STUDY ON MECHANICAL PROPERTIES OF RED MUD AS A PARTIAL REPLACEMENT OF CEMENT WITH HYDRATED LIME FOR M40 GRADE CONCRETE WITH SUPERPLASTICISER

Sowmyashree T[1], Arpitha D J[2], Manjunath C S[3], Siddu Karthik C S[4]

[1]*Assistant professor, Department of Civil Engineering, Vijaya Vittala Institute of Technology, Bangalore.*
[2]*Department of Civil Engineering, Sapthagiri College of Engineering, Bangalore.*
[3]*Assistant professor, Department of Civil Engineering, Vijaya Vittala Institute of Technology, Bangalore.*
[4]*Assistant professor, Department of Civil Engineering, Vijaya Vittala Institute of Technology, Bangalore.*

Abstract

Now construction industry is full advanced due to which within short period of time tremendous increase in the utilization of cement and concrete for various construction activities. It is expected that the same rate will continued in the next decade and this may cause effects to the environment. 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 in different grades of concrete for variable percentages and there effects on the strength of the concrete. Here 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 properties of concrete, which are the important parameters to be studied in concrete production of different proportion of raw materials. However, when used in combination with 30% red mud, cement and 5% lime the composites shows significant compressive strength of 50.05 N/mm2for M40 grade of concrete. Tensile strength of.98 N/mm2for M40 grade of concrete. Selected combinations of mixes were later used to produce beam of size 500 x 100 x 100mm. These beams are tested for flexural strength of results 3.29 N/mm2for M40 grade of concrete.

Keywords: *Red Mud, Hydrated Lime, Grade Concrete, Superplasticiser*

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1. 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.

1.1 Positive Effects Of Using Red Mud In Concrete

(1) Benefits to Environment

Replacing 25% of cement all over the world by industrial waste will reduce carbon dioxide emissions by 320 million tonnes. Replacing industrial waste in concrete will reduce scarcity of place for dumping and also contamination of ground water during monsoon.

(2) Minimizing Greenhouse Gas Effect

The challenge for the civil engineering service will be the sustainable development in construction field and the concept for sustainable development includes the usage of eco-friendly high performance materials and produced at economic cost with the least possible environmental impact. By considering this sustainable improvement, the industrial waste can be used to replace the large quantity of cement in the concrete manufacturing process.

(3) Saving in the Energy Requirements in the Production of Ordinary Portland Cement

The production of one ton of Portland cement requires 1.62 to 1.9 tons of raw materials. These materials are primarily of

good quality clay and limestone. A proper usage of industrial waste such as red mud & fly ash would conserve the resource exploitation and saves natural resources. It would also save the energy consumption and provide strength to the concrete structures.

(4) Economical Benefits

Cement production consumes large quantities of energy. Replacement of cement can give considerable energy savings. These waste does not need an additional energy input before use. It is clear that the energy savings for cement replacement by such admixture in concrete will be in direct proportion to cement used.

2. 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, 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

- To determine the process for production of red mud concrete for M40 grade.
- 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.

3. METHODOLOGY

The aim is to determine the strength parameters of red mud concrete produced by replacing cement by red mud and hydrated lime. Several experimental works are carried out. The work study conducted is laboratory oriented. The materials such as red mud, lime, cement, fine aggregate, course aggregate and super plasticizers are used in this project.

- 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 prepared with suitable w/c ratio for 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
- Production of concrete cubes for both 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 7, 14 &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.

3.1 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)

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.

Fig 3.1: Red Mud

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%

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 $Ca(OH)_2$

3.2.7 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.

4 EXPERIMENTAL INVESTIGATIONS

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		
A-1	**Stipulations for Proportioning**	
1	Grade Designation	M40
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^3
5	Maximum Water Cement Ratio	0.45
6	Workability	100 mm (Slump)
7	Exposure Condition	Sever
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate
10	Maximum Cement Content	450 kg/ m^3
11	Chemical Admixture Type	Super Plasticizer

4.2 Mix Proportion

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

4.3 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.
- 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 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.
- Slump was measured (in mm) immediately by determining the difference between the height of the mould and that of the highest point of then specimen being tested.

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

- 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 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,

$$\mathbf{fc = P/A}$$

Where,
fc = Cube Compressive strength in N/mm^2
P = Cube Compressive load causing failure in N
A = Cross sectional area of cube in mm^2

Fig 4.1: Compressive strength test for cubes

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 (7daysand 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

$$fst = 2P/(\pi DL)$$

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 4.2: 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 centre of the beams were marked.
- The flexural strength corresponding to failure of the specimen is calculated using the formula.

