

# Study on Mechanical Properties of Red Mud as a Partial Replacement of Cement with Hydrated Lime in the Production of Concrete

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**ABSTRACT:** Rapid industrialization in the world leads to the maximum discharge of waste products which in turn causing the effects and hazards to environment. In this project work red mud waste is partially replaced with cement and the strength and durability parameters are evaluated by utilizing it in a best way. Red Mud is a waste generated by the aluminum industry in a Bayer's process Availability of raw material required for manufacturing of cement and production of concrete are less and require more energy for production. This increased demand cause fast depletion in resources. To overcome this situation it is very important to utilize the industrial waste materials and by-products for the manufacture of cement and in concrete construction. Here in this work by considering the cementations behaviour of red mud, an experiment was carried out to replace the Portland Cement by red mud and hydrated lime for M20 grade of concrete for variable percentages and also there effects on the strength. Present study is mainly focused on the compressive strength, split tensile strength, flexural strength. However, when used in combination with 30% red mud, cement and 5% lime the composites shows significant compressive strength of 27.3N/mm<sup>2</sup> for M20. Tensile strength of 2.60 N/mm<sup>2</sup> for M20 grade of concrete. Selected combination of mix is later used to produce beam of size 500 x 100 x 100mm. These beams are tested for flexural strength of results 2.4 N/mm<sup>2</sup> and 3.29 N/mm<sup>2</sup> for M20. From this study it is revealed that 30% replacement of red mud along with 5% hydrated lime is found to be optimum.

**KEYWORDS:** Red mud, Hydrated lime, Grade concrete, Mechanical properties of concrete.

## I. INTRODUCTION

Concrete is the primary construction material used around the world and most widely used in all types of civil engineering works and it is a man-made product, essentially consisting of cement, aggregates, water and admixtures. Concrete in spite of being the most popular and most economical construction material has major shortcomings in terms of embedded energy and is also one of the major causes of greenhouse gas effect. However, the production of cement leads to the dissipation of significant amount of carbon dioxide, & greenhouse gas emission. One ton of Portland cement clinker production creates one ton of carbon dioxide and other greenhouse gases. To reduce the emission of carbon dioxide concerning the production of cement, we must reduce the usage of cement, and therefore the demand of Portland cement. Therefore, there is a need to look for alternate types of materials. The carbon dioxide emissions associated with the manufacturing of Portland cement can be reduced significantly by reducing the production of current clinker. In this project loss in production of Portland cement can be overcome by the increased use of red mud in different percentages with hydrated lime and super plasticizers.

## II. OBJECTIVES OF THE STUDY

The experimental investigation was carried out to solve the problems due to huge requirement of the raw material in nature for the manufacturing of conventional building material and also to reduce hazards caused by wastes of industries on the environment. The finding of alternate low-cost and environment sustainable building materials from industrial residue is a best economic way to overcome from problems and hazards. Importance must be given to cheap,

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locally available and environmental friendly building materials and hence it is very necessary to utilize & check out the suitable waste products during the construction process.

The major objectives of this study were

1. To determine the process for production of red mud concrete for M20 grade.
2. To show the advantage of strength gained by red mud usage along with hydrated lime.
3. To extend and to know the strength properties of red mud concrete in terms of compression, tensile and flexural parameters.

## III. METHODOLOGY

### 3.1 GENERAL

1. The materials are to be collected and the properties of material are to be studied as per standards mentioned in IS codes.
2. Investigate the chemical composition of the red mud, lime and also its characteristic behaviour when it is replaced with cement.
3. Using these properties, mix design is to be prepared with suitable w/c ratio for M20 grade of concrete.
4. Required slump can be obtained experimentally by slump cone test and compaction factor test for Red mud and lime replacement with cement in percentages
5. Production of concrete cubes for both M20 grade of size 150mm x 150 mm, beams and cylinders of 150mm diameter and 300 mm length to determine the compressive, flexural and split tensile strength of respective specimens. The samples will be tested at 7, 14 & 28 days age of different proportions of red mud with hydrated lime.
6. Graphs are plotted using test results and conclusions are to be made based on test results.

### 3.2 CHARACTERIZATION OF CONSTITUENT MATERIALS

**3.2.1 CEMENT :-** Ordinary Portland cement of 53 grade was used in this study. The cement was tested according to IS: 12269-1987. Different test were carried out on the cement to ensure that it confirms to the requirements of the IS: 12269-1987 specifications.

