IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 01-10
www.iosrjournals.org

Experimental Studies On Concrete Utilising Red Mud As A Partial Replacement Of Cement With Hydrated Lime

P.Ashok[1], M.P.Sureshkumar[2],
1. P.G Student, Dept of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode, Anna University, India.
2. Assistant Professor, Dept of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode, Anna University, India.

ABSTRACT: *The Bayer Process 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 (landfills), leading to important environmental issues. It comprises of oxides of iron, titanium, aluminum and silica along with some other minor constituents. Presence of Alumina and Iron oxide in red mud compensates the deficiency of the same components in limestone which is the primary raw material for cement production. Presence of soda in the red mud which when used in clinker production neutralizes the sulfur content in the pet coke that is used for burning clinker enrooted cement production and adds to the cement's setting characteristics. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud management issues i.e. of utilization, storage and disposal. Different avenues of red mud utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible. Experiments have been conducted under laboratory condition to assess the strength characteristics of the aluminum red mud. The project work focuses on the suitability of red mud obtained for construction. Five test groups were constituted with the replacement percentages 0%, 5%, 10%, 15%, 20% of red mud and 5% of hydrated lime with cement in each series. To achieve Pozzolanic property of red mud, hydrated lime was added. This paper points out another promising direction for the proper utilization of red mud.*

Key words: *Cement mortars, Red mud, hydrated lime, monotonic load and Deflection.*

I. INTRODUCTION

Bayer's process for Alumina production uses Caustic and Bauxite as the main raw material for Alumina production and generates Red mud which practically doesn't have wide industrial application and is generally dumped as a non value by product in the backyards of a Alumina Refinery called as Red Mud yard. Over the years the red mud produced were lying in the yard not without any usage. Huge space of about 3.0 acres needed per annum to store the Red Mud and dykes. But a breakthrough was made when MALCO discovered that red mud could be tried as an alternative for the Low Grade Bauxite (LGB) which the cement industries used for its cement production. An idea struck as why not try Red Mud in cement industries instead of Bauxite as the composition of both are almost similar. It's quite possible as the cement industries were on the look out to make up for the deficiency of Alumina, in their raw materials viz - Lime stone for Cement production.

1.1 Demand

World Cement Demand at a glance (million metric tons)

Table 1. World cement demand

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	197.7	208.5	233.0	1.1	2.2

Europe					
Asia / Pacific	954.5	1470.0	1895.0	9.0	5.2
Other Regions	328.2	401.5	506.0	4.1	4.7

1.2 Literature Review

A search over Internet may say that the Red Mud has already been tried for usage of Cement manufacturing but there is not enough evidence to support the large scale use of Red Mud anywhere in the cement industries. With this paper the authors want to share MALCO's experience of successfully substituting the use of LGB (Low grade Bauxite) with Red mud which hitherto, the nearby cement industries have been buying from us to make up for the deficiency in their raw material for cement production and the local cement industries continued usage of Red Mud instead of LGB. Besides the most important fact the authors want to underline is the neutralization of soda in Red Mud with Sulfur in pet coke leading to better cement properties.

1.3 Composition of Red Mud and its Properties

Red Mud as such containing about 65% to 70% Solids with the remaining as moisture is a thixotropic substance which exhibits shear thinning behavior i.e., when the shear rate is increased, the apparent viscosity decreases. The following is the composition of the Dry Red Mud of MALCO

Table 2. Composition of red mud

COMPONENTS	**WEIGHT %**
Al_2O_3	20 – 22
Fe_2O_3	40 – 45
SiO_2	12 – 15
TiO_2	1.8 – 2.0
CaO	1.0 – 2.0
Na_2O	4 – 5

Particle Size : less than 44 microns
Appearance & Odor : Red, Earthy odor, slight pungent
pH : 11 to 12

1.4 Source of Red Mud in Bayer's Process

The Bayer's process is the principle industrial means of refining bauxite to produce alumina (aluminium oxide). Bauxite, the most important ore of aluminium contains only 30 to 54% aluminium oxide, alumina, Al_2O_3, the rest being a mixture of silica various iron oxide, and titanium di-oxide. The aluminium oxide must be purified before it can be refined to aluminium metal. In the Bayer process, bauxite is digested by washing with a hot solution of sodium hydroxide, NaOH at 175^oC. This converts the aluminium oxide in the ore to sodium aluminates, NaAL $(OH)_4$, according to the chemical equation.

