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# Study and Analysis of Concrete Strength Parameters Using Red Mud as Partial Replacement of Binder Content with and without Hydrated Lime

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**Abstract:** ***The Bayer Process is the method used 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 like landfills, leading to important environmental issues. Based on economics as well as environmental related issues, enormous efforts have been done worldwide towards management red mud in utilization, storage and disposal. In the project an effort is made to assess the strength characteristics of the aluminum red mud as partial replacement for cement in concrete. Specimens were made by adding the red mud as replacement for cement in percentages from 0% to 60% at an internal of 10%. To enhances the binding properties hydrated lime of 5% is added to the mix.***

**Keywords:** Bayer Process, Red mud, Hydrated lime

## 1. Introduction

India is enriched with its mineral resources deposit. India has very long history of the mineral excavation, production and the utilization. India ranked top ten among the countries who produce the mineral. The mineral industries act as a back born of the Indian economy, as the most of the industrial activities relay upon the mineral as the raw materials. In spite of this advantage the mineral industries cause many environmental problems too. The process of mining and the material extraction leads to the waste generation.

Management of the Solid waste generated from the industries and the agriculture is the major problem faced by India. The shortage of land to deposit and the costlier method of recycling demands an alternative way of disposing these solids wastes.

One of the innovative ways to solve these problems is to use the industrial waste in the production of concrete. The use of solid waste in the concrete have the two advantages as the use of the industrial waste makes the concrete more economical and it will solve the problem of the environmental pollution.

Red mud is a byproduct during the manufacturing of the Aluminum. Aluminum is produced from the Bauxite ore. Aluminum is one of the mostly used metal in food packing industry, construction industry, electronics industry, defense and transportation sector. Light weight, high strength and recyclability make it more preferred metal for the industry.

There is various processes for extraction of Aluminum from the Bauxite, such as Sinter Process, Bayer Process, combined process and nephleine process. Among the different methods Bayer Process is the most widely used method for manufacturing of Aluminum. In this process first Bauxite is water washed, powdered and milled at very high pressure and temperature. After this digestion process is carried out. In the process the caustic soda is added to the powdered bauxite ore. During this process sodium aluminate solution and un-dissolved bauxite residue are formed. This bauxite residue contains silicon, iron and titanium and other materials. This Bauxite residue which is highly caustic in nature is called as Red Mud. Usually this red mud is dumped into the residue pond.

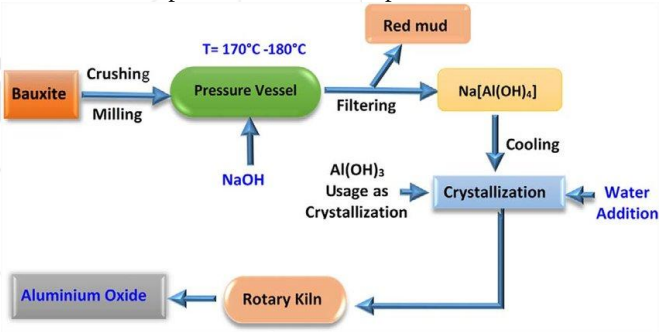


**Figure 1.1** : Bayer Process

The disposal of red mud is an environmentally challenging process as it contains 60% of bauxite. Two tonnes of red mud is produced for each one tone production of alumina. Since the red mud is alkaline in nature it cannot be disposed to air, water or land. Currently the method of disposal for the red mud is done either by dumping in land or in places near the sea. Therefore the disposal of the red mud is major problem of concern from the environmental point of view.

### 1.1 India Current Scenario

As the economic growth in India is continuing, there is huge demand and Consumption of Aluminum in India. India has world 5% Bauxite deposit and therefore has enormous opportunity in the future. As per the studies it is estimated that, in India for production of one tonne of aluminum 5-6 tons of bauxite and 10-14 tons of coal being used. This in turn produces about 3 tons of bauxite waste. Therefore, the

consumption of such huge amount of natural resources and disposal of such large amount of waste creates environmental problems.

## 2. Objectives

1) Reduction in emission of CO in cement manufacturing by replacing it with some cementations materials.
2) Utilization of industrial waste products.
3) Production of more durable and sustainable concrete.
4) Study the effect of red mud as partial replacement the cement on the properties of the concrete in the fresh and hardened state. Also an effort is made to study the effect of red mud with lime and without lime
5) To achieve sustainable development.

## 3. Literature Survey

**(a)Akarsh .N .K [2017]** The study present the work of examines the likelihood of supplanting Portland cement by red mud. As a result of putting away issue, the waste contrarily influences the earth. To tackle this issue, Portland cement was supplanted up to 40% of red mud by weight of cement. The Proprieties of the concrete, like compressive, tensile and flexural strength of red mud concrete were evaluated. This study shows that the addition of red mud on enhances the properties of concrete.