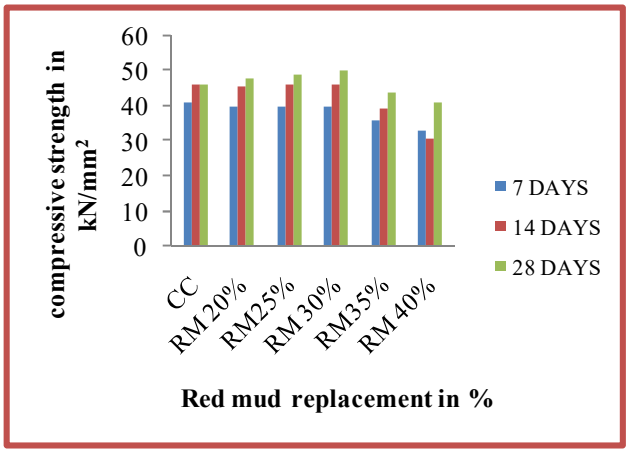
$$F_b = PL/(bd^2)$$

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.

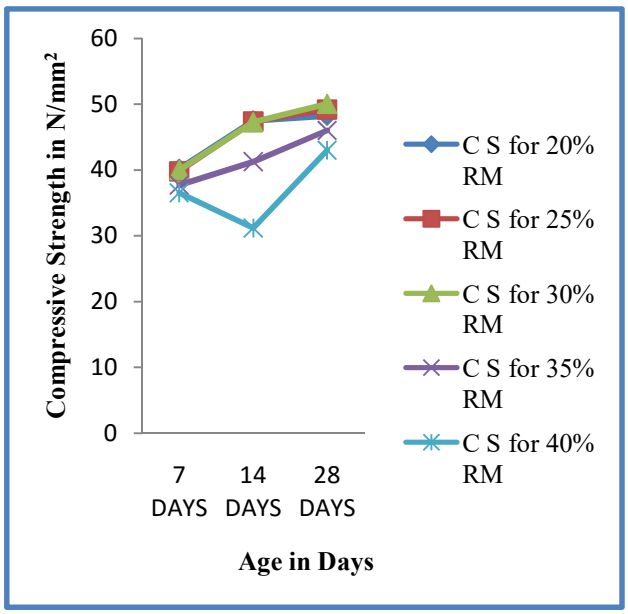
Fig 4.3: Flexural Test for Beam

5. RESULTS AND DISCUSSIONS

5.1 Compression Test Results



Graph 5.1: Compressive Strength of M40 Grade Red Mud Concrete at 7, 14, 28days.



Graph 5.2: Compressive Strength of M 40 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%

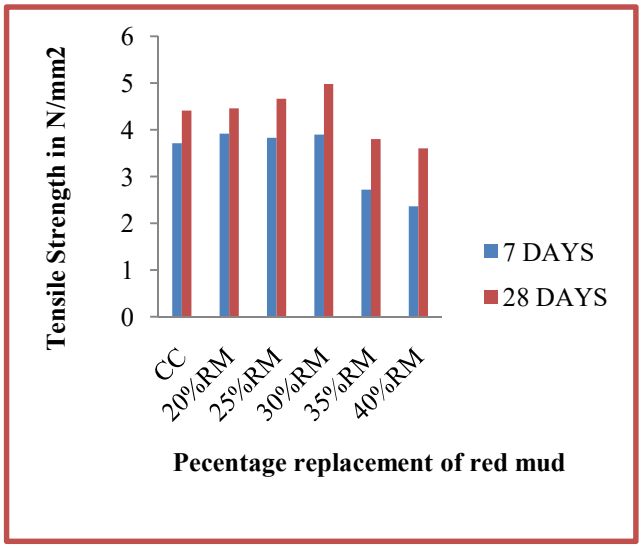
5.2 Split Tensile Strength Test Results

Table 5.1: Tensile Strength of red mud concrete of M40 grade for 7 days.

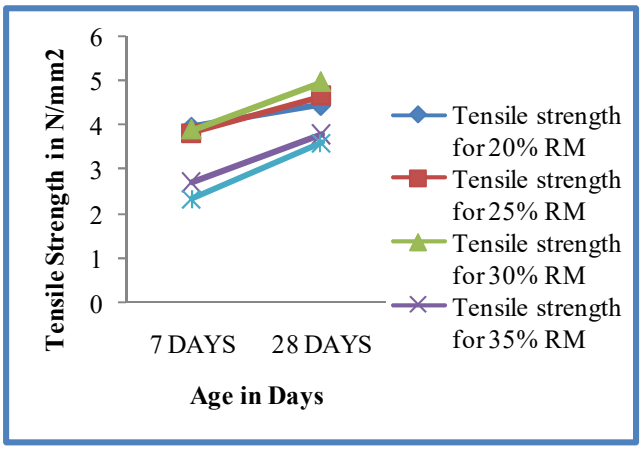
Sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) $A = \pi DL$ mm²	Tensile strength (F=2P/A) N/mm²	Average Tensile Strength N/mm²
1	20%	281	141372	3.97	3.92
		278		3.93	
		273		3.86	
2	25%	277	141372	3.91	3.83
		262		3.706	
		274		3.87	
3	**30%**	**281**	**141372**	**3.97**	**3.9**
		278		**3.93**	
		269.5		**3.81**	
4	35%	192	141372	2.7	2.72
		189		2.67	
		198		2.80	
5	40%	160	141372	2.26	2.36
		172		2.43	
		169		2.39	

