ISSN 2229-5518

Effect of Replacement of Cement by Red mud on the Properties of Concrete

Sunitha M.Pujar, Dr.K.B.Prakash

Abstract— Rapid industrialization leads to the maximum discharge of waste products which in turn causes the environmental hazards. These wastes can be a substitute for conventional material, when utilized in a best way. Red mud is a waste generated by the aluminum industry (an average of 4 million tons/year) in a Bayer's process and their disposal is a major problem for these industries because of the complex physio-chemical properties of waste products which are highly caustic and causes ground water contamination, leading to health hazards. 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. Here in this work by taking the cementitious behavior of industrial wastes into account, an experiment was carried out to partially replace the portland cement by red mud in concrete for variable percentages and also there effects on the strength of the concrete.

One main objective of this work is to study the effects of red mud on properties of concrete of M30 grade. The red mud percentage for replacement of cement is varied as 0%, 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% & 20%.

Index Terms— Redmud, Workability, Strength Properties, Soroptivity

1 INTRODUCTION

Red mud is a by-product of the Bayer process, which is used for the production of alumina from bauxite. Washed and crushed bauxite is treated with a solution of hydroxide at an elevated temperature and pressure. This process brings all the recoverable alumina from bauxite into solution and the residue known as red mud. For each part of alumina produced by this process, about one part of red mud is generally discarded as a waste. In Western countries, about 35 million tons of red mud is produced yearly. Due to its caustic nature, it poses a major environmental problem. Disposal of this waste was the first major problem encountered by the alumina industry after the adoption of the Bayer process. These attempts were based mainly on the use of red mud as a partial substitute for clay in the production of bricks and other ceramic products. So far, the various uses of red mud developed includes, tiles, glazes and red mud–polymer composites panels as wood substitute, iron rich cement etc. Fundamental studies carried out for the extraction of iron oxide or titanium oxide are reported to be economically unsustainable and therefore red mud as such has been used for various applications. Red mud has also been used for catalytic hydro-de chlorination of tetrachloroethylene for the treatment of gold ores, in making silicate bonded un sintered ceramics, heavy clay products, sintered ceramics etc. In view of above, there is a great scope to evolve innovative strategy and to develop novel functional applications of red mud based materials, for effective utilization of red mud. The application of radiation technology in medicine, agriculture, nuclear reactor and other industries is increasing day by day all over the world.

Red mud has a reddish brown color and a superfine, fine particle-size distribution as it's physical characteristics, as well as alkalis, iron oxides and hydroxides, aluminum hydroxides, calcium carbonate, titania, and silica in its chemical composition. The superfine particles characteristic of red mud makes this a promising admixture for mortar and concrete .Clay minerals into pozzolanic admixtures that are able to consume the calcium hydroxide produced by cement hydration.

1.1 OXIDE CONSTITUENTS OF RED MUD

Red mud is considered due to its high pH varies Between 10 to 14 and discharged as high alkaline slurry. Red mud contains six major oxides named CaO, SiO2, Fe2O3, Al2O3, TiO2 and Na2O and small quantities of numerous minor elements. And few of above mentioned oxides are present in cement also. Hence red mud is called as a cementatious material. The below table including a composition of percentage of oxides present in a red mud, the estimated chemical composition of red mud based on literature survey is shown in Table 1

Table 1 Chemical composites of with wash Red mud, Cement and Unwash Red mud.

Ingredient	Oxides	% in RM (Un-washed)	% in OPC	% in RM (washed)
Lime	CaO	3.00	62.0	3.50
Silica	SiO2	8.5	22.0	9
Aluminium	Al2O3	20.00	5.0	22
Iron oxide	Fe2O3	42.00	3.0	47
Sodium oxide	Na2O	4.5	-	3.5
Titanium	TiO2	10.4	-	12.4
Alkalies	-	-	01	-
LOI	-	14.00	-	19.00

1.2 Red mud neutralization

Neutralization of red mud will help to reduce the environmental impact caused due to its storage and also lessen significantly the on going management of the deposits after closure. It will also open opportunities for re-use of the residue which to date have been prevented because of the high pH. Neutralization of red mud to pH around 8.0 is optimal because the chemically adsorbed Na is released, alkaline buffer minerals are neutralized and toxic metals are insoluble at this pH. Efforts are being carried out to study the amelioration of red mud by possibly incorporating a pH-reduction processing step during disposal of red mud and include studies on processes based on acid neutralization, CO2 treatment, seawater neutralization, bioleaching and sintering.