$AL_2O_3+2NaOH+3H_2O$ □ $2NaAL(OH)_4$

1.5 Basic property tests of solid particles of Red mud

Solid particle characteristics refer to the grain size and distinctive modality. Several years ago, a few investigators abroad showed interest in the relation between grain size and flocculation settling, as well as in the geotechnical analysis of red mud. Domestic research focused largely on flocculation settling and ways of disposal according to grain shape. Our test on basic properties of solid red mud particles deals with the definition of the size dimension given our rheological constitutive relations. The main physical and chemical properties and particle characteristics of red mud have a considerable effect on the pipeline transport process. Red mud is easier to transport via a pipeline than other similar kinds of material, such as city sludge and coal slurry, for its solid grains are small, it has very fine particles and a medium relaxed permutation.

II. OBJECTIVES OF THE STUDY

The major objectives of this study were:

1. To identify various industrial wastes suitable for utilization in cement manufacture
2. Physico-chemical and mineralogical characterization of industrial wastes.
3. To assess the compatibility of industrial solid waste as raw material/ blending material/ admixture
4. To examine the constraints related to utilization of industrial waste
5. To make recommendations to promote utilization of industrial waste

III, UTILIZATION OF IRON VALUES OF RED MUD

(a) As an independent raw material to recover iron alone or along with other valuable constituents such as $A1_20_3$, TiO, etc;

(b) Use as an additive to the feed in conventional iron making blast furnace (BF) - mostly after sintering with iron ore;

(c) Other miscellaneous applications in the iron and steel industry.

Two main approaches which have been generally investigated to recover iron values are based on:

(a) Solid state reduction of red mud followed by magnetic separation to recover iron; and

(b) Reduction smelting in a blast/electric/low shaft furnace (with or without pre reduction) to produce pig iron.

IV MATERIALS USED

4.1 Cement

Ordinary Portland Cement (53 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:3

Table 3. Physical properties 53 Grade Cement

S.NO	CHARACTERISTICS	VALUES
1	Standard consistency	**53**
2	Fineness of cement as retained on 90 micron sieve	**3%**
3	Initial setting time	**30 minutes**
4	Specific gravity	**3.15**
5	7days compressive strength	**37 Mpa**

Table 4. Chemical Properties of Cement

S.NO	COMPONENTS	WEIGHT
1	Lime (CaO)	63%
2	Silica (SiO_2)	22%
3	Alumina (Al_2O_3)	6%
4	Iron oxide (Fe_2O_3)	3%
5	Magnesium oxide (MgO)	2.5%
6	Sulphur trioxide & loss of ignition (SO_3)	1.5%
7	Alkalies	0.5%

4.2 Fine Aggregate

Locally available sand is used as fine aggregate in the cement mortar. The physical properties of sand are shown in below table. 5

Table 5. Physical Properties of River Sand

PROPERTY	RIVER SAND
Specific gravity	2.6
Sieve analysis	Zone-II

4.3 Coarse Aggregate

Coarse aggregate are the crushed stone is used for making concrete. The maximum size of aggregate used for this investigation is 20mm and specific gravity is 2.78.

4.4 Water

Fresh and clean water is used for casting and curing of specimen. The water is relatively free from organic matters, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard. Combining water with a cementitious material forms a cement paste by the process of hydration. A cement paste glues the aggregate together fills voids within it, and makes floor freely.

4.5 Hydrated Lime

Hydrated lime is a type of dry powder made from limestone. It is created by adding water to quicklime in order to turn oxides into hydroxides. Combined with water and sand or cement, hydrated lime is most often used to make mortars and plasters. Its chemical name is calcium hydroxide, or $Ca(OH)_2$.

4.6 Red Mud

Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminium industry's most important disposal problems. The red colour is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. In addition to iron, the other dominant particles include silica, unleached residual aluminium, and titanium oxide. Red mud cannot be disposed of easily. As a waste product of the Bayer process the mud is highly basic with a pH ranging from 10 to 13.

