

EXPERIMENTAL STUDIES ON M40 GRADE CONCRETE UTILIZING RED MUD AS A PARTIAL REPLACEMENT OF CEMENT WITH HYDRATED LIME

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ABSTRACT

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. 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. 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. 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.

Keyword Concrete mixes, Red mud, hydrated lime

1. Introduction

Red mud is the solid waste residue of the digestion of bauxite ores with caustic soda in bayer's process of alumina (Al₂O₃) production. Around 35–40% of the bauxite ore goes into the waste as alkaline red mud slurry which consists of 15–40% solids and 0.8–1.5 tons of red mud is produced per ton of alumina production. Approximately annually 70 million tons of red mud is produced all over the world. More than 4 million tons of red mud waste is generated annually in India only. Its high alkalinity is main pollution hazard to water, land and air and huge costs are associated with its storage and residue since very large area required for its storage and disposal India is one of the major producers of aluminium. Red mud is usually disposed in mud lakes in the form of slurry or heap in ponds as dry mud nearby around alumina plants or directly dumped into nearby sea by means of pipelines. Red Mud contains fine particles, metal content, high alkalinity (pH 10–12.5) and trace because of this nature its disposal in large quantities of has caused serious environmental threats like soil contamination, groundwater pollution and sea water pollution. Moreover, when we store this it occupies large areas of land, and the storage of dry red mud can result in dust pollution which can cause serious respiratory and other health problem for the people living nearby the red mud storage ponds. Also the disposal of red mud turned out to be very costly, estimated about 2% of the alumina price. Over the years some great research work has been done all over the world to develop different economic and feasible ways for the utilization of red mud. The huge quantity of red mud production require a safe disposal and it needs large areas of land for disposal and creates environmental problems. The remediation programs and its implementation costs approximately 120 millions per annum and it is growing at a rapid rate. For the betterment of waste management the idea of recycled waste material has become very popular and important. Most of the recent

researches has been done on concrete which aims on the inclusion of industrial waste in concrete. This idea can be of a great benefit in industrial solid waste management. Thus the waste materials that meet the properties required for concrete ingredients can be used for concreting which will also lead to economic ways of concreting.

Advantages of Using Red Mud in Concrete

- **Betterment of Environment:** Replacing 30% of cement from construction practices worldwide by industrial waste can reduce carbon dioxide emissions upto 320 million tonnes. Replacing industrial waste in concreting practices will reduce the problem of lack of land for dumping the waste and also ground water contamination can be controlled.
- **Improving soil quality:** As a civil engineer our main focus should be on using sustainable materials which will the required structural strength, and also be environment friendly. If we use red mud waste in manufacturing concrete the land storage issues will be resolved, and significant improvement in the nearby soil quality can be seen.
- **Saving in the Energy Requirements in the Production of Ordinary Portland cement:** approximately 1.62-1.9 tons raw material needed for production of single ton of cement. Most of the industrial waste consists of clay, limestone and pozzolanic materials. A proper usage of industrial waste such as red mud & fly ash would conserve the manipulation of resources and also saves natural resources. It would also save the energy consumption and provide required strength to the concrete structures.
- **Economical advantages:** Cement production requires huge amount of energy. Replacement of cement can give significant energy savings. There is no energy requirement for reusing such waste.

Objectives of study:

- To discover different industrial wastes which can be well utilized in cement manufacture.
 - To identify the obstacles related to use of industrial waste.
 - To draw guidelines to encourage utilization of industrial waste.
 - To use of industrial wastes in place of conventional raw materials that will help in decreasing the environmental pollution and also in maintaining properly our natural resources.
 - To develop some alternative economic construction materials which will also environment friendly. Presently the demand of cement is very high than its total production and is rapidly increasing. By keeping the above objectives in mind our aim in this research work is to determine the suitability and utilization of dry red mud as a partial replacement of Portland cement in making concrete.
- 1.4 Properties of Red Mud
- 1.4.1. Physical Properties of Red Mud:
- Fineness of red mud varies between 1000- 3000cm²/gm usually.
 - PH is between 10.5 to 12 hence alkaline in nature.
 - Specific gravity of red mud is 2.62.
- 1.4.2. Chemical Properties of Red Mud: Red Mud is containing about 65% to 70% Solids and remaining is moisture. The chemical composition of the Dry Red Mud is shown below