2 Materials And Methodology

2.1 Materials

The binder materials used in mixes were ordinary Portland cement (OPC) 43 grade conforming to IS: 8112 – 1989, Red mud used for the replacement of cement is brought from aluminum industry obtained by Bayer's process, HINDALCO, Belgaum, Washed Red mud and Unwashed Red mud.
Locally available river sand belonging to zone II of IS 383-1970 was used. Locally available crushed aggregates confirming to IS 383-1970 was used. Water fit for drinking and commercially available high performance super plasticizing admixture, Conplast SP430; conforming to ASTM C 494 (1992) were used in this experimentation.

2 .2 Methodology

Casting of specimens

Cement, sand and aggregate were taken in mix proportion 1:1.64:2.74 which correspond to M30 grade of concrete. Cement is replaced with red mud (as 0%, 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% & 20%). All the ingredients were dry mixed homogeneously. To this dry mix, required quantity of water was added (W/C= 0.45) and the entire mix was again homogeneously mixed. This wet concrete was poured into the moulds which was compacted through hand compaction in three layers and then kept into the vibrator for compaction. After the compaction, the specimens were given smooth finishes and were covered with gunny bags. After 24 hours, the specimens were demoulded and transferred to curing tanks where in they were allowed to cure for 28 days.

Test methods on concrete and its specimen

Different types of tests are conducted on concrete in its fresh state to know the workability, in its hardened state to know the mechanical strength characteristics and also durability parameters. Types of test conducted are as below
Workability: Slump test, compaction factor test.
Mechanical strength characteristics:
A.Compressive strength
B.Split tensile strength
C.Flexure strength
D.Shear strength
E.Water absorption
F.Sorptivity test
To study the effects on mechanical properties following test are conducted.

3 Experimental Results

3.1 Mix design

The mix design procedure adopted to obtain a M30 grade concrete is in accordance with IS 10262- 2009.
The mix proportion for M 30 grade concrete arrived at is

W/C ratio	Cement	Fine aggregate	Coarse aggregate
0.45	413	676 kg/m3	1130 kg/m3
0.45	1	1.64	2.74

3.2 TEST RESULTS

Following tables give the compressive strength, split tensile strength, flexural strength, shear strength and impact strength test results for concrete .The variation in strength is depicted in the form of graphs.

Table 3.1 Slump test results

Percentage replacement of cement by red mud	Slump (mm) values	
	Washed red mud	Unwashed red mud
0%	72	72
2%	75	75
4%	77	74
6%	78	74
8%	79	73
10%	74	72
12%	72	70
14%	70	67
16%	69	65
18%	68	64
20%	65	62

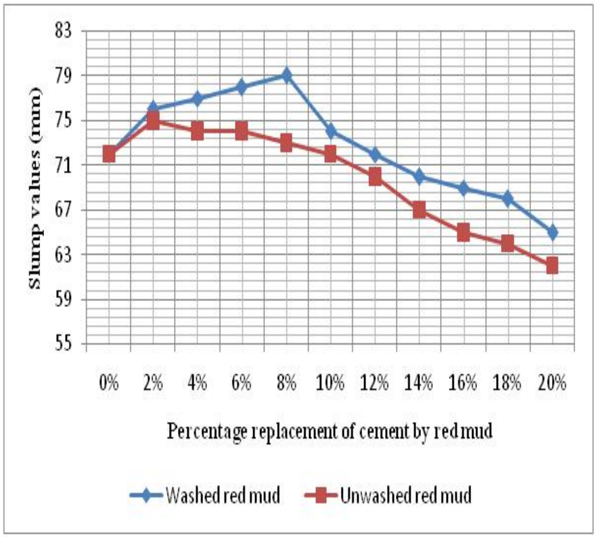

Fig 3.1 Variation of slump

Table 3.2 Compaction factor test results

Percentage of replacement of cement by red mud	Compaction factor (%)	
	Washed red mud	Unwashed red mud
0%	0.80	0.80
2%	0.86	0.85
4%	0.88	0.84
6%	0.87	0.83
8%	0.89	0.82
10%	0.85	0.81
12%	0.82	0.78
14%	0.79	0.77
16%	0.78	0.76
18%	0.76	0.75
20%	0.74	0.74

