Experimental Study on Partial Replacement of Cement by Neutralized Red Mud in Concrete

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Abstract - ***Disposal of large quantities of red mud; a solid-waste generated at the Aluminum plants all over the world possess an increasing problem of storage, land cost & availability and pollution. Because of the complex physico-chemical properties of red mud it is very challenging task for the designers to find out the economical utilization and safe disposal of red mud..***

Due to industrialization, infrastructure development and soft housing policy of Government of India, the construction industry is in full boom due to which within short span of time there is a 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 invite the threat to the environment. Availability of raw material required for manufacturing of cement and production of concrete are limited in nature. This increased demand will lead to fast depletion of natural resources and will cause big threat to environment.

So as to overcome this problem it is very much essential to utilize the industrial waste materials and by-products generated in manufacturing of cement and in concrete construction. In this paper the attempt is made to check the effectiveness of neutralized red mud as a partial replacement of portland cement.

Keywords - Water conservation, Contour trenches, watershed development, Village pond, Social mapping

I. INTRODUCTION

A. General

Cement in general sense of the word, can be described as a material with an adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact mass. This definition encompasses a large variety of cementing material. For constructional purposes the meaning of the term cement is restricted to the bonding materials used with stones, sand, bricks, blocks etc. Cement is the most important material in structural constructions as it is used at different stages of construction in the form of mortar or concrete.

Demand

I: World Cement Demand at a glance (million metric tons)

Item	2000	2005	2010	Annual Growth	
				05/00	10/05
Cement Demand	1630.0	2250.0	2830.0	6.7	4.7
North America	149.6	170.0	196.0	2.6	2.9
Western Europe	197.7	208.5	233.0	1.1	2.2
Asia / Pacific	954.5	1470.0	1895.0	9.0	5.2
Other Regions	328.2	401.5	506.0	4.1	4.7

World consumption of cement is forecast to continue to increase throughout the next 15 years, taking the annual volume up from the 2250 MT of 2005 to around 3130 MT by 2015 and 3560 MT by 2020, representing overall forward expansion of approximately 56%

According to the "GLOBAL CEMENT to 2020", world production and consumption of cement approximated 2250 MT in 2005 this level representing an increase of approximately 5.75% (124 MT) on the previous year and a continuation of the annual underlying expansion which has seen year-on-year growth in almost every year since the 1970's.

II. INDUSTRIAL SOLID WASTE AND ITS PRODUCTS

A. Allumina Generation

Production of aluminium metal in the public sector unit namely National Aluminium Company Ltd. (NALCO) and private sector units namely Bharat Aluminium Company Limited (BALCO) {which has 49% Central Govt. equity}, Hindustan Aluminium Company Ltd.(HINDALCO) and Madras Aluminium Company Ltd.(MALCO) in the country during the month of January 2009 was mentioned in table II.

National Aluminium Company Limited sold 91,352 tones of alumina/hydrated and exported 6,972 tones of aluminum during the month of January, 2008. The nation's solid wastes are increasing and posing a severe threat to the environment.

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II: Allumina Generation

Name of company	Existing capacity	January,2008		Cumulative Production Target	Cumulative Production	
		Production Target	Production Actual	April-January 2008	April-January 2008	April-January 2007
NALCO	345000	29600	30955	292200	298922	300399
BALCO	345000	30109	31318	299838	301652	256620
HINDALCO	455000	41079	41288	392747	397702	367174
MALCO	380000	3384	3302	32931	31376	31637
Total	1183000	104172	106863	1017716	1029652	955830

B. Red Mud

The red mud is one of the major solid wastes coming from Bayer process of alumina extraction. At present about 3 million tones of red mud is generated annually which is not being disposed or recycled satisfactorily.

The conventional method of disposal of red mud in ponds has often adverse environmental impacts during monsoon. The waste may be carried by run-off to the surface water courses and result of leaching may cause contamination of ground water and also destroy the fertility of soil. Further disposal of large quantities of Red mud dumped, posses increasing problems of storage.