Table 6. Chemical properties of the Dry Red Mud of MALCO

COMPOUND	WEIGHT[%]
Al_2O_3	14.14
SiO_2	11.53
Fe_2O_3	48.50
TiO_2	5.42
CaO	3.96
V_2O_5	0.116
MgO	0.049
ZnO	0.027
Na_2O	7.50
P_2O_5	0.297
MnO	0.17
K_2O	0.058
L.O.I	7.25

V. CONCRETE MIX

The physical properties of blended cement (Portland cement replaced by 0%, 5%, 10%, 15%, 20% with 5% of hydrated lime on weight basis by neutralized red mud)

With constant water/cement ratio three concrete design mix of grade M30 was prepared and each concrete design mix was studied for Compressive.

Table 7. Concrete Design Mix Proportions

Cement	Sand	Aggregate	w/c ratio
1	1.25	2.72	0.45

Table 8. Replacement of red mud

Replacement % of red mud	0	5	10	15	20

VI. RESULT AND DISCUSSION

Test results for workability of red med concrete mixes for M_{30} Grade.

6.1 Slump Cone Test

A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product.

Table shows the slump test results for replacement percentage whish falls in the slump range.

Table 9. Slump test result

% replacement of cement	Hydrated lime (%)	Slump value (mm)	Type of slump
00	5	25	True
05	5	25.5	True
10	5	27	True
15	5	27.5	True
20	5	29	True

6.2 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 the 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 a fully compacted volume. The results of the compaction factor test can be correlated to slump, although the relationship is not linear. This test is difficult to run in the field and is not practical for large aggregates (over 1 inch) Compared to the slump test, the apparatus is bulky and a balance is required to perform measurements

Table shows the compaction factor results for replacement percentage shows the workability value.

Table 10. Compaction factor results

% replacement of cement	Hydrated lime (%)	Compaction factor
00	5	0.85
05	5	0.87
10	5	0.89
15	5	0.92
20	5	0.94

6.3 Compressive Strength Test

Mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load. Brittle materials such as rock, brick, cast iron, and concrete may exhibit great compressive strengths; but ultimately they fracture. The crushing strength of concrete, determined by breaking a cube, and often called the cube strength.

Table and graph shows the 28 days compressive strength of red mud concrete cubes without hydrated lime

Table 11. Compressive Strength without hydrated lime

Grade of concrete	% of red mud used	28 days compressive strength (N/mm^2)
M30	0	33.30
	5	37.42
	10	38.12
	15	38.50
	20	38

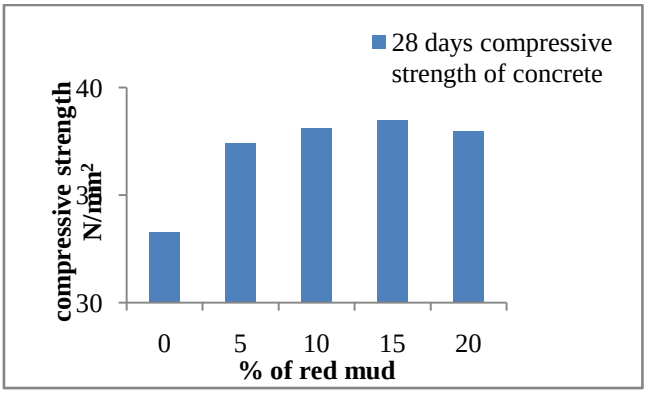

Figure 1. 28 Days Compressive strength of red mud concrete without hydrated lime

Table and graph shows the 28 days compressive strength of red mud concrete cubes with hydrated lime

Table 12. Compressive Strength with hydrated lime

Grade of concrete	% of red mud used	Hydrated lime	28 days average compressive strength (N/mm^2)
M30	00	5	35.60
	05	5	39.09
	10	5	40.20
	15	5	41.50
	20	5	35.20

