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Experimental studies on concrete utilising red mud as partial replacement of cement

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ABSTRACT

The Bayer Process for the production of alumina from Bauxite ore is characterized by low energy efficiency which results in the production of significant amounts of dust-like, high alkalinity bauxite residues known as Red Mud. Red mud is produced almost at an equivalent mass ratio to metallurgical alumina and is biased into sealed or unsealed artificial confinements, leading to crucial environmental issues. It contains oxides of iron, titanium, aluminium and silica along with some other minor constituents. Presence of Alumina and Iron oxide in red mud compensates the absence of the same components in limestone which is the essential raw material for cement production. Based on economics as well as environmental related issues, massive efforts have been directed worldwide towards red mud disposal issues. The project work spotlights the suitability of red mud obtained for construction. Five test groups were constituted with the replacement percentages 0%, 5%, 10%, 15%, 20% of red mud with cement in each series. To achieve Pozzolan's property of Red Mud. This paper points out another encouraging guidance for the proper utilization of red mud.

Keywords— *Bayer process, Compressive strength, Red mud, Slump test, Consistency test, Economy*

1. INTRODUCTION

Bayer's process for Alumina production uses Caustic and Bauxite as the primary raw material for Alumina production and generates Red mud which practically doesn't have any industrial application and is usually dumped as a non-value by-product in the backyards of Alumina Refineries 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 use 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.

1.1 Red Mud

Red mud is a product of the Bayer process, the principal industrial means of distilling bauxite to give alumina as raw material for the electrolysis of aluminium by the Hall-Heroult process. Red mud is a mixture of solid and metallic oxides containing impurities and represents one of the aluminium industry's most important disposal problems. The red color is caused by the oxidized iron present in it, which can make up to 60% of the mass of the red mud. In addition to iron, the other dominant particles are silica, unbleached residual aluminum, and oxides of titanium.

1.2 Objectives of the project

The major objectives of this study were:

- To improve physiochemical the properties of concrete.
- Physiochemical and mineralogical characterization of industrial wastes. (Red Mud)
- To determine the process concrete mix design of red mud concrete.
- To analyse the strength properties of red mud concrete in terms of compression.

- To extend and to know the strength properties of red mud concrete in terms of tension.
- Cost analysis of red mud concrete.

2. LITERATURE REVIEW

An Overview of Chemical Processes to Manufacture Red Mud (2015) Arun S. Wagh, PhD (Inorganic polymer solutions, U.S.A): Major deposits of red mud are in highly populated emerging economic regions. Recycling red mud as construction materials is important to these countries for economic as well as environmental reasons. We present two methods, the first method (Geopolymeric method) takes advantage of the high alkalinity and high alumina content in red mud. Adding sodium silicate, we developed sodium alumina-silicate binding phases in red mud. This process generates rapid-setting alternative red mud cement that can be used to manufacture concrete, bricks, and building blocks. Both processes have been proven and used in other fields.

Potential Use of Natural Red Mud as pozzolana for Portland cement (December 22, 2010) Daniel VerasRibeiro, Joao A. Labrincha and Marcio R Morelli: Red mud, the main waste generated in aluminum and alumina production by the Bayer process, is considered hazardous due to its pH and waste exceeds 117 million tons/year. This paper report on a study of the influence of the Red mud on the characteristics of cement mortars without previous calcination treatment, requiring less energy and time and reducing cost in terms of setting time, pozzolanic activity and change in mechanical strength.

Stabilization of Flyash with Red Mud and Cement (September 2017) Nukaraju Bharathi and Amulya Gundla: In this study for the use of Red mud with Fly Ash in geotechnical application with various percentages of cement were added. Tests like compaction, grain size distribution analysis, unconfined compressive strength, permeability were conducted to study the interaction of Fly Ash, Red mud and cement particles. Unconfined compressive strength was determined for the curing periods 3, 7 and 28 days of Red Mud mixed with various percentages of cement (0, 5, 10, 15, 20 and 25). From the test results, it was clear that as the percentage of cement increases compression strength increases and maximum values attained at 28 days curing periods. Hence Flyash- Red mud- cement stabilized material can be used in the Geo technical applications like Embankments and Liners.