III. OBJECTIVES OF WORK

Basically this paper is based on the dissertation work carried out to overcome the problems created due exhaustion and obsolescence of raw material required for manufacturing of conventional building material and also minimize the thrust of Indusial waste on the environment by utilizing the same in the Construction Industry. Some other objectives are;

- Planned exploitation of waste materials essentially helps to maintain ecological balance. The successful utilization of a waste material depends on its use being economically competitive with the alternate natural material.
- The development of alternate low-cost and ecologically suitable building materials from agricultural and industrial wastes is an economic necessity.
- Importance must be given to cheap and locally available building materials and hence it is necessary to check & utilize the suitable waste products to replace some of the conventional materials. The use of such materials would minimize the use of scarce materials and also generate appreciable economy.
- Conventional building materials such as bricks, cement, lime and their derivatives are becoming increasingly uneconomical because of obsolescence, exhaustion of raw materials, low plant efficiencies and over-whelming costs.
- The use of industrial wastes in place of conventional raw materials will help to decrease the environmental pollution and also conserve our natural resources.
- Current demand of cement is far in excess of production and is rapidly increasing.

By keeping the above objectives in mind the aims of present study was to check the suitability and utilization of neutralized red mud as a partial replacement of Portland cement and also in concrete.

IV. MATERIALS USED

A. Cement

Ordinary Portland Cement (Vasavadatta 43 Grade) confirming to IS: 269-1976 was used throughout the investigation. Different tests were performed on the cement to ensure that it confirms to the requirements of the IS specifications. The physical properties of the cement were determined as per IS: 4031-1968 and are presented in table III.

III: Physical Analysis of Vasavadatta (43 Grade) Cement

SrNo	Properties	Value
01	Specific Gravity	3.15
02	Standard Consistency	30 %
03	Initial Setting Time	103 min
04	Final Setting Time	231 min
05	Soundness	2.5
06	Fineness	8.5%
07	3 Days Compressive Strength	29.70 N/mm^2
08	7 Days Compressive Strength	39.67 N/mm^2
09	28 Days Compressive Strength	51.64 N/mm^2

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B. Coarse Aggregates

Locally available river sand, basalt stone chips were used for preparation of concrete. Machines crushed locally available hard basalt, well graded 12.5 mm and down size were used. Some of their properties were tested as per IS Code and the values are given in table below.

IV: Properties of Course Aggregate

Sr. No.	Properties	Value
1.	Specific Gravity	3.05
2.	Fineness Modulus	3.44
3.	Water Absorption (24 hours)	0.5%
4.	Density (Kg/m3)	1754.73

C. Sand (Fine Aggregate)

Locally available river sand passing through 4.75mm sieve as per IS: 383 provisions were used as fine aggregates.

V: Properties of Fine Aggregate (Sand)

Sr. No.	Properties	Value
1.	Specific Gravity	2.85
2.	Fineness Modulus	2.580
3.	Water Absorption (24 hours)	2.5%
4.	Density (Kg/m^3)	1813.23

D. Red Mud

Red mud is reddish brown in colour. Its characteristics depend on the nature of bauxite ore used in the extraction of aluminium, which significantly differs from place to place. The material was sieved and fine uniform powder passing through 1.18 mm sieve was neutralized by using commercially available Hydrochloric acid (1N).

VI: Properties of Fine Aggregate (Sand)

Sr. No.	Properties	Value
1.	Density (Kg/m^3)	1474.38

V. CONVECTIONAL CONCRETE DESIGN MIX

With the above said objectives and aim, a comparative study on strength parameters is done against conventional concrete to study the behavior of cement concrete with neutralized red mud.

The experimental tests carried out on parameters are:

- The physical properties of blended cement (portland cement replaced by 0%, 5%, 10%, 15%, 20% and 25% on weight basis by neutralized red mud)
- With constant water/cement ratio three concrete design mix of grade M30, M40, and M50 was prepared and each concrete design mix was studied for Compressive.

VII: Final Concrete Design Mix Proportions

Grade of Concrete	Cement	Sand	Coarse Aggregate	Water	Chemi-cal
M 30	1	2.925	4.696	0.45	3 lit
M 40	1	2.535	4.069	0.40	3.4 lt
M 50	1	2.228	3.576	0.36	4 lt.

VIII: Proportion of Cement for NRM concrete design mix

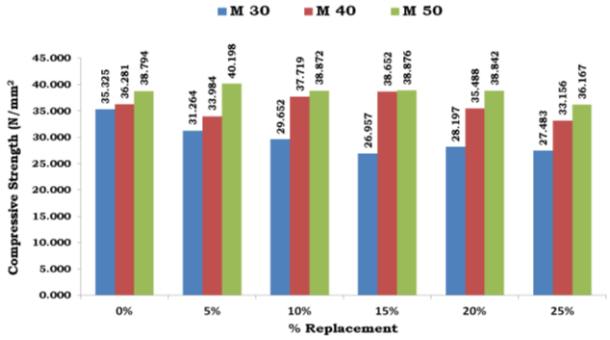
% Replacement	0%	5%	10 %	15 %	20 %	25 %
Cement	1	0.95	0.90	0.85	0.80	0.75
NRM	0.00	0.05	0.10	0.15	0.20	0.25