Table -1: Chemical composition of Red Mud

Components	Percentage (by weight)
Fe ₂ O ₃	30-60%
Al ₂ O ₃	10-20%
SiO ₂	10-20%
Na ₂ O	2-10%
CaO	2-8%
TiO ₂	1.8-2%

2. LITERATURE REVIEW

P. Ashok, M.P. Suresh Kumar (2012) done experimental studies on current utilizing red mud and hydrated lime as a partial replacement of cement M30 grade. The percentage of red mud partial replacement of cement are, 0%, 5%, 10%, 15%, 20%, and 25% and 5% hydrated lime partial replacement of cement. From the experimental studies 15% partial replacement of cement with red mud and 5% hydrated lime improved cement concrete properties.

Mahin ShaO B, Remya C P, Salja P A, Shifal K S (2016) carried out their work to overcome the problems created due to exhaustion and obsolescence of raw material required for manufacturing of conventional building material and also to minimize the thrust of industrial waste on the environment by utilizing the same in the Construction Industry. For this they partially replaced cement with red mud in concrete up to 25%, and concluded that for each percentage replacement up to 20% the compressive strength values of the red mud concrete coincides with that of conventional concrete.

M.P.Suresh Kumar, S.K. Gotham (2014) studied the potential utilization of industrial waste (red mud) in concrete. They made investigation on partial replacement of cement with red mud for studying mechanical properties of concrete. The percentage of red mud partial replacement of concrete are, 0%, 5%, 10%, 15%, and 20% for M20 grade concrete. From the experimental studies 10% partial replacement of cement with red mud improved hardened concrete properties.

Ping Wang, and Dong-Yan Liu (2012), Physical and Chemical Properties of Sintering Red Mud and Bayer Red Mud and the Implications for Beneficial utilization. In this study performances of two common types of red mud, Bayer red mud and Sintering red mud, were investigated in this research. Their compositions, mechanical properties and microstructure characterization were measured. The study concludes that both kinds of red mud have the possibility of large scale application in the production of cement mixture. However, the influence of hazardous elements and radioactivity in red mud should be avoided when applying the red mud in the production of building material.

Hanumantha Rao. C.H.V, Satyanarayana P.V.V, Naidu.P.S (2018) have compared engineering properties of natural soil and red mud and they found that red mud is a silt size dominating industrial waste exhibited high dry density and shear strength values. Red mud can be used as fill material, embankment material, foundation material, sub grade material, backfill material as reinforced and unreinforced in retaining wall; it also reduces thrust on natural soils when used as construction material.

M S S Lima, L P Thives, V Haritonov and K Bajars (2017) studied application of red mud in construction industry, its hazardous nature is a great challenge to researcher to develop new methods for the application of red mud. Research work covers into two main areas: cement production/ceramic material and road construction. Backgrounds from other researchers were taken into consideration and analysed according to environmental, economic and technical feasibilities.

3. MATERIALS AND METHODOLOGY

Cement Type and Grade: OpC 53 grade
Fineness of opC as retained on 90 micron sieve: 3%
Standard consistency: 33
Specific gravity: 3.15
3.2 Fine Aggregate It is the aggregate most of which passes 4.75 mm IS sieve. Specific gravity of fine aggregate is found to be 2.64.
3.3 Coarse aggregate The coarse aggregate is brought from a local quarry. The coarse aggregate with size less than 20mm and greater than 12.5 mm and having a specific gravity 2.84 fineness modulus of 7.07 is used in this study.
3.4 Red mud The Red mud used for the replacement of cement is brought from BALCO Korba, residue from manufacturing of aluminium from bauxite in Bayer's process.
3.5 Hydrated Lime Hydrated lime is a type of dry powder made from limestone. It is created by adding water to quicklime to make oxides into hydroxides. Its chemical name is $\text{Ca}(\text{OH})_2$.