Innovative application for bauxite residue: Red mud-based inorganic polymer spheres as pH regulators (21 June 2018) Rui M. Novais , Joao Carvalheiras, Maria P. Seabra, Robert C. Pullar, Joao A. Labrincha: In this paper, Red mud geopolymer spheres where synthesized, with varying porosity and red mud content, and then their use as pH regulator was evaluated. The alumina silicate source of these inorganic polymers was 100% waste-based, consisting of a mixture of red mud and fly ash waste. Geopolymer spheres containing up to 60wt. % where red mud was successfully produced, while higher red mud contents distorted specimens spherical shape suggesting the use of red mud based spheres has pH buffering materials in waste water treatment and anaerobic digestion system.

3. MATERIALS USED

The materials used in the experiment
(a) Ordinary Portland cement (Grade 53)
(b) Red mud
(c) Fine aggregate
(d) Coarse aggregate
(e) Water

3.1 Cement

Ordinary Portland cement of 53 grade was used in this study. The cement was tested according to IS: 12269-1987. The different test was carried out on the cement to ensure that it conforms to the requirements of the IS: 12269-1987 specifications.

Table 1: Properties of cement

S no.	Characteristics	Values
1	Standard consistency	53
2	Initial setting time	30 minutes
3	Specific gravity	3.09

3.2 Red Mud

The Red mud used for the replacement of cement is brought from Tirupati Allum Industry, Jalgaon, Obtained from the manufacturing of alumina from bauxite ore by Bayer's process. The characteristics of Red mud depend on the nature of the bauxite ore used.

Table 2: Characteristics of red mud

S no.	Characteristics	Values
1	Specific Gravity	2.83
2	Ph	3-4

Table 3: Composition of red mud

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

3.3 Fine Aggregate

Locally available sand is used as a fine aggregate

Table 4: Properties of fine aggregate

Property	Value
Specific Gravity	2.41
Sieve Analysis	Zone II
Water Absorption	1.2%
Silt Content	4.5%

3.4 Coarse Aggregate

The coarse aggregate used in this investigation is 20 mm down size locally available crushed stone obtained from quarries. Specifications for coarse aggregate are as per IS 383:1970. The physical properties have been determined as per IS 2386:1963.

Table 5: Properties of coarse aggregate

S no.	Characteristics	Values
1	Specific Gravity	2.83
2	Ph	3-4

3.5 Water

The water used in the mix design was potable drinking water, locally available and it's free from organic materials and suspended Solids, which might have affected the properties of the fresh and hardened concrete.

4. METHODOLOGY

- Collection of Materials.
- Properties of Materials.

- Casting of specimen with replacement of 0%, 5%, 10%, 15%, 20%, and 25%.
- Curing of specimens
- Testing of specimens
- Analysis of Result

5. RESULTS AND DISCUSSION

5.1 Slump test

The vertical settlement of the fresh concrete is known as Slump. Steps involved in the slump test:

- Fresh concrete is filled into a mould of specified shape and dimensions (bottom diameter of 200mm, top diameter of 100mm and height of 300mm) and the settlement or slump is measured after removing the mould.
- The increased water-cement ratio increases the slump value, different slump values have been recommended for different grades of concrete. The slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works.
- A concrete is said to be workable if it can be easily mixed, placed, compacted and finished. A workable concrete should not show any segregation or bleeding.
- The internal surface of the mould was thoroughly cleaned.
- The mould was filled in four layers and each layer was tamped with twenty-five strokes of the tamping rod of diameter 16mm.
- The mould was removed from the concrete immediately by raising it slowly and carefully in a vertical direction. The slump was measured (in mm) immediately by determining the difference between the height of the mould and that of the highest point of the specimen being tested.