**(b) P. Syam Sai [2017] ,** in this study experiments have been performed to evaluate the quality attributes of the aluminum red mud. Test samples were made with the replacement of 0- 20% at an interval of 50% of red mud and 5% of hydrated lime with cement bond in M40 and M50 grade concrete. To impart cementations property of red mud, hydrated lime is incorporated. This study emphasizes on the promising usage of red mud in the sustainable development.

**(c) Mahin Sha O B [2016],** In this study experiments were done to supplant the cement by red mud in concrete for various rates and to studies its impacts on the quality and different properties of the concrete. The test result shows that the addition of red mud up to 20% shows the properties of the concrete comparable with the conventional concrete.

## 4. Material Testing and Methodology

### 4.1 Materials used and proportion

**Table 4.1:** material properties

| *Material* | *Property* | *Observed value* |
|---|---|---|
| *cement* | Specific gravity | 3.15 |
| | Consistency | 31.5% |
| | Initial Setting Time (I.S.T.) | 33 minutes |
| *Fine Aggregate* | Specific Gravity | 2.65 |
| | Fineness Modulus | 3.23 |
| | Water Absorption, % | 1.08 |
| *Coarse Aggregate* | Specific Gravity | 2.62 |
| | Fineness Modulus | 2.18 |
| | Water Absorption, % | 0.89 |
| *Red Mud* | Size of dry red mud | Less than 44 micron |
| | Specific Gravity | 3.14 |
| | pH | 10.5 to 11 |
| | Density | 2.70 g/cm$^3$ |
| *Superplastisizer* | Conplast-SP430 | |
| *Hydrated Lime* | Specific gravity | 2.25g/cm3 |
| | Bulk density | 220-840 kg/m3 |
| | Appearance | White or off white |
| | Odour | Slight earthy |

**Table 4.2**: mix proportion

| *W/C ratio* | *Cement* | *Fine aggregate* | *Coarse Aggregate* |
|---|---|---|---|
| 0.45 | 383 kg | 557.5kg | 1053kg |
| | 1 | 1.45 | 2.75 |

### 4.2 Test Conducted

#### 4.2.1 Slump Test

Workability is an essential property of the concrete so that compaction can be done with minimum effort. The moisture in the fled condition may vary due to many factors such as error in batching of water, surface moisture in the aggregate and absorption of water by the aggregate. Slump test is the simple test to check the workability of the concrete in the site using an apparatus called as slump cone

#### 4.2.2 Compressive Strength Test

The ability of the concrete to resist the force which is trying to compress it is called as compressive strength. The specimens were cured for 7, 14 and 28 days and tested using Compression Testing Machine (CTM) at the room temperature as per IS 516-1959. The load is applied gradually on the specimen till it fails and the load corresponding to this stage is recorded. To eliminate any error the average value of the three-sample result was taken.

#### 4.2.3 Split Tensile Strength

A well-known method of determine the tensile strength of the concrete indirectly is split tensile strength. The cylindrical specimen prepared is kept horizontally on the CTM machine and the load is applied until the specimen fails. It is estimated that the portion directly under the loading, about 1/6 of depth will be in compression remaining 5/6 of the depth will under tension. The testing is done after 7, 14 and 28 days if the curing. The split tensile strength of the specimen corresponding to the load at failure is calculated

#### 4.2.4 Flexural Strength Test

It is the test conducted check the strength of the concrete to transverse load which causes bending. The test specimens are the beams of od the size 150x150x700mm square beams and which are, subjected to three-point loading. The test is conducted for 7, 14and 28 curing. The load corresponding to the beam failure is calculated and the bending strength or modulus of rupture (fb) is found

#### 4.2.5Carbonation Test

Carbonation of cement is indicating reinforcement corrosion in the RCC. The reaction starts when the $CO_2$, in the atmosphere within the sight of moisture, reacts with hydrated concrete minerals to deliver carbonates, for example, calcium carbonate. The process of carbonation can be explained as the neutralization of the base constituents of cementitious materials via carbonic acid which have been produced by the dissolution of $CO_2$ in the pore the solution of the material.

