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Comparison on Durability Properties of Red Mud as a Partial Replacement of Cement with Hydrated Lime for Different Grades of Concrete with and without Superplasticiser

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***Abstract* - In this research an attempt has been made to produce different grades of concrete using huge industrial waste such as red mud as a partial replacement of cement with the hydrated lime. This project presents the results of investigation on production of concrete members using a combination of materials which predominantly includes red mud and lime. The present study is mainly focused on the compressive strength, split tensile strength, flexural strength and durability properties of concrete, which are the important parameters to be studied in concrete production of different proportion of raw materials for different grades of concrete. However, when used in combination with 30% red mud, cement and 5% lime the composites shows significant compressive strength of 27.3N/mm^2 and 50.05 N/mm^2 for M20 and M40 grade of concrete. Tensile strength of 2.60 N/mm^2, 4.98 N/mm^2 for M20 and M40 grade of concrete. These beams are tested for flexural strength of results 2.4 N/mm^2 and 3.29 N/mm^2 for M20 and M40 grade of concrete. From this study it is revealed that 30% replacement of red mud along with 5% hydrated lime is found to be optimum. Durability tests are conducted.**

Key Words: Red mud, super plasticiser, Hydrated lime, Different grades of concrete.

I. INTRODUCTION

Red mud is a by-product of the Bayer's process, which is obtained from the production of alumina from bauxite ore. Bauxite ore is washed and crushed and it is treated with hydroxide solution at high pressure and temperature. This process gives all the reusable alumina from bauxite ore into solution and the byproduct is known as red mud. For every byproduct of alumina produced by this process, make some part of red mud as a waste. In all the countries, about 45 million tons of Red mud is produced yearly. Due to its hazards nature, it affects environment majorly. Disposal of this waste was the most major problem faced by the alumina industry after the adoption of the Bayer process. The conventional method of disposal of red mud in ponds and pits has put adverse effect on environment. During rainy seasons, the waste may be carried by run of to the surface water which leads to the ground water contamination. Further disposal of huge amount of Red mud creates problem to the disposal site.

II. OBJECTIVES OF THE STUDY

- To determine the process for production of red mud concrete for different grades.
- To show the advantage of strength gained by red mud usage along with hydrated lime.
- To extend and to know the strength properties of red mud concrete in terms of compression, tensile and flexural parameters.
- To develop the process for production of cubes for durability parameters such as saturated water absorption, acid attack and carbonation tests.

III. METHODOLOGY

- The materials are to be collected and the properties of material are to be studied as per standards mentioned in IS codes.
- Investigate the chemical composition of the red mud, lime and also its characteristic behaviour when it is replaced with cement.
- Using these properties, mix design is to be carried out with suitable w/c ratio for M20 and M40 grade of concrete.
- Required slump can be obtained experimentally by slump cone test and compaction factor test for Red mud and lime replacement with cement in percentages

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- Production of concrete cubes for both M20 & M40 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 28 days age of different proportions of red mud with hydrated lime.
- Graphs are plotted using test results and conclusions are to be made based on test results.
- For both M20 & M40 grade of concrete durability aspects are carried out at 28 and 56 days.

A. GENERAL

The materials used in the experiment

1. Ordinary Portland cement (Grade 53)
2. Red mud
3. Fine aggregate
4. Coarse aggregate
5. Water
6. Hydrated lime
7. Super plasticizer (Conplast SP430)

B. CHARACTERIZATION OF CONSTITUENT MATERIALS

1) CEMENT

Ordinary Portland cement of 53 grade was used in this study.

Table 1: Physical properties of the cement

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

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.

Table 2: Characteristics of red mud

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

3) FINE AGGREGATE

Locally available sand is used as a fine aggregate

Table 3: Properties of fine aggregate

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

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 4: Properties of coarse aggregate

Property	Value
Specific gravity	2.69
water absorption	0.48%

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.

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 $Ca(OH)_2$

7) SUPERPLASTICISER CONPLASTSP430:

Conplast SP430 is a super plasticizing admixture. Conplast SP430 is a Sulphonated naphthalene polymer based admixture and is supplied as a brown liquid instantly assorted in water. Conplast SP430 has been manufactured to give high water reductions unto 25% without loss of workability and produce high quality concrete of reduced permeability.