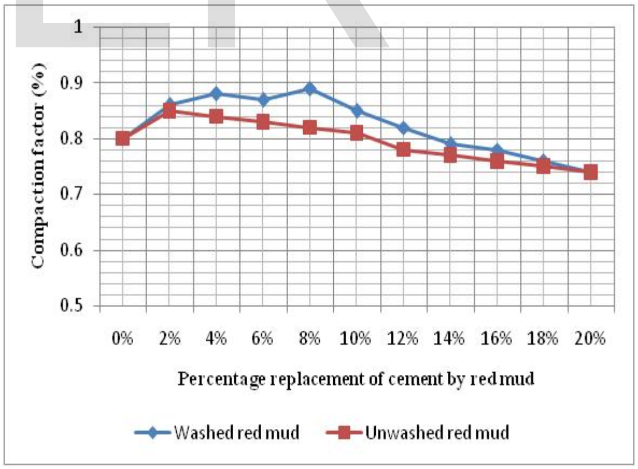

Fig 3.2 Variation of compaction factor

Table 3.3 Overall results of compressive strength

Percentage replacement of cement by red mud	Compressive strength of concrete produced by replacing cement by washed red mud (MPa)	Percentage increase or decrease of compressive strength w.r.t reference mix	Compressive strength of concrete produced by replacing cement by unwashed red mud (MPa)	Percentage increase or decrease of compressive strength w.r.t reference mix	Percentage increase of compressive strength for concrete produced by washed red mud
0% (Reference mix)	45.04	-	45.04	-	0.00
2%	51.11	+13.48	49.78	+10.52	+2.67
4%	52.00	+15.45	48.59	+7.88	+7.02
6%	53.19	+18.08	45.48	+0.98	+16.94
8%	55.85	+24.00	42.07	-6.59	+32.76
10%	48.89	+8.55	39.56	-12.17	+23.58
12%	48.15	+6.90	38.96	-13.50	+23.58
14%	46.22	+2.62	37.04	-17.76	+24.79
16%	44.44	-1.32	35.85	-20.40	+23.97
18%	42.81	-4.94	35.7	-20.74	+19.93
20%	40.00	-11.19	34.96	-22.38	+14.42

Table 3.4 Overall results of split tensile strength

Percentage replacement of cement by red mud	Split tensile strength of concrete produced by replacing cement by washed red mud (MPa)	Percentage increase or decrease of split tensile strength w.r.t reference mix	Split tensile strength of concrete produced by replacing cement by unwashed red mud (MPa)	Percentage increase or decrease of split tensile strength w.r.t reference mix	Percentage increase of split tensile strength for concrete produced by washed red mud
0% (Reference mix)	3.39	-	3.39	-	0.00
2%	3.44	+1.47	3.44	+1.47	0.00
4%	3.63	+7.08	3.35	-1.18	+8.36
6%	3.77	+11.21	3.16	-6.78	+19.30
8%	3.96	+16.81	3.06	-9.73	+29.41
10%	2.93	-13.57	2.83	-16.52	+3.53
12%	2.88	-15.04	2.78	-17.99	+3.60
14%	2.55	-24.78	2.55	-24.78	0.00
16%	2.50	-26.25	2.22	-34.51	+12.61
18%	2.26	-33.33	1.89	-44.25	+19.58
20%	2.12	-37.46	1.65	-51.33	+28.48