A commonly used technique for estimation of the depth of carbonation is to apply the newly broken surface of cement with an solution of phenolphthalein in diluted alcohol. If the $Ca(0H)_2$ is unaffected by $CO_2$ the shading ends up being pink. In the event that the solid is carbonated it will stay uncolored. For use as an indicator in the examination, it is dissolved in an appropriate solvalent, for example, ethanol in a 1% arrangement. The one percentage phenolphthalein arrangement is prepared by diluting 1gm of phenolphthalein in 90 cc of ethanol. The liquid is then made up to 100 cc by including neutralized water. The indicator solution was splashed on the newly removed sample (cylindrical) which is exposed to the atmosphere and the uncolored layer depth I measured from the surface preferably at 6 to 8 points. The test is conducted after 7, 28- and 56-days of air cooling.

#### 4.2.6 Sulphate Attack Test

Sulfate attack is a typical in general or industrial structures. Hardened sulfates don't affect the concrete extremely however in the solution form, they find a passage into permeable concrete and respond with the hydrated cement compounds. Of all the sulfates, magnesium sulfate makes the most extreme harm to the concrete. A whitish appearance is the sign of sulfate attack.

The speed of sulfate occurrence accelerates with the expansion of the solution strength. The saturated solution of magnesium sulfate can make major harm to the concrete with high W/C in a shorter span of time. In case the concrete is manufactured with low W/C proportion, it can resist the activity of magnesium sulfate for 2 or 3 years. In this project samples were kept at 5% of magnesium sulfate solution and compressive strength test was completed at 7, 28 and 56 days of restoring in $MgS0_4$ solution.

## 5. Results and Discussion

### 5.1 Slump Test

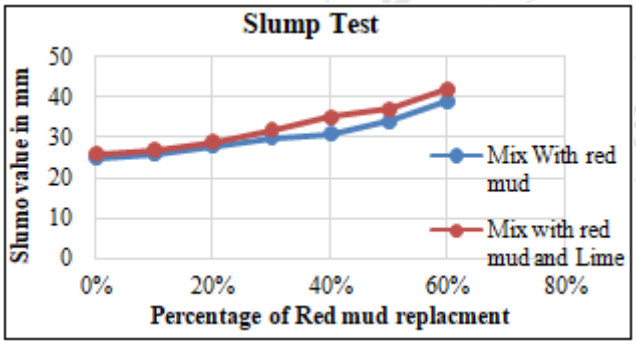


**Figure 5.1:** Slump Test

It can be seen that the slump value of the concrete made with red as replacement to the cement is more than that of the Control Mix. It can be seen that as the replacement level of red mud increases the slump value also increase. The mix with lime shows more slump value as compared to the mix without lime. The increase in the slump value leads to increase in the water requirement. The increase in the demand of water is due to the fact that the red mud is lighter than the cement and it contains finer particle and it occupies more volume in the concrete.

### 5.1 Compressive Strength

The samples with red mud show comparable result as the control mix at 28 days of curing for 10% of replacement of red mud. Also, we can see that the specimen with hydrated lime shows higher compressive strength as compared to the specimens without hydrated lime. The variation in the strength for the control mix and the mix with hydrated lime is only 5%. It can be also observed that as the replacement level of the red mud increases the compressive strength reduces for the both cases with and without hydrated lime. The strength reduction is around 27% as compared to the control mix. It can be concluded that the concrete with lower red mud content shows the better result and the optimum percentage of replacement can be 30%. The addition of hydrated lime enhances the compressive strength.

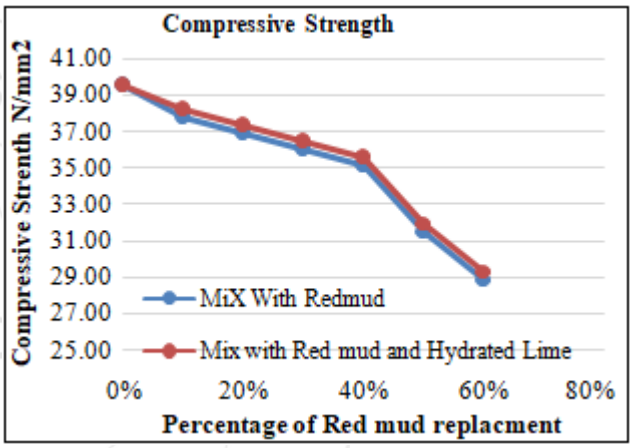


**Figure 5.2:** Comparison of Compressive Strength

### 5.2 Split Tensile Strength

As the percentage of red mud increase the split tensile strength reduces. The addition of the hydrated lime improves the split tensile strength as compared to the sample without Hydrated lime. The results are comparable with red mud replacement up to 30%, thereafter the values are drastically reducing. So, the optimum dosage of red mud can be 20-30% with addition of the hydrated lime.