VI. RESULT ANALYSIS OF COMPRESSIVE STRENGTH TESTING

Compressive strength of the concrete design mix was check by casting and testing of cubes (size 150 mm x 150 mm x 150 mm) after the curing period of 7 days, 28 days & 56 days. The obtained results are tabulated below

IX: 7 Days Compressive Strength in N/mm^2

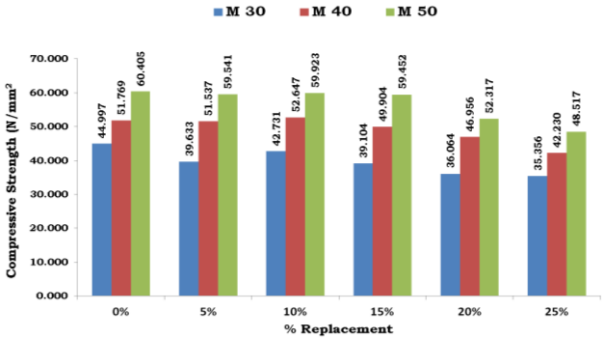
Grade of Concrete	% Replacement					
	0%	5%	10%	15%	20%	25%
M 30	35.325	31.264	29.652	26.957	28.197	27.483
M 40	36.281	33.984	37.719	38.652	35.488	33.156
M 50	38.794	40.198	38.872	38.876	38.842	36.167



7 Days Compressive Strength in N/mm^2

X: 28 Days Compressive Strength in N/mm^2

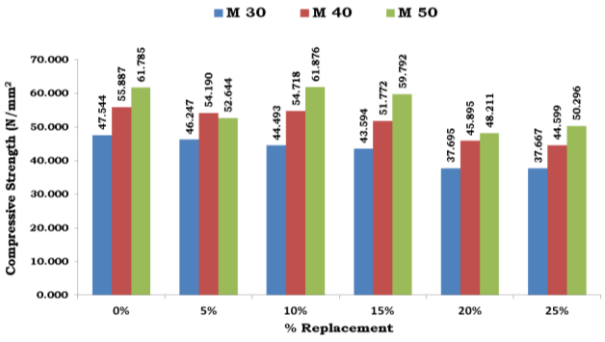
Grade of Concrete	% Replacement					
	0%	5%	10%	15%	20%	25%
M 30	44.997	39.633	42.731	39.104	36.064	35.356
M 40	51.769	51.537	52.647	49.904	46.956	42.230
M 50	60.405	59.541	59.923	59.452	52.317	48.517



28 Days Compressive Strength in N/mm^2

XI: 56 Days Compressive Strength in N/mm^2

Grade of Concrete	% Replacement					
	0%	5%	10%	15%	20%	25%
M 30	47.544	46.247	44.493	43.594	37.695	37.667
M 40	55.887	54.190	54.718	51.772	45.895	44.599
M 50	61.785	52.644	61.876	59.792	48.211	50.296



56 Days Compressive Strength in N/mm^2

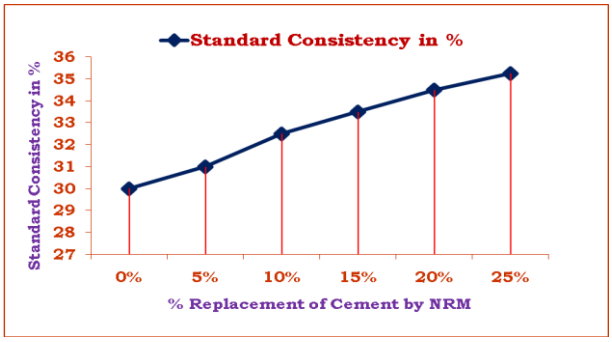
VII. DISCUSSIONS ON

A. Effect of Replacement of Cement by NRM on Standard Consistency and Setting Time

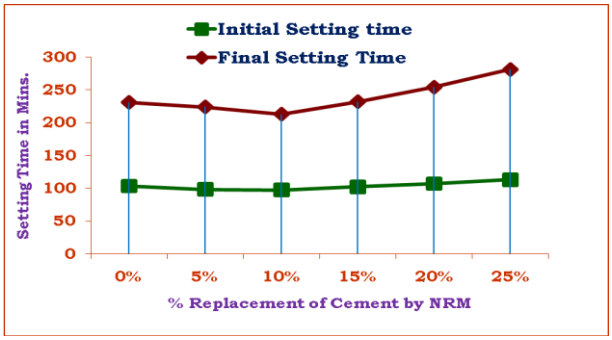
Blended cement samples, five in number are prepared with replacement of cement by NRM with increment of 5 percent (i.e. 5%, 10%, 15%, 20% & 25%). setting time with different percentage of NRM in cement.