Table 3.5 Overall results of shear strength

Percentage replacement of cement by red mud	Shear strength of concrete produced by replacing cement by washed red mud (MPa)	Percentage increase or decrease of shear strength w.r.t reference mix	Shear strength of concrete produced by replacing cement by unwashed red mud (MPa)	Percentage increase or decrease of shear strength w.r.t reference mix	Percentage increase of shear strength for concrete produced by washed red mud
0% (Reference mix)	5.00	-	5.00	-	0.00
2%	7.04	+40.80	6.48	+29.60	+8.64
4%	7.22	+44.40	6.30	+26.00	+14.60
6%	7.41	+48.20	6.11	+22.20	+21.28
8%	7.78	+55.60	5.93	+18.60	+31.20
10%	6.48	+29.60	5.56	+11.20	+16.55
12%	6.30	+26.00	5.19	+3.80	+21.39
14%	5.56	+11.20	4.63	-7.40	+20.09
16%	5.00	0.00	3.70	-26.00	+35.14
18%	4.81	-3.80	2.96	-40.80	+62.50
20%	3.70	-26.00	2.59	-48.20	+42.86

Table 3.6 Overall results of flexural strength

Percentage replacement of cement by red mud	Flexural strength of concrete produced by replacing cement by washed red mud (MPa)	Percentage increase or decrease of flexural strength w.r.t reference mix	Flexural strength of concrete produced by replacing cement by unwashed red mud (MPa)	Percentage increase or decrease of flexural strength w.r.t reference mix	Percentage increase of flexural strength for concrete produced by washed red mud
0% (Reference mix)	5.87	-	5.87	-	0.00
2%	8.00	+36.29	7.73	+31.69	+3.49
4%	8.80	+49.91	7.60	+29.47	+15.79
6%	9.13	+55.54	7.53	+28.28	+21.25
8%	9.73	+65.76	7.47	+27.26	+30.25
10%	7.53	+28.28	7.27	+23.85	+3.58
12%	7.20	+22.66	7.07	+20.44	+1.84
14%	7.13	+21.47	6.93	+18.06	+2.89
16%	7.00	+19.25	6.67	+13.63	+4.95
18%	6.93	+18.06	6.40	+9.03	+8.28
20%	6.80	+15.84	6.26	+6.64	+8.63

Table 3.7: Water absorption test results

Specimen identification	Water absorption (%)	
	Washed red mud	Unwashed red mud
0%	2.72	2.72
2%	2.7	2.45
4%	2.67	2.46
6%	2.56	2.52
8%	2.5	2.6
10%	2.75	2.7
12%	2.78	2.73
14%	2.85	2.79
16%	2.88	2.81
18%	2.91	2.88
20%	2.96	2.92

Table 3.8: Sorptivity test results

Percentage re-placement of ce-ment by red mud	Sorptivity values (mm/min0.5)	
	Washed red mud	Unwashed red mud
0%	0.64	0.64
2%	0.58	0.4
4%	0.55	0.46
6%	0.5	0.52
8%	0.48	0.54
10%	0.58	0.56
12%	0.65	0.57
14%	0.76	0.62
16%	0.79	0.68
18%	0.84	0.72
20%	0.91	0.74