Tests conducted on Cement and Red Mud:

- Fineness test
- Initial setting time test
- Specific Gravity test
- Sieve Analysis
- Specific Gravity Test
- Water absorption test for Coarse aggregate
- Grade Designation : M25
- Type of Cement : OPC 53 grade conforming to IS 12269-1987
- Maximum nominal size of aggregate: 20mm
- Minimum cement content : 300 kg/m³
- Workability: 50mm
- Exposure condition: Mild
- Degree of supervision: Good
- Type of coarse aggregate: Crushed, Angular

- Fine Aggregate Zone(confirming IS 383): Zone II
- Specific gravity of Coarse Aggregate:2.84
- Specific gravity of Fine Aggregate:2.64
- Specific gravity of Cement : 3.15
- Specific gravity of Red Mud: 2.62
- Free surface moisture of coarse aggregate: less than 1%
- Free surface moisture of coarse aggregate: less than 1%
- Target mean strength :31.6N/mm²
- Maximum water cement Ratio:0.55
- Adopted Water Cement ratio:0.5 3.8.1 Calculated Mix Design

Table-2: Detailed Mix Proportion

S.NO	Materials	Proportions
1	Water	191.6 lit
2	Cement	383.2 kg/m ³
3	Coarse Aggregate	1087.75 kg/m ³
4	Fine Aggregate	800.94 kg/m ³
5	Calculated proportions	1:2.09:2.83

Table- 3: Replacement of Red Mud:

% Replacement of Red Mud	0	5	10	15	20

Casting, Curing and Testing This involves the testing of hardened and fresh concrete, the concrete cubes tested for 7 days and 28 days curing periods. The moulds were removed and cubes were left in curing tank after 24 hours of casting. The compressive strength tests were carried out in compression testing machine (CTM), and the obtained results were analyzed on the basis of their curing periods

Results and Discussion Tests on Fresh concrete: Slump Cone Test

Table -4: Slump test results without using Hydrated Lime:

% Replacement of Cement by Red mud	Slump Value (mm)	Type of Slump
0%	40	True
5%	38	True
10%	30	True
15%	25.5	True
20%	25	True

Table-5: Slump test results with 5% Hydrated Lime:

% Replacement of Cement by Red mud	% Replacement of Cement by Hydrated Lime	Slump Value (mm)	Type of Slump
0%	0%	40	True
5%	5%	40	True
10%	5%	32.5	True
15%	5%	30	True
20%	5%	27	True

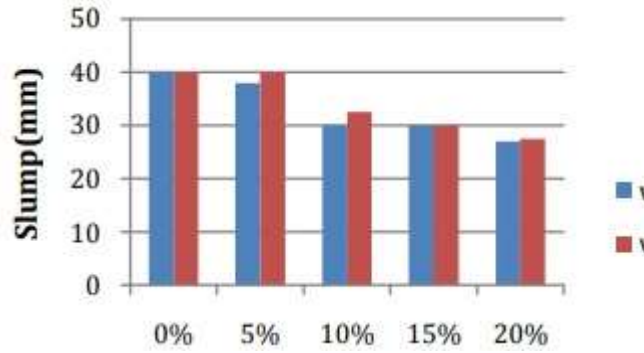


Chart-1 Slump Test Result

Compaction Factor Test: The results of the compaction factor test can be correlated to slump and this relationship is not linear. This test is difficult to run in the field and is not convenient for large size aggregates (greater than 1 inch)

Table-6: Compaction Factor without using Hydrated Lime:

% Replacement of Cement by Red mud	Compaction Factor
0%	0.90
5%	0.89
10%	0.87
15%	0.86
20%	0.85

Table-7: Compaction Factor results with 5% Hydrated Lime:

% Replacement of Cement by Red mud	% Replacement of Cement by Hydrated Lime	Compaction Factor
0%	0%	0.90
5%	5%	0.89
10%	5%	0.89
15%	5%	0.87
20%	5%	0.86

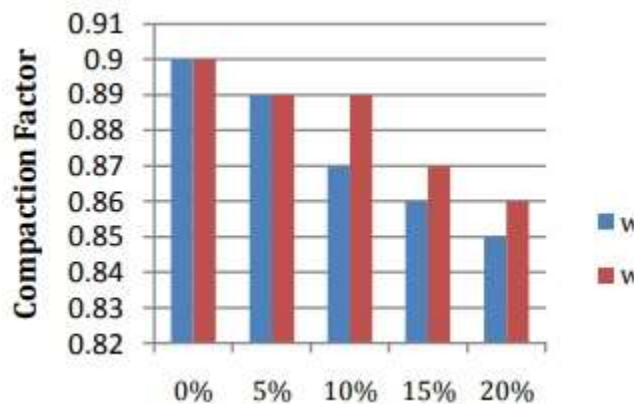


Chart-2 Compaction Factor Test result

Compressive Strength test

Compressive strength test is the most common test conducted on hardened concrete and it is easy to carry out and also most of the desirable characteristic properties of concrete can be determined by this test. The tests are

performed in a compression testing machine. The compressive strength of concrete cubes are tested at 7 and 28 days of curing period.

Table-8: Compressive Strength of Concrete Cubes without using hydrated lime:

% Replacement of cement by Red mud	Compressive strength (N/mm ²)	
	7 days	28 days
0%	28.5	33.4
5%	24.6	30.9
10%	22.5	29.3
15%	21.2	27
20%	18.2	25.1

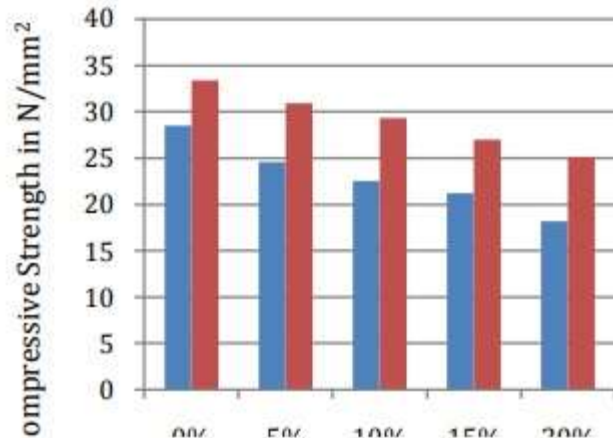


Chart-3 Compressive Strength of Concrete cubes without using hydrated lime

Table-9: Compressive Strength of Concrete Cubes with 5% Hydrated Lime:

% Replacement of Cement by Red mud	% Replacement of Cement by Hydrated Lime	Compressive strength (N/mm ²)	
		7 days	28 days
0%	0%	28.5	33.4
5%	5%	22.5	30.04
10%	5%	21.3	28.8
15%	5%	19.7	26.2
20%	5%	18.6	24.5



Fig -2: Compression Strength Test

4. CONCLUSIONS

Based on the experimental investigation the following conclusion are drawn

- Red Mud absorbs more water as compare to cement, that can be seen by reduction in slump.
- The compressive Strength is decreased by increasing the replacement percentage in each set. Upto 10% replacement the compressive strength of cubes fulfills the acceptance criteria (as per IS 456 2000).
- The cost making of M 25 grade Red Mud Concrete (for 10 % Replacement) is around 4% less than the Conventional Concrete. So we can conclude that Red mud can be effectively used as replacement material for cement and replacement enables the large utilization of waste product.
- The Optimum percentage of the replacement for structural use of cement by weight is found to be 10% of red mud in first set and 10% red mud+5% hydrated lime in second set .For this replacement results got are nearly equal to the results of conventional concrete.
- Finally we can conclude that red mud can be used as a sustainable alternative for cement in construction industry with quality supervision.

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