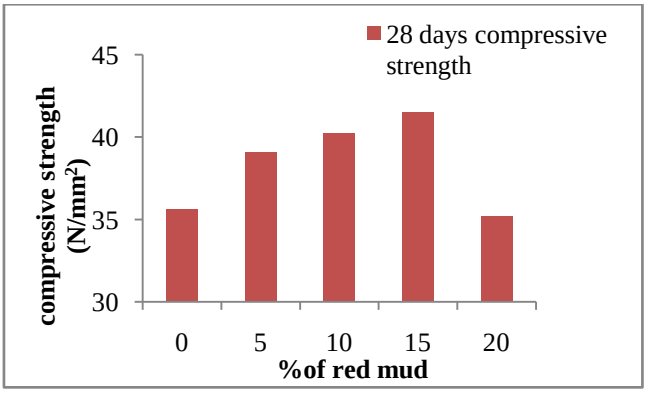

Figure 2. 28 Days Compressive strength of red mud concrete with hydrated lime

The compressive strength results showed that the upto 15% of red mud replacement with cement gives ultimate strength.

6.4 Split Tensile Strength Test

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to Determine the load at which the concrete members may crack. The cracking is a form of tension failure. This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders and drilled cores.

Table and graph shows the 28 days split tensile strength of red mud concrete cubes without hydrated lime

Table 13. Split Tensile Strength without hydrated lime

Grade of concrete	% of red mud used	28 days average split tensile strength (N/mm^2)
M30	00	3.56
	05	3.72
	10	3.97
	15	3.80
	20	3.50

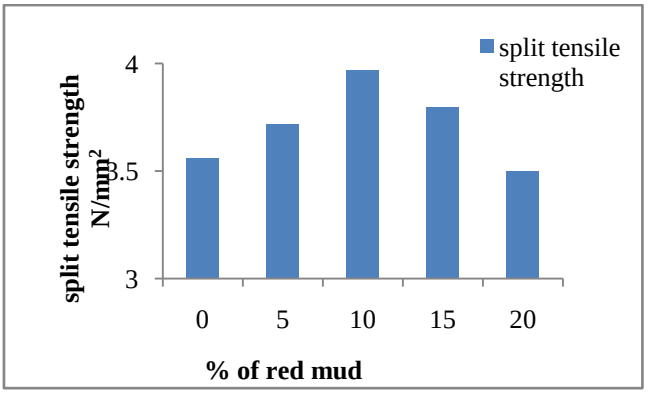

Figure 3. 28 Days split tensile strength without hydrated lime

Table and graph shows the 28 days tensile strength of red mud concrete cubes with hydrated lime

Table 14. Split Tensile Strength with hydrated lime

Grade of concrete	% of red mud used	% of hydrated lime	28 days average split tensile strength (N/mm^2)
M30	00	5	3.56
	05	5	3.92
	10	5	4.22
	15	5	4.05
	20	5	3.63

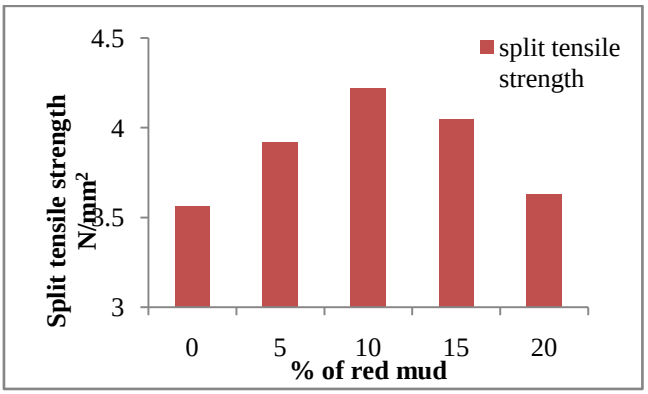

Figure 4. 28 Days Split tensile strength with hydrated lime

The split tensile strength of cylindrical specimen's results also indicated that the addition of red mud yielded comparable strength with that of control cylindrical specimens. The optimum % was obtained at the 10% replacement of red mud with cement.

6.5 Flexure Strength Test

This ASTM test method covers the determination of the splitting tensile strength of cylindrical concrete specimens. This method consists of applying a diametral compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength.