3.2.1 GRAPHS FOR TEST RESULTS

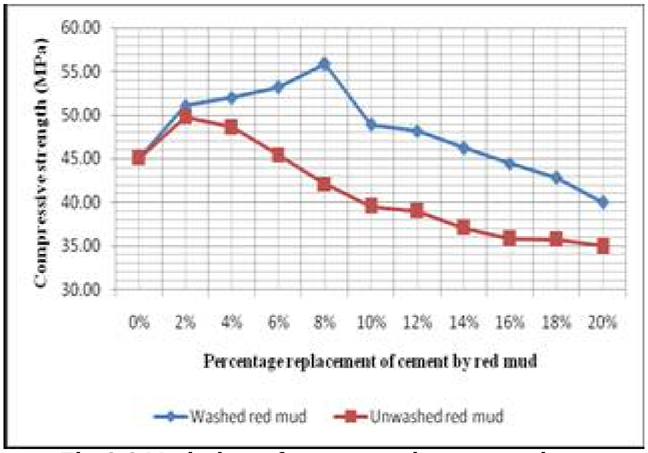

Fig 3.3 Variation of compressive strength

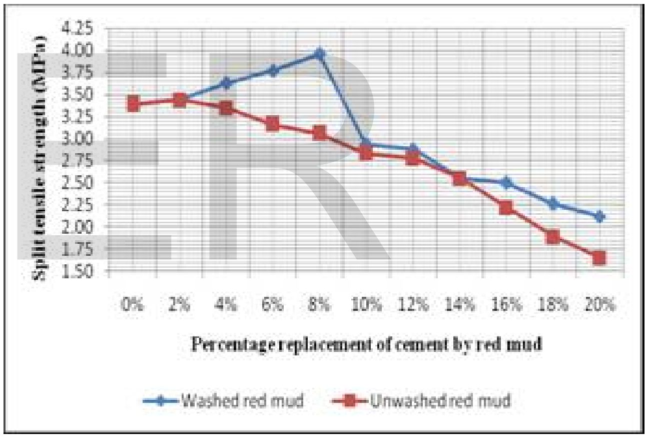

Fig 3.4 Variation of split tensile strength

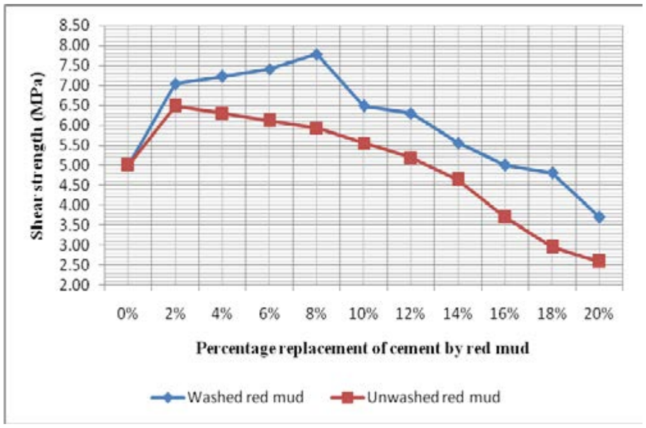

Fig 3.5 Variation of shear strength

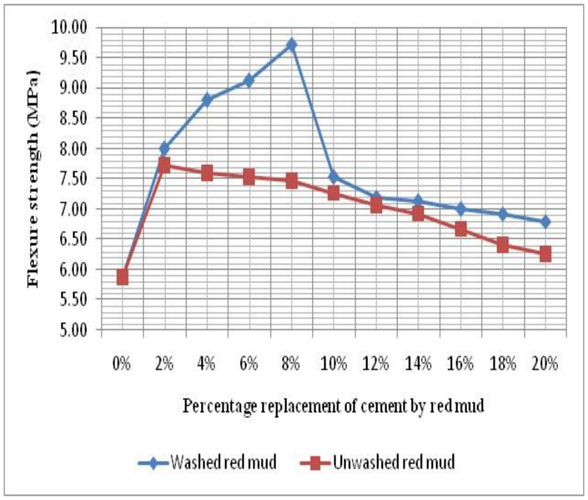

Fig 3.6 Variation of flexural strength

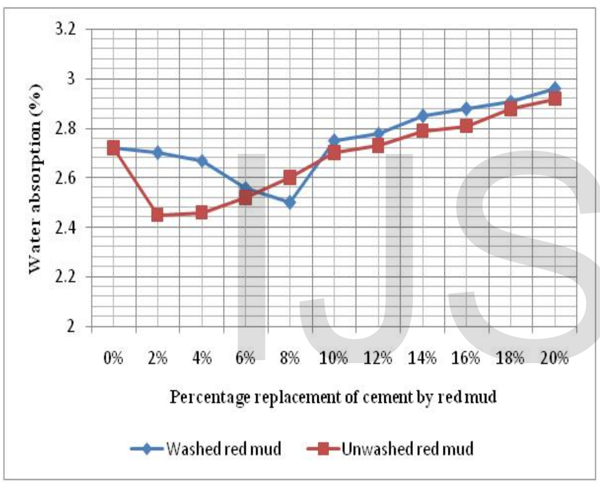

Fig 3.7 Variation of water absorption

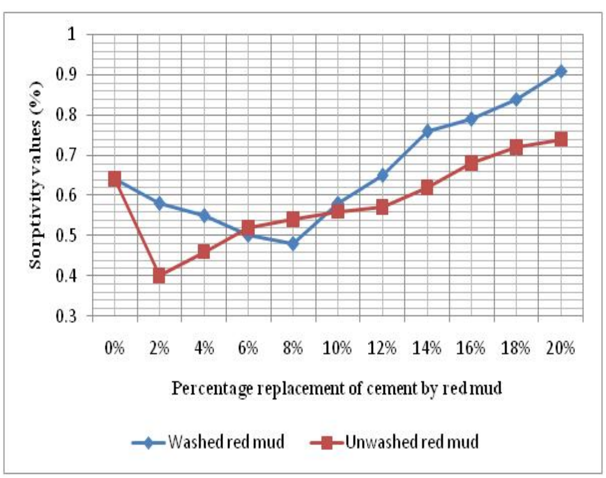

Fig 3.8 Variation of Sorptivity

5 CONCLUSIONS

Following conclusions can be drawn based on the studies made

1. Workability of concrete is higher at a cement replacement level of 8% by washed red mud. Beyond this replacement level workability decreases drastically.
2. Workability of concrete is higher at a cement replacement level of 2% by unwashed red mud. Beyond this replacement level workability decreases drastically.
3. Workability of concrete produced by replacing cement by washed red mud is higher as compared to concrete produced by unwashed red mud.
4. Compressive strength of concrete produced by replacing cement by washed red mud goes on increasing upto 8% replacement of cement by washed red mud and reaches peak at 8%.
5. Compressive strength produced by replacing cement by unwashed red mud goes on increasing upto 2% replacement and reaches peak at 2%.
6. Compressive strength of concrete produced by replacing cement by washed red mud is higher as compared to concrete produced by unwashed red mud.
7. Split tensile strength of concrete produced by replacing cement washed red mud goes on increasing upto 8% replacement and reaches peak at 8%.

8. Split tensile strength produced by replacing cement by unwashed red mud goes on increasing upto 2% replacement and reaches peak at 2%.
9. Split tensile strength of concrete produced by replacing cement by washed red mud is higher as compared to concrete produced by unwashed red mud.
10. Flexural strength of concrete produced by replacing cement by washed red mud goes on increasing upto 8% replacement and reaches peak at 8%.
11. Flexural strength of concrete produced by replacing cement by unwashed red mud goes on increasing upto 2% replacement of cement and reaches peak at 2%.