Table 3.1: Physical properties of the cement

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

**3.2.2 RED MUD:-** The Red mud used for the replacement of cement is brought from Hindalco Steel industry Belgaum, Obtained from 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 3.2: Characteristics of red mud

Sl. no	Characteristics	Values
1	Specific gravity	2.83
2	Ph	10-12.5

**3.2.3 FINE AGGREGATE:-** Locally available sand is used as a fine aggregate

Table 3.3: Properties of fine aggregate

Property	Value
Specific gravity	2.41
Sieve analysis	Zone II
water absorption	1.2%
Silt content	4.5%

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### 3.2.4 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 3.4: Properties of coarse aggregate

Property	Value
Specific gravity	2.69
water absorption	0.48%

### 3.2.5 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.

### 3.2.6 HYDRATED LIME

Hydrated lime is a type of dry powder made from limestone. It is created by adding water to quicklime to made oxides into hydroxides. Its chemical name is  $\text{Ca(OH)}_2$

## IV. EXPERIMENTAL INVESTIGATION

### 4.1 MIX DESIGN FOR M20 GRADE

The mix design procedure adopted to obtain a M20 grade concrete is in accordance with IS 10262- 2009. The details are stipulated as below

MIX DESIGN- As per IS 10262:2009		
Sl. No.	Stipulations for Proportioning	
1	Grade Designation	M20
2	Type of Cement	OPC 53 grade confirming to IS-12269-1987
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content	320 kg/ m <sup>3</sup>
5	Maximum Water Cement Ratio	0.55
6	Workability	75 mm (Slump)
7	Exposure Condition	Mild
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate
10	Maximum Cement Content	450 kg/ m <sup>3</sup>

### 4.2 Mix proportion

W/C ratio	Cement	Fine aggregate	Coarse aggregate
0.50	383	557.39 kg	1052.90 kg
	<b>1</b>	<b>1.45</b>	<b>2.75</b>

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## 4.3 SLUMP TEST:-

The vertical settlement of the fresh concrete is known as slump.

Table 4.1: Slump values for M20 Grade without adding super plasticizer.

Red Mud Replacement in %	Hydrated Lime in %	Slump Value	Type of Slump
20	5	20mm	True
25	5	20.5mm	True
30	5	22.5mm	True
35	5	25mm	True
40	5	27.5mm	True

## 4.4 COMPACTION FACTOR TEST

Table 4.2: Compaction Factor for M20 Grade of red mud Concrete

Red Mud Replacement in %	Hydrated Lime in %	Compaction factor M20 grade
20	5	0.81
25	5	0.81
30	5	0.89
35	5	0.96
40	5	1.21

For all % replacement an average compaction factor is within the range

## 4.5 COMPRESSION TEST

- 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 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,

$$f_c = P/A$$

Where,

$f_c$  = Cube Compressive strength in  $N/mm^2$

$P$  = Cube Compressive load causing failure in  $N$

$A$  = Cross sectional area of cube in  $mm^2$

## 4.6 SPLIT TENSILE TEST

- The split tensile test is carried out on the cylindrical mould of dia 150mm and length 300mm.
- The inner surface of mould is coated with oil and is placed on Plate.
- The moulds are prepared by filling concrete in five layers and each layer was tamped with twenty five strokes of the tamping rod of dia 16mm. The top surface is finished using trowel.
- After 24 hours concrete cylinders are demoulded and the specimens are kept in water for curing.
- At each desired curing period (7days and 28days) specimens are taken out from water and dried.
- The cylinders are tested in compression testing machine, applying the load diametrically to get the split tensile strength of concrete.
- The split tensile strength corresponding to failure of the specimen is calculated using the formula

$$f_{st} = 2P/(\pi DL)$$

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Where,

$f_{st}$  = Split tensile strength of concrete in  $N/mm^2$

$P$  is the load at failure in N.

$D$  is the diameter of the specimen in mm

$L$  is the length of the specimen in mm.



Fig 4.1: Split Tensile Test for cylinder

### 4.7. FLEXURAL TEST

The flexural test is carried out on the beam moulds of size 500mmx100mmx100mm.

- Concrete is poured in two layers, after each layer was poured it was compacted using needle vibrator.
- The beams were remoulded after 24hours, and then the beams were kept for curing under water for 28 days.
- After 28 days of curing the beams were removed from the water and dried.
- Testing of beam Specimens are carried out by compression testing machine, cleaning and white washing with a thin coat of lime to facilitate the detection of cracks and the propagation of cracks.
- The position at which single point loads are to be applied and the center of the beams were marked.
- The flexural strength corresponding to failure of the specimen is calculated using the formula.

$$F_b = PL/(bd^2)$$

Where,

$F_b$  = flexural strength of concrete in  $N/mm^2$

$P$  is the load at failure in N.