Table 5.2: Tensile Strength of red mud concrete of M40 grade for 28 days.

sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) $A = \pi DL$ mm²	Tensile strength (F=2P/A) N/mm²	Average Tensile Strength N/mm²
1	20%	293	141372	4.14	4.461
		289		4.04	
		286		4.00	
2	25%	355	141372	4.986	4.664
		352		4.944	
		290.71		4.07	
3	**30%**	**354**	**141372**	**4.958**	**4.98**
		355.1		**4.972**	
		356.57		**4.99**	
4	35%	273	141372	3.98	3.8
		262		3.706	
		270		3.78	
5	40%	261	141372	3.65	3.6
		259		3.62	
		270		3.78	



Graph 5.3: Split tensile Strength of M 40 Grade red mud concrete for 7&28 days.

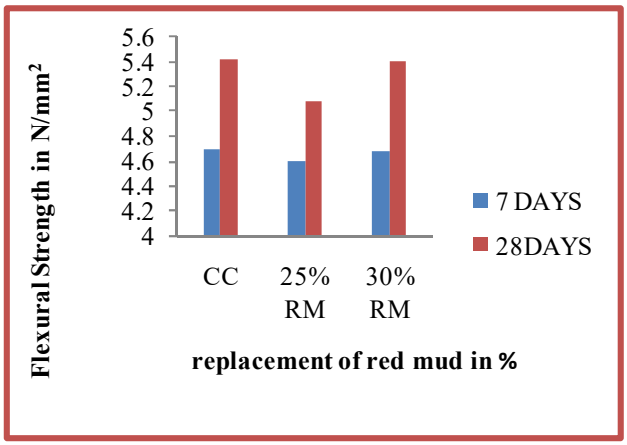


Graph 5.4: Split tensile Strength of M 40 Grade red mud

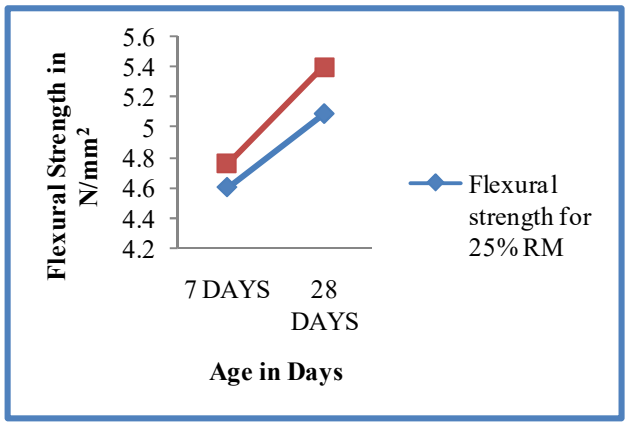
- The split tensile strength of M40 grade red mud concrete results are observed at 7 and 28 days respectively.
- Split tensile strength is higher at the replacement of 30% for both M40 as shown in the table and graph.
- After 30% replacement the split tensile strength decreases with increasing replacement of red mud with concrete.

5.3 Flexural Strength Test Results

- Flexural strength of M40 grade red mud concrete results are observed at 7 and 28 days respectively.
- Flexural tensile strength is increasing up to the replacement of 30% for both M40 grade of red mud concrete as shown in the graph.
- After 30% replacement the Flexural tensile strength decreases with increasing replacement of red mud with concrete.



Graph 5.5: Flexural Strength of M 40 Grade Red Mud Concrete for 7 & 28 days.



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

5 CONCLUSIONS

Based on the experimental study the following conclusion have been drawn.

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 M40 concrete.
2. Strength results of 30% of red mud replacement concrete shows almost same results of conventional concrete of respective 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 for M40 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 M40grade concrete.
5. The addition of super plasticizer for M40 grade concrete increases workability.
6. Water absorption of concrete increases with increased percentage of red mud.
7. Increased percentage of red mud increases the water absorption and decreases the strength of concrete.
8. 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 M40, due to presence of Al_2O_3 and SiO_2 in red mud and argillaceous content of hydrated lime.

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