12. Flexural strength of concrete produced by replacing cement by washed red mud is higher as compared to concrete produced by unwashed red mud.
13. Shear strength of concrete produced by replacing cement by washed red mud goes on increasing upto 8% replacement and reaches peak at 8%.
14. Shear strength of concrete produced by replacing cement by unwashed red mud goes on increasing upto 2% replacement and reaches peak at 2%.
15. Shear strength of concrete produced by replacing cement by washed red mud is higher as compared to concrete produced by unwashed red mud.
16. Water absorption of concrete produced by replacing cement by washed red mud goes on decreasing upto 8% replacement and reaches lowest value at 8%.
17. Water absorption produced by replacing cement by unwashed red mud goes on decreasing upto 2% replacement and reaches lowest value at 2%.
18. Water absorption of concrete produced by replacing washed red mud is higher as compared to concrete produced by unwashed red mud.
19. Sorptivity of concrete produced by replacing cement by washed red mud goes on decreasing upto 8% replacement and reaches lowest value at 8%.
20. Sorptivity produced by replacing unwashed red mud goes on decreasing upto 2% replacement and reaches lowest value at 2%.
21. Sorptivity of concrete produced by replacing washed red mud is higher as compared to concrete produced by unwashed red mud.

REFERENCES

1. *Junior N. Gordon, Willard R. Pinnock, Marcia M. Moore* "**A preliminary investigation of strength development in Jamaican red mud composites**", *Cement and Concrete Composites*, *Volume 18, Issue 6*, *1996*, *pp 371-379.*
2. *Maneesh Singh, Upadhaya. S.N, Prasad. P.M.* "**Preparation of iron rich cements using red mud**", Cement and Concrete Research, Vol. 27, 1997, pp 1037-1046.
3. *Pera. J, Boumaza.R. and Ambroise. J.* " **Development of a pozzolanic pigment**

from red mud" Cement and Concrete Research, Vol. 27, pp1513-1522, 1997

4. *Zhihua Pan, Lin Cheng, Yinong Lu, Nanru Yang* "**Hydration products of alkali-activated slag–red mud cementitious material**" Cement and Concrete Research, Volume 32, Issue 3, March 2002, pp 357-362.