IV. EXPERIMENTAL INVESTIGATION

A. Mix design for M20 grade

The mix design procedure adopted to obtain a M20 and M40 grade concrete is in accordance with IS 10262- 2009. The details are stipulated as below

MIX DESIGN- As per IS 10262:2009		
A1	Stipulations for Proportioning	
1	Grade Designation	M20, M40
2	Type of Cement	OPC 53 grade
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content	320 kg/ m^3
5	Maximum Water Cement Ratio	M20-0.55, M40-0.45
6	Workability	M20-75 mm (Slump), M40-100mm
7	Exposure Condition	M20-Mild, M40-Severe
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate
10	Maximum Cement Content	450 kg/ m^3

B.Mix proportion – M20

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

Mix proportion – M40

W/C ratio	Cement	Fine aggregate	Coarse aggregate	Admixture
0.42	353	778.67 kg	1097.24 kg	7.06
	1	2.2	3.11	0.02

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C. SLUMP TEST

Table 5: 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

Table 6: Slump values for M40 Grade with the addition of conplast sp430

Red Mud % Replacement	Hydrated Lime in %	Slump Value	Type of Slump
20	5	18mm	True
25	5	20mm	True
30	5	20mm	True
35	5	21.8mm	True
40	5	25mm	True

D. COMPACTION FACTOR TEST

- The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of fully compacted concrete.
- It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of fully compacted volume.
- The results of compaction factor test can be correlated to slump.

$$\text{Compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

Table 7: Compaction Factor for M20 and M40 Grade of red mud Concrete

Red Mud Replacement in %	Hydrated Lime in %	Compaction factor M20 grade	Compaction factor M40 grade with Conplast SP430
20	5	0.81	0.82
25	5	0.81	0.82
30	5	0.89	0.86
35	5	0.96	0.92
40	5	1.21	0.98

For all % Replacement an average compaction factor is within the range.

E. DURABLITY TEST

1) SATURATED WATER ABSORPTION TEST

- Cubes of dimensions 150 x 150 x 150 mm were cast.
- The specimens were dried in an oven at a temperature of 105ºC to constant mass. Then weight was taken (W_1).
- After cooling down to room temperature the specimen were immersed in water. The specimens were removed out of water at regular interval of time and weighed(W_2).
- The process was continued till weight becomes constant (Fully saturated).The difference between water saturated mass and oven dried mass gives the saturated water absorption (SWA).
- The Saturated water absorption is calculated as follows

$$SWA = \frac{W2 - W1}{W2} \text{x} 100$$

Where,
W_1= Oven dried weight of specimen
W_2= Weight of fully saturated specimen

2) ACID RESISTANCE TEST

Cubes of sizes 150mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack test take 1% of dilute sulfuric acid. The cubes were to be immersed in acid solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The specimen was tested in the compression testing machine under a uniform rate of loading 140 kg/cm2 as per IS 516.By this test mass loss and strength of specimen due to acid attack was determined.

3)CARBONATION TEST

The method of testing consists of determining the depth of carbonated deposit on the surface of hardened concrete by means of an indicator.
Steps involved in carbonation test:

- Take a solution of 1% phenolphthalein in 70% ethyl alcohol
- Spray the indicator all over the concrete split specimen which is subjected to carbonation

Phenolphthalein solution turns non-carbonated surface to red colour and remains colorless in the area of carbonated concrete.

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V RESULTS AND DISCUSSION

A) SATURATED WATER ABSORPTION TEST

Table 8: Test results on saturated water absorption for M20 Grade concrete after 28 days

Percentage replacement of red mud	Wt. of cubes before immersion W_1(Kg)	Wt. of cubes after immersion W_2(Kg)	SWA in %	Compressive Strength N/mm^2	Loss in Compressive Strength (%)
25%	8.41	8.59	1.17	23.01	9.7%
	8.52	8.61	1.05		
	8.50	8.62	1.41		
	Average SWA		1.21		
30%	8.48	8.60	1.41	23.18	10.09%
	8.51	8.62	1.29		
	8.52	8.64	1.40		
	Average SWA		1.36		
35%	8.52	8.66	1.84	21.22	21.02%
	8.51	8.68	1.99		
	8.51	8.69	2.11		
	Average SWA		1.98		