Ultimate Flexural Strength and Deflection of Reinforced Concrete Beams

Table 15. Flexural Strength for red mud concrete without hydrated lime

% replacement of cement	Ultimate Flexural Strength (kN)	Deflection (mm)
00	76	5.02
05	81	5.07
10	83	5.43
15	92	5.70
20	76	4.90

Table 16. Flexural Strength for red mud concrete with hydrated lime

% replacement of cement	% of hydrated lime	Ultimate Flexural Strength (kN)	Deflection (mm)
00	5	76	5.02
05	5	84	5.15
10	5	87	5.52
15	5	93	5.86
20	5	78	5.10

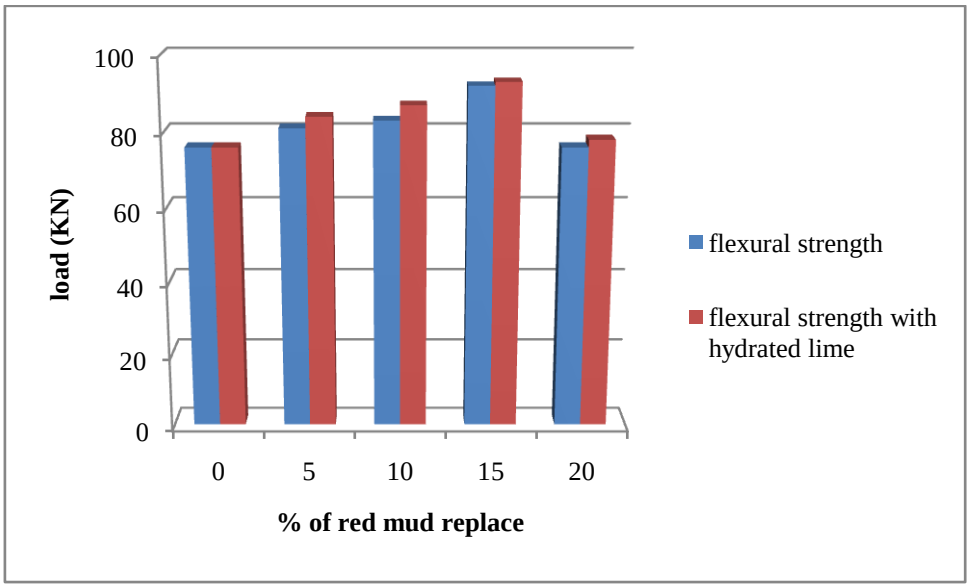

Figure 5. 28 Days Flexural Strength

VII. 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 upto 21.712 % 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.

Red mud can be effectively used as replacement material for cement and replacement enables the large utilization of waste product.

Red mud did not effect of the cement properties, rather improved the cement quality by way reducing the setting time & improved compressive strength.

Used for road construction as an embankment landfill is an attractive option with a high potential for large volume reuse.

Replacement of 20%OPC by calcined red mud is thus possible.

Calcinations of redmud at 700^0C leads to a pozzolanic material essentially reactive at early ages.

In building material industry as a raw material in manufacture of building and pavement blocks and road surfacing.

Dewatered (ferro alumina) as a raw material in cement manufacture.

In ceramic industry as an additive to make special ceramics.

This thermal treatment changes the phase composition of the material, mainly by promoting the elimination of hydrated phases and improves its amorphous character;

Physical parameters of red mud are affected by calcination process: the surface area and the unitary mass decrease and the specific gravity increases;

The results of pozzolanic activity by chemical and physical methods were very satisfactory and indicate the feasibility of red mud use as a pozzolan, in addition to Portland cement.