5. *Zhihua Pan, Dongxu Li, Jian Yu, Nanru Yang* "**Properties and microstructure of the hardened alkali-activated red mud–slag cementitious material**" *,Cement and Concrete Research, Volume 33, Issue 9, September 2003, pp 1437-1441.*

6. Tim Newson, Tom Dyer, Chris Adam and Sandra Sharp, (2006) in their paper entitled, **"Effect of structure on the geotechnical properties of bauxite residue",** ASCE, pp 1061-1090.

7. *Amritphale. S.S, Avneesh Anshul, Navin Chandra, Ramakrishnan.N. "* **A novel process for making radiopaque materials using bauxite—red mud**", Journal of the European Ceramic Society 27, 2007, pp 1945–1951.

8. Hamid R. Nikraz, Andrew J. Bodley, David J. Cooling, P. Y. L. Kong and Mahfooz Soomro (2007) in their paper entitled **"Comparison of physical properties between treated and untreated bauxite residue mud",** ASCE, pp 1061-1561

9. Gospodarka Surowcami and Mineralnymi (2007) in their paper entitled **"Characterization and applications of red mud from bauxite processing"** , ASCE, pp 1586-1638

10. *Ramesh Chandra Sahu, Patel. R. K. Ray. B. C.* "**Neutralization of red mud using mine water**" Conference on Emerging Trends in Mining and Allied Industries, NIT, Rourkela, 2008.

11. *Na Zhang , Henghu Sun , Xiaoming Liu, Jixiu Zhang* "**Early-age characteristics of red mud–coal gangue cementitious material**", Journal of Hazardous Materials, Vol 167, pp 927–932, 2009.

12. *Daniel Véras Ribeiroa , Joao António Labrinchab , Marcio Raymundo Morellia* "**Potential use of natural red mud as pozzolana for Portland cement** "Materials Research, vol 14, pp 60-66, 2010.

13. *Daniel Véras Ribeiroa , Joao António Labrinchab , Marcio Raymundo Morellia* (2010) in their paper entitled, **"Use of red mud as addition for portland cement mortars",** Journal of material science and engineering, Volume 4

14. *Senff.L, Hotza.D, Labrincha.J.A.*"**Effect of red mud addition on the rheological behaviour and on hardened state characteristics of cement mortars**" Construction and Building Materials, Vol 25, pp 163–170, 2010.

15. *. Nuruddin. M.F , Bayuaji. R , Masilamani. M.B, Biyanto. T.R* , " **Sidoarjo mud: A potential cement replacement material**" Civil Engineering Dimension, Vol. 12, No. 1, March 2010, 18-22.

16. *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, Issue 8*, *August 2011*, *pp 847-853.*

17. *Sawant .A.B, Kumthekar. M. B, and Swami. V. A.* "**Utilization of industrial waste (Neutralized red mud) in concrete**" International Journal of Advances in Science and Technology, Vol. 3, pp 114-134, 2011.

18. *Daniel Véras Ribeiro, João Antonio Labrincha, Márcio Raymundo Morelli* "**Chloride dif-**

fusivity in red mud-ordinary portland cement concrete determined by migration tests" Materials Research, Vol 14(2) 2011, pp 227-234.

19. *Na Zhang, Xiaoming Liu, Henghu Sun, Longtu Li* "**Pozzolanic behaviour of compound-activated red mud-coal gangue mixture**" *Cement and Concrete Research*, *Volume 41, Issue 3*, *March 2011*, *Pages 270-278.*

20. *Suchita Rai et al (2012) in their paper entitled* **" Neutralization and utilization of red mud for its better waste management",** Conference on Emerging Trends in Mining and Allied Industries, NIT Rourkela,

21. *Sawant .A.B, Kumthekar .M.B, Diwan .V.V and Hiraskar.K.G* (2012) in their paper entitled, **"Experimental study on partial replacement of cement by neutralized red mud in concrete",** International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012

22. Ernest K. Schrader **" Impact resistance and test procedure for concrete"**, ACI Journal, Title no 78-12, pp 141-146