Graph 1: Saturated Water Absorption test result after 28 days for M20 Grade

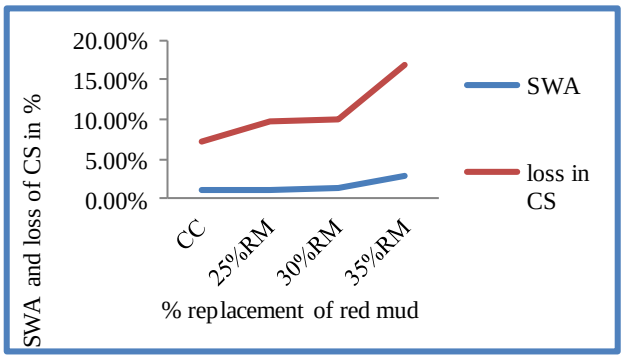
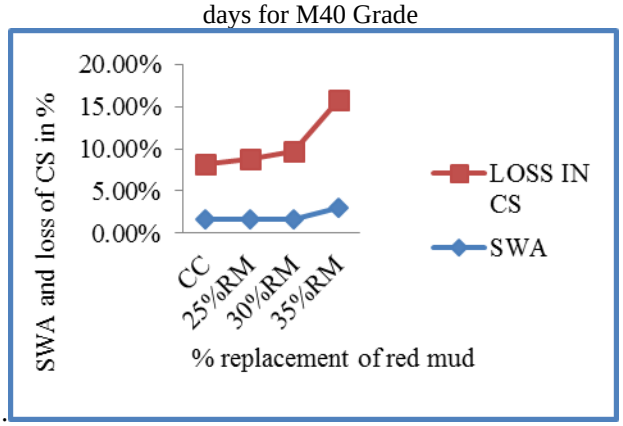


Table 9: Test results on saturated water absorption for M40 Grade concrete after 28 days

Percentage replacement of red mud	Wt. of cubes before immersion W_1(Kg)	Wt. of cubes after immersion W_2(Kg)	SWA %	Compressive Strength N/mm^2	Loss in Compressive Strength (%)
25%	8.47	8.59	1.41	46.2	7.2%
	8.46	8.60	1.65	45.6	
	8.41	8.57	1.90	45.9	
	Average SWA		1.65	Avg loss in CS	
30%	8.49	8.68	2.2	46.02	8.09%
	8.44	8.56	1.42	46.12	
	8.50	8.62	1.41	45.89	
	Average SWA		1.67	Avg loss in CS	
35%	8.51	8.69	2.11	40.13	12.76%
	8.52	8.68	1.97	39.91	
	8.53	8.69	1.97	41.03	
	Average SWA		2.01	Avg loss in CS	

Graph 2: Saturated Water Absorption test result after 28 days for M40 Grade



- From the test results the maximum percentage replacement of red mud and hydrated lime with the cement is obtained as 30%
- Up to the 30% replacement the water absorption is relatively small, after this range the water absorption gradually increases with increasing replacement of red mud.
- The loss in compressive strength of cubes is calculated for all the replacement, hear also a drastic increase in loss of compressive strength after optimum percentage replacement is crossed.
- The test results for 25%, 30% & 35% of SWA and loss in compressive strength is as shown in tables and graphs.

B. Acid Resistance Test

Table 10:Acid Effect of M20 Concrete for 56 Days

% replacement of red mud	Avg Wt Before Immersion (kg)	Avg Wt After Immersion (kg)	Loss in Weight (%)	Compression strength in N/mm^2	Loss in Compressive Strength
25%	8.49	8.39	1.17	23.98	8.6%
	8.52	8.43	1.1	24.08	
	8.52	8.41	1.29	24.61	
	Average wt. loss in %		1.18	Avg loss in CS	
30%	8.55	8.42	1.52	24.51	8.7%
	8.53	8.40	1.52	24.01	
	8.51	8.36	1.76	24.9	
	Average wt. loss in %		1.62	Avg loss in CS	
35%	8.56	8.40	1.86	19.8	17.7%
	8.59	8.36	2.6	20.01	
	8.61	8.41	2.3	20.04	
	Average wt. loss in %		2.25	Avg loss in CS	

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Graph 3: Acid attack test result after 56 days for M20 Grade.

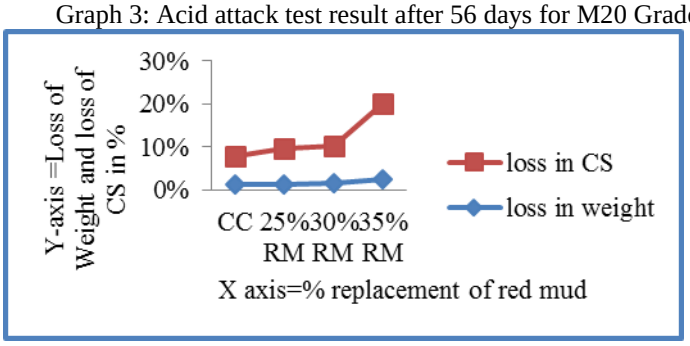
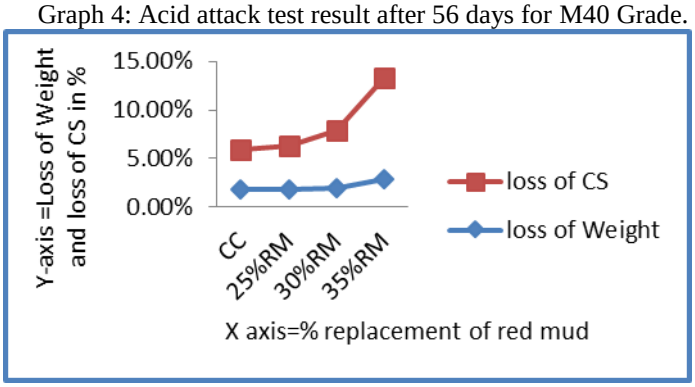