REFERENCES

[1]. L. G. Yang, Z. L. Yao, and D. S. Bao, "Pumped and cemented red mud slurry filling mining method," Mining Research and Development, vol. 16, pp. 18–22, 1996.
[2]. (2). Premchand, Rakesh Kumar, J.P. Srivastava, "Utilization of iron values of red mud for metallurgical applications", Environmental and Waste Management (ISSN: 0971-9407), pp. 108-119, 1998.
[3]. N. Yalc¸in and V. Sevinc¸, "Utilization of bauxite waste in ceramic glazes," Ceramics International, vol. 26, no. 5, pp. 485–493, 2000.
[4]. S. Srikanth, A. K. Ray, A. Bandopadhyay, B. Ravikumar, and A. Jha, "Phase constitution during Sintering of red mud and red mud-fly ash mixtures," Journal of the American Ceramic Society, vol. 88, no. 9, pp. 2396–2401, 2005.
[5]. Tim Newson, Tom Dyer. Chris Adam, Sandra Sharp, "Effect of Structure on the Geotechnical Properties of Bauxite Residue", journal of geotechnical and geoenvironmental engineering, pp. 143-151 2006.
[6]. WANG Xing, QU Yuan-yuan, HU Wei-wei, CHEN Jie,ZHAO Xue-yi, WU Miao, "Particle characteristics and rheological constitutive relations of high concentration red mud", J China Univ Mining & Technol, volume-18 pp. 0266–0270, 2008.
[7]. V. Jobb´agy, J. Somlai, J. Kov´acs, G. Szeiler, and T. Kov´acs, "Dependence of radon emanation of redmud bauxite processing wastes on heat treatment," Journal of Hazardous Materials, vol. 172, no. 2-3, pp. 1258–1263, 2009.
[8]. Daniel Véras Ribeiro, João António Labrincha, Marcio Raymundo Morelli, " Potential Use of Natural Red Mud as Pozzolan for Portland Cement" 2010.
[9]. X. F. Zheng, "Recycling technology of aluminum and sodium from low temperature bayer progress red mud," Shandong Metallurgy, vol. 32, pp. 16–17, 2010.
[10]. RibeiroD.V, Rovere.C.A.D, SouzaC.A.C, Kuri.E.S, J.A.Labrincha, Abrantes.J.C.C, and Morelli.M.R, "Effect of RedMud on the Corrosion of Reinforced Concrete Studied by Electrochemical Impedance Spectroscopy", International Scholarly Research Network, ISRN Materials Science, Article ID 365276, 2011.
[11]. Xiaoming Liu, Na Zhang, Henghu Sun, Jixiu Zhang, Longtu Li, "Structural investigation relating to the cementitious activity of bauxite residue — Red mud" Cement and Concrete Research, Volume 41 pp. 847–853, 2011.
[12]. Daniel versa Ribeiro, Marcio Raymundo morelli, "Cementitious Activity of Calcined Red Mud", International Journal of Pavement Engineering & Asphalt Technology, Vol. 12, pp 40-49, 2011
[13]. (13). Labrincha.J.A, Ribeiro.D.V, Morelli.M.R, "Effect of the addition of red mud on the corrosion parameters of reinforced concrete", Cement and Concrete Research, Volume 42, pp.124–133, 2012.
[14]. Sawant.A.B, Kumthekar.M.B, Diwan.V.V, Hiraskar.K.V, "Experimental Study on Partial Replacement of Cement by Neutralized Red Mud in Concrete", International Journal of Engineering and Advanced Technology (IJEAT), Volume-2, Issue-1, pp 282-286, 2012.
[15]. (15). Ping Wang, and Dong-Yan Liu, "Physical and Chemical Properties of Sintering Red Mud and Bayer Red Mud and the Implications for Beneficial Utilization", doi: 10.3390/ma5101800, volume 5,pp 1800-1810, 2012
[16]. Suchita Rai, K.L. Wasewar, J. Mukhopadhyay, Chang Kyoo Yoo, Hasan Uslu, "Neutralization and utilization of red mud for its better waste management" ARCH. ENVIRON. SCI,volume 6,pp. 13-33, 2012
[17]. Gawu.S.K.Y, Amissah.E.E, Kuma.J.S, "The proposed Alumina Industry and how to Mitigate against the red mud Footprint in Ghana" Journal of Urban and Environmental Engineering, volume 6, pp.48-56, 2012.
[18]. Sneha Samal, Ajoy K. Ray, Amitava Bandopadhyay, "Proposal for resources, utilization and processes of red mud in India", International Journal of Mineral Processing, volume 118 pp. 43–55, 2013.
[19]. Mohan Kushwaha1, Dr. Salim Akhtar, Survesh Rajput, "Development of the Self Compacting Concrete By Industrial Waste (Red Mud)", Research and Applications (IJERA) ISSN: 2248-9622, Vol. 3, pp. 539-542, 2013
[20]. Sawant.A.B, Kumthekar.M.B, SawantS.G, "Utilization of Neutralized Red Mud (Industrial Waste) in Concrete" International Journal of Inventive Engineering and Sciences (IJIES) ISSN: 2319–9598, Volume-1, pp 9-13, 2013