$b$  is the diameter of the specimen in mm.

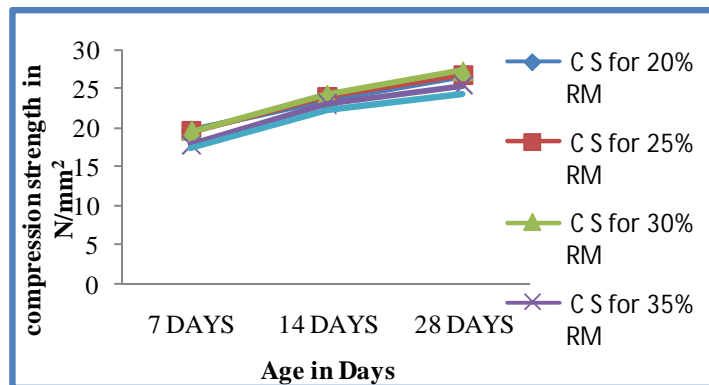
$d$  is the length of the specimen in mm.



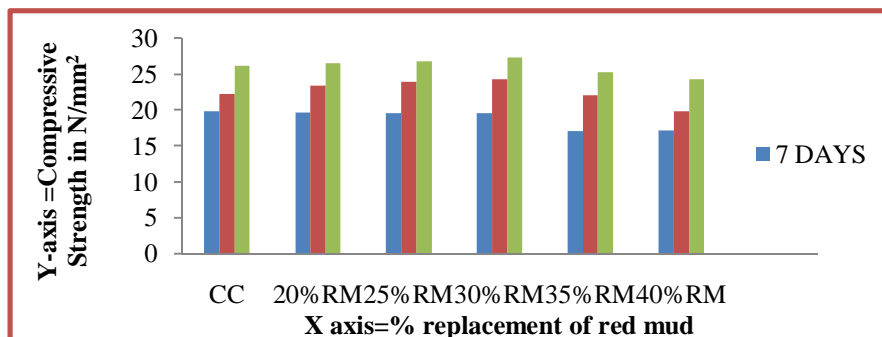
Fig 4.2: Flexural Test for Beam

## V. RESULTS AND DISCUSSIONS

### 5.1 COMPRESSION TEST RESULTS



Graph 5.1: Compressive Strength of M20 Grade Red Mud Concrete at 7, 14, 28days.



Graph 5.2: Compressive Strength of M 20 Grade red mud concrete for 7, 14 & 28days.

- At 30% replacement of red mud with concrete achieved higher compressive strength
- Till 30% replacement the compressive strength increases with increasing red mud content
- Increase in the replacement of cement with hydrated lime leads to decreasing in its strength up to 15 to 18%

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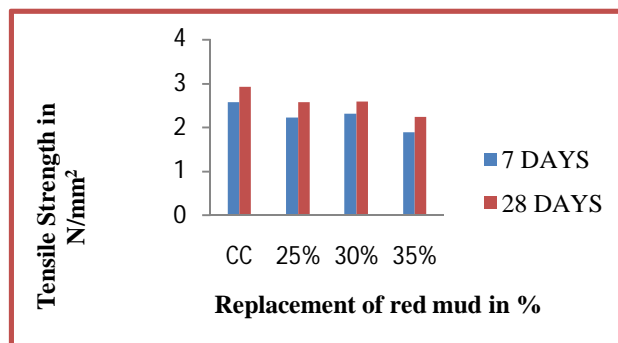
### 5.2 SPLIT TENSILE STRENGTH TEST RESULTS

Sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) $A = \pi DL$ mm <sup>2</sup>	Tensile strength (F=2P/A) N/mm <sup>2</sup>	Average Tensile Strength N/mm <sup>2</sup>
1	25%	170	141372	2.38	2.43
		176		2.46	
		175		2.45	
2	30%	180	141372	2.52	2.51
		179		2.50	
		178		2.49	
3	35%	162	141372	2.26	2.2
		160		2.24	
		159		2.22	

Table 5.1: Tensile Strength of red mud concrete of M20 grade for 7 days.

Sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) $A = \pi DL$ mm <sup>2</sup>	Tensile strength (F=2P/A) N/mm <sup>2</sup>	Average Tensile Strength N/mm <sup>2</sup>
1	25%	182	141372	2.54	2.58
		189		2.64	
		184		2.57	
2	30%	187	141372	2.61	2.60
		188		2.63	
		184.2		2.57	
3	35%	168	141372	2.3	2.24
		163		2.2	
		160		2.24	

Table 5.2: Tensile Strength of red mud concrete of M20 grade for 28 days.