Table 6: Workability of concrete

Red mud Replacement in %	Slump Value(mm)
00	80
05	86
10	93
15	95
20	97

5.2 Consistency test

The standard consistency of cement paste is that consistency, which permits the Vicat plunger to penetrate to a point 5 to 7mm from the bottom of the Vicat mould. It is used to determine the quantity of water required to produce a cement paste of standard consistency

Apparatus

(a) Vicat Apparatus Conforming to IS:5513-197
- The Vicat apparatus consists of a frame having a movable rod with a cap at one end and at the other end.
- Plunger for determining the standard consistency

(b) Vicat Mould and Non-porous base plate

(c) Gauging Trowel

Table 7: Standard consistency of Red Mud as partial replacement of cement

Standard Consistency	
Red mud Replacement in %	**% of Water Required**
0	33
5	35
10	41
15	45
20	52

5.3 Compression Test

- A compression test is carried out on specimen of the size 150mm in all dimensions.
- Concrete is poured into the moulds in three layers and each layer was tamped with twenty-five strokes of the tamping rod of diameter 16mm.
- The top surface is finished using a trowel and keeps it for 24 hours.
- After 24 hours concrete cubes are demoulded and the specimens are kept in water for curing.
- Cubes are tested under compression testing machine to get the compressive strength of concrete at 7days, 14days and 28 days. The compression strength is calculated by using the formula:

$$fc = P/A$$

Where,

fc = Cube Compressive strength in N/mm^2

P = Cube Compressive load causing failure in N

A = Cross-sectional area of the cube in mm^2

Table 8: Compression Test Results for M20 Grade Concrete

% of Red Mud Used	7 Days Compressive Strength (N/mm2)	14 Days Compressive Strength (N/mm^2)	28 Days Compressive Strength (N/mm^2)
0	23	25.10	27.10
5	20.50	22.57	24.38
10	21.12	23.10	25.28
15	21.94	23.12	26.21
20	23.23	25.74	27.41

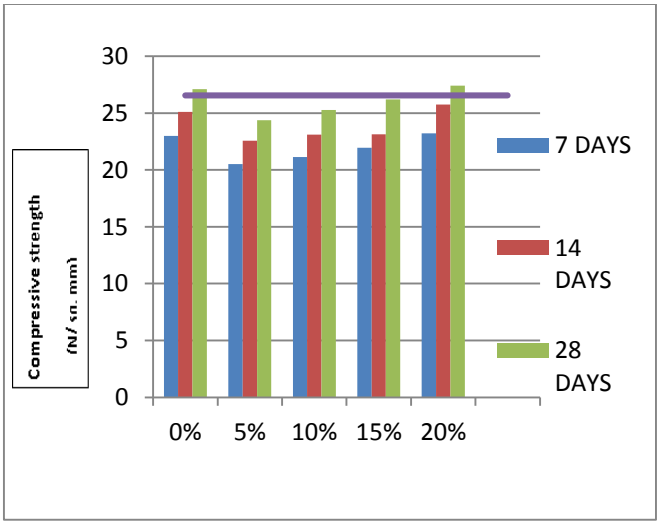

Fig. 1: Percentage replacement of cement by red mud v/s Compressive strenngth

Fig. 2: Fineness test of Red Mud

Fig. 3: Fineness test of Red Mud Sample at TOM lab of SSBT's COET, Bambhori, Jalgaon

Fig. 4: Mixing of sample

Fig. 5: Compressive strength testing in CTM at TOM lab of SSBT's COET, Bambhori, Jalgaon.

6. CONCLUSIONS

From this experimental study following points can be drawn:

- Red mud can be effectively used as a replacement material for cement and replacement enables the large utilization of the waste product.
- Red mud did not effect of the cement properties, rather improved the cement quality by way reducing the setting time and improved compressive strength.
- Used for road construction as an embankment landfill is an attractive option with a high potential for large volume reuse.
- Increased percentage of red mud increases the water absorption and decreases the strength of concrete.
- Red mud usage with cement leads to improvement in binding quality by showing the same setting time as conventional cement and also improves strength parameters up to 20% replacement for M20 grade concrete.

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