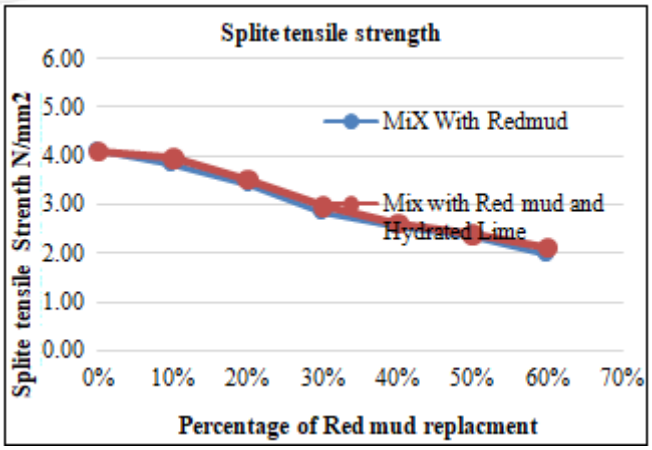


**Figure 5.3:** Comparison of Split Tensile Strength

### 5.3 Flexural Strength

As the percentage of the red mud is increases the flexural strength reduces. For the control mix the flexural resistance is 7.2 N/mm$^2$ and for the Mix with10 % replace of red mud is 5.62 N/mm$^2$. The addition of hydrated lime enhances the flexural strength to 6.45 N/mm$^2$. If the red mud is added more than 20% the flexural strength is drastically reduces. So that optimum dosage of the red mud is 20% with the hydrated lime gives the better strength as compared to other mixes.

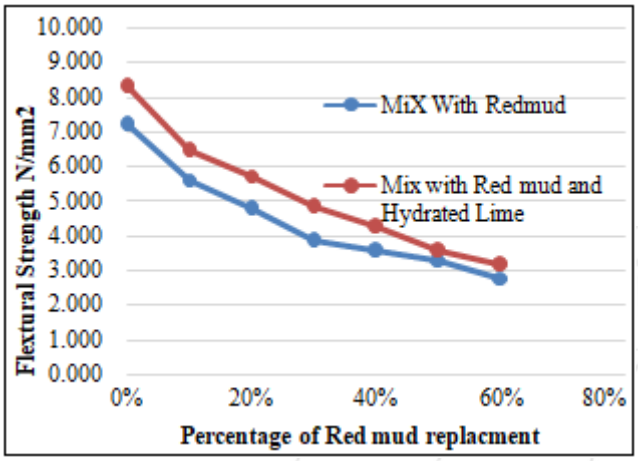


**Figure 5.4:** comparison of flexural strength

### 5.4 Carbonation Test

It can be seen that depth of carbonation was only can be seen for just for mixes with lower red mud content. The mix with higher red mud content does not appear any event of carbonation. As the substance of red mud expanded in concrete, depth of carbonation reduced. It might be because of higher fineness of red mud which makes the concrete denser than control blend and furthermore because of the presence of oxides of Al, Fe, Na, Ti and so forth. Consequently, the expansion of red mud diminishes the corrosion capability of concrete and results are positive in nature. The same trend can be seen in case of the mix with hydrated lime, but the strength is little much higher than that of the sample with red mud alone.

### 5.5 Sulphate Resistance Test

Specimens were taken out from water curing tank at 28 days and put into the 5% magnesium sulfate solution and compressive strength test was performed at 7, 28 and 56 days of ponding in sulfate solution to assess the impact of sulfate effect on concrete.

The variation in the strength after 7 days curing is less as compared to 28 and 56 days. Also, as the red mud content increase the variation in the strength is diminishes. This will be due the less pores present in the mix, because finer red mud will occupy the pores and make the concrete denser and also high content of Al, Fe, Na, Ti etc will be a factor for this result.

## 6. Inference

It was seen from the test consequences of fresh properties that affinity to water increments with the increasing the amount of red mud. This expansion in demand of water is expected to the way that the red mud being marginally lighter in weight has better particles and possesses more volume which need more water for a similar consistency. The incrementing the content of red mud reduces the strength properties of the concrete; however there is possibility of utilizing red mud in concrete in sustainable development. Carbonation rate reduces with the expansion in red mud content. This shows that, red mud exhibited higher resistivity to corrosion. The addition of red mud makes the concrete resistive to sulphate attack. The optimum content of the red mud replacement is 20%. The use of red md in concrete can be a best option to reduce the environmental pollution and the reduction of carbon foot print by the construction industry.

## 7. Future Scope of Study

1) In this test untreated red mud is used the study can be further carried out by adding neutralized red mud and the properties can be checked.
2) Further study can be made by addition materials such as fly ash or GGBS can be added with red mud and properties can be studied

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