Table 11: Acid Effect of M40 Concrete for 56 Days

Percentage replacement of red mud	Average Weight Before Immersion (kg)	Average Weight After Immersion (kg	Loss in Weight (%)	Compressive Strength in N/mm^2	Loss in Compressive Strength (%)
25%	8.57	8.41	1.90	46.91	4.5%
	8.53	8.40	1.52	46.99	
	8.58	8.40	2.09	46.71	
	Average wt loss in %		1.83	Avg loss in CS	
30%	8.54	8.42	1.72	46.98	6%
	8.59	8.43	1.8	47.01	
	8.59	8.40	2.2	47.11	
	Average wt loss in %		1.90	Avg loss in CS	
35%	8.61	8.43	2.09	40.13	10.36%
	8.60	8.40	2.32	41.23	
	8.63	8.46	1.96	40.89	
	Average wt loss in %		2.12	Avg loss in CS	

Graph 4: Acid attack test result after 56 days for M40 Grade.



- From the test results the maximum percentage replacement of red mud and hydrated lime with the cement is obtained as 30% by treating with sulphuric acid.
- Up to the 30% replacement the weight loss is of small amount, after this range the weight loss of cubes gradually increases with increasing replacement of red mud.
- The loss in compressive strength of cubes is calculated for all the replacement, hear also a drastic increase in loss of compressive strength after optimum percentage replacement is crossed.
- The test results for 25%, 30% & 35% of average weight loss in cubes and loss in compressive strength is as shown in tables and graphs.

C. TEST RESULTS ON CARBONATION EFFECT

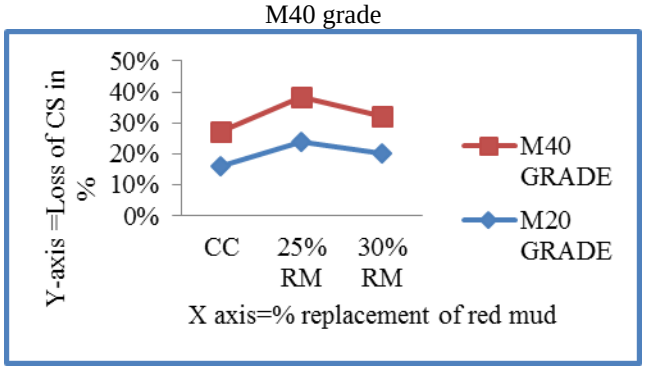
Table 12: Results on carbonation effect of red mud concrete of M20 grade

Red mud replacement in %	Compressive strength N/mm^2	Loss in Compressive Strength (%)
25%	19.8	24%
30%	21.8	20

Table 13: Results on carbonation effect of red mud concrete of M40 grade

Red mud replacement in %	Compressive strength N/mm^2	Loss in Compressive Strength (%)
25%	42.1	14.37%
30%	43.8	12%

Graph 5: carbonation effect of red mud concrete of M20 & M40 grade



- By this result it can be concluded that more weight loss is observed in compressive strength of 25% and 30% as tabulated in tables.
- The loss in compressive strength of cubes is calculated for 25% and30%replacement of red mud for both M20 and M40 grade. The test results for 25% and 30% of average loss in compressive strength.
- From the test results carbon effected area is observed by seeing the unchanged colour on the surface of cubes when it is treated with the solution of phenolphthalein and ethyl alcohol.

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 both in case of M20 and M40grade concrete.
2. Strength results of 30% of red mud replacement concrete shows almost same results of conventional concrete of respective M20 and M40 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 both for M20 and M40 grade concrete..

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4. After 30% replacement of red mud, the increased quantity of red mud decreases all the strength parameters and workability of the concrete both for M20 and M40 grade concrete.
5. The addition of super plasticizer for M40 grade concrete increases workability.
6. The addition of lime is contributing to enhancement of pozzolonic property of concrete both for M20 and M40 grade concrete.
7. Water absorption of concrete increases with increased percentage of red mud.
8. Increased percentage of red mud increases the water absorption and decreases the strength of concrete.
9. 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 both M20 and M40 grades, due to presence of Al_2O_3 and SiO_2 in red mud and argillaceous content of hydrated lime.

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