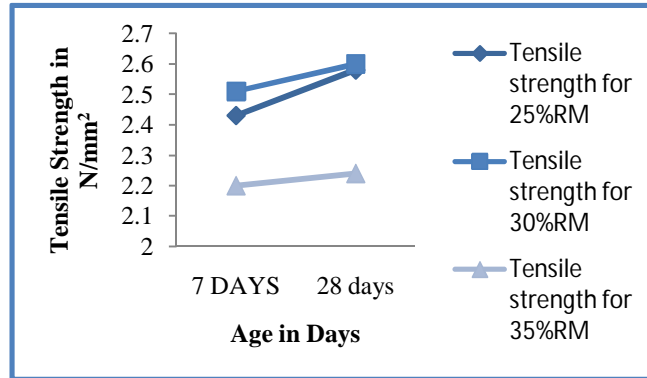
Graph 5.3: Split tensile Strength of M 20 Grade red mud concrete for 7&28 days.



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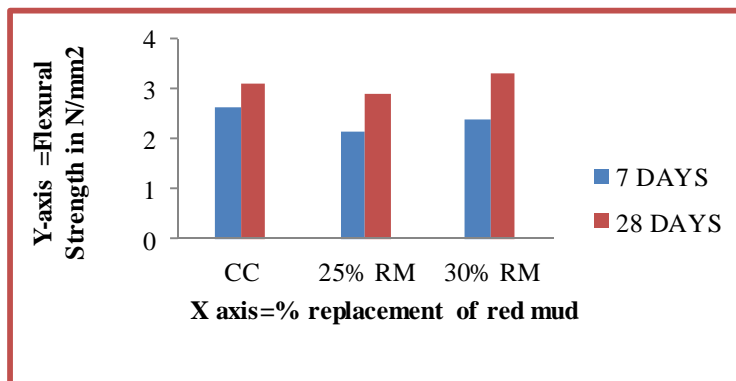


Graph 5.4: Split tensile Strength of M 20 Grade red mud

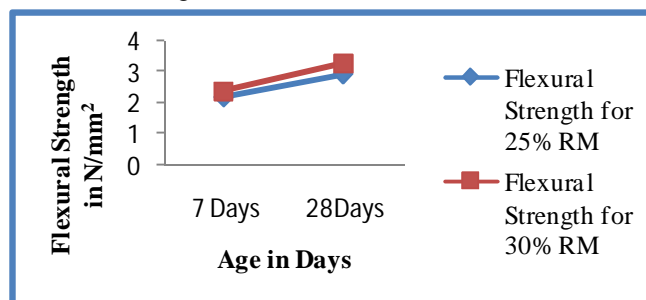
1. The split tensile strength of M20 grade red mud concrete results are observed at 7 and 28 days respectively.
2. Split tensile strength is higher at the replacement of 30% for both M20 as shown in the table and graph.
3. After 30% replacement the split tensile strength decreases with increasing replacement of red mud with concrete.

### 5.3 FLEXURAL STRENGTH TEST RESULTS

1. Flexural strength of M20 grade red mud concrete results are observed at 7 and 28 days respectively.
2. Flexural tensile strength is increasing up to the replacement of 30% for both M20 grade of red mud concrete as shown in the graph.
3. After 30% replacement the Flexural tensile strength decreases with increasing replacement of red mud with concrete.



Graph 5.5: Flexural Strength of M 20 Grade Red Mud Concrete for 7 & 28 days.



Graph 5.6: Flexural Strength of M 20 Grade Red Mud Concrete at 28 days.



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## VI. CONCLUSIONS

1. Optimum percentage replacement of red mud with cement by weight is found to be 30%, it is due to the increased pozzolonic property of cement due to addition of red mud in case of M20 concrete.
2. Strength results of 30% of red mud replacement concrete shows almost same results of conventional concrete of respective M20 grade concrete.
3. 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 30% replacement for M20 grade concrete.
4. After 30% replacement of red mud, the increased quantity of red mud decreases all the strength parameters and workability of the concrete for M20 grade concrete.
5. Water absorption of concrete increases with increased percentage of red mud.
6. Increased percentage of red mud increases the water absorption and decreases the strength of concrete.
7. Use of red mud, and hydrated lime in the production of concrete is showing the same strength properties as in case of conventional concrete for M20, due to presence of  $Al_2O_3$  and  $SiO_2$  in red mud and argillaceous content of hydrated lime.

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