As seen that with the increase in NRM in the mix, the water required for standard consistency also increases and the relationship between the standard consistency and requirement of water for that is linear. As the NRM having small grain size, due to which surface area was increased and also the water required was increased.

Beyond 10% replacement of cement by NRM the setting times are increased. It also interesting to observe that for 15% replacement of cement by NRM the setting time almost same or near to that of Vasavadatta Cement and after this further increase in the % replacement of cement by NRM, the setting time of the mix also increase.



Graphical representation of Standard Consistency



Graphical representation of Setting Time

B. Effect of Replacement of Cement by NRM on Compressive Strength of Concrete

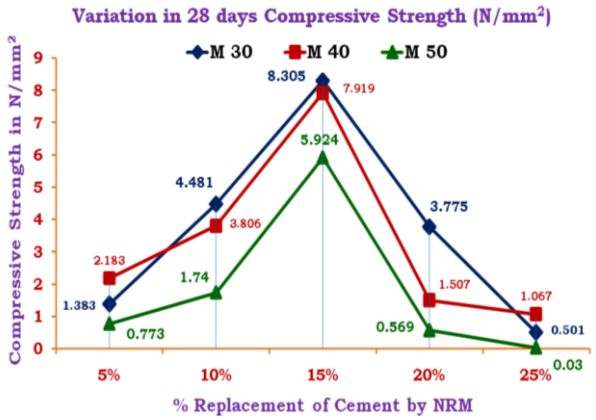
For each grade of concrete design mix i.e. M 30, M 40 and M 50, there was an initial decrease in the compressive strength for 5 % replacement of cement by NRM.

But from the next replacements i.e. 10 % and 15 % the compressive strength are increased with the increase in the % replacement of cement by NRM. Then after, for 20 % and 25 % replacement of cement by NRM there was a decrease in the compressive strength as the % replacement of cement by NRM increased.

Hence by observing all graphs of each grade of concrete design mix, it can be said that the 15 % replacement of cement by NRM gives the maximum compressive strength.

XII: Compressive Strength Comparison

Grade of Concrete	M 30	M 40	M 50
28 Days Target Compressive Strength of Conventional Concrete (N/mm^2)	38.250	48.250	58.250
28 Days Target Compressive Strength of NRM Concrete with 15% NRM (N/mm^2)	46.555	56.169	64.174
% Increase in Compressive Strength	21.712	16.412	10.17



Combined Graph of Variation in Compression Strength

C. Effect of Replacement of Cement by NRM on Economy

XIII: Economical Comparison between Conventional and NRM Concrete (15% replacement of cement by NRM)

Grade of Concrete	M 30	M 40	M 50
Cost of Conventional Concrete (in Rs.)	2138.58	2328.71	2506.20
Cost of 15 % NRM Concrete (in Rs.)	1978.52	2145.72	2301.50
% Economy achieved	7.48 %	7.86 %	8.17 %

VIII. CONCLUSION

From this experimental study following points can be drawn: After testing of 5 blended cement samples (5% to 25 % replacement of Cement by NRM) with an increment of 5 %, it can be said that the optimum use of NRM is 15% as a partial replacement of cement by NRM.

- The cost of M 30 grade NRM Concrete (i.e. 15 % Replacement) is around 7.48 % less than the Conventional Concrete, with an increase of 21.712 % in the 28 days Compressive strength.
- The cost of M 40 grade NRM Concrete (i.e. 15 % Replacement) is around 7.86 % less than the Conventional Concrete, with an increase of 16.412 % in the 28 days Compressive strength.
- The cost of M 50 grade NRM Concrete (i.e. 15 % Replacement) is around 8.17 % less than the Conventional Concrete, with an increase of 10.170 % in the 28 days Compressive strength.
- The percentage economy is increased with the increase in the grade of concrete but at the same time there is a reduction in the percentage increase in the Compressive Strength.
- Considering all the above point it is interesting to say that the optimum utilization of Neutralized Red Mud in concrete is 15 % as a partial replacement of cement by NRM.

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