	3.08	3.2
7	60%	2.98	2.9

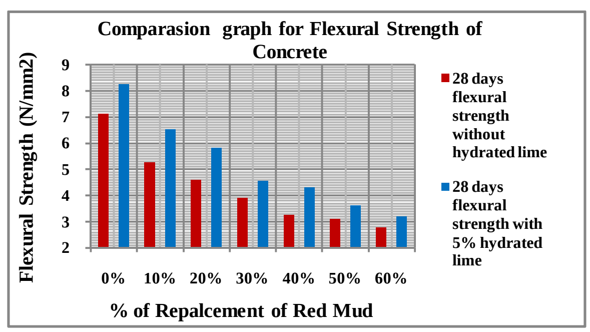
Graph for Split tensile strength of concrete



Flexural strength of concrete:

Sl.No	% Red mud used	28 days flexural strength without hydrated lime N/mm^2	28 days flexural strength with 5% hydrated lime N/mm^2
1	0%	7.12	8.26
2	10%	5.26	6.54
3	20%	4.61	5.82
4	30%	3.91	4.56
5	40%	3.26	4.32
6	50%	3.1	3.62
7	60%	2.8	3.2

Graph for Flexural strength of concrete:



CONCLUSIONS

From this research the following conclusions are made

1. The material properties of the cement, coarse aggregates, and fine aggregates are within the acceptable limits hence theses materials are suitable for the research.

2. The slump value and the compaction factor values of concrete increases with increasing in the percentage of red mud in concrete.
3. For each percentage replacement up to 60% the compressive strength values of the red mud concrete decreases with increase in the percentage of red mud. At 20% replacement of red mud in both cases coincides with that of conventional concrete. But beyond 10% there is reduction in the strength of conventional concrete.
4. From the experimental work it was found that with increase in red mud content (greater than 20%) decreases the compressive strength as well as tensile strength of concrete.
5. Optimum percentage of the replacement of cement by weight is found to be 20%. By this replacement results got are nearly equal to the results of conventional concrete.
6. We use mixture of red mud and cement for nonstructural work. There is a future scope for the use of red mud concrete in structural point of view. Concrete prepared by using red mud is suitable in ornamental works and gives aesthetically pleasant appearance.
7. Used for road construction as an embankment and landfill is an attractive option with a high potential for large volume reuse.
8. The above results show that the optimum utilization of Red mud in concrete is 20% as a partial replacement of cement.
9. This study concludes that Red mud can be innovative supplementary cementitious materials but judicious decision must be taken by expert engineers.

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