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PRODUCTION OF ORDINARY PORTLAND CEMENT (OPC) FROM NALCO RED MUD

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Abstract

A process for production of Ordinary Portland Cement (OPC) from NALCO Red Mud has been successfully developed from a raw mix containing limestone, red mud, shale and fine coal. The raw materials are ground to the required fineness and then blended to prepare the raw mix. The raw mix is fed in to a kiln and fired to a temperature of 1400-1450 degree centigrade to obtain clinker. Clinker was cooled and gypsum was added in to it to obtain OPC. 3-3.5% of NALCO red mud was used for production of OPC.OPC prepared from this clinker conformed to the requirements of three Indian Standard Specifications for 33, 43 & 53 grade of OPC. The process is efficient, cost-economic and effectively addresses the environmental problems associated with the waste red mud generated during the refining of bauxite for alumina manufacture.

Introduction

National Aluminium Company Limited (NALCO), a Navaratna Company and a Govt. of India Enterprise under Ministry of Mines has set up Asia's largest integrated alumina and aluminium complex in the state of Orissa, utilizing state of the art technology from Aluminium Pechiney, France and is producing 4,8,00,000 tpa of bauxite, 1,5,75,000 tpa of alumina, 3, 45,000 tpa of aluminium metal and 960MW of captive power. During the refining of bauxite for production of alumina employing the Bayer process at NALCO's alumina refinery, at Damanjodi in the district of Koraput, Orissa, on a dry basis ,about 2 million tones /annum of red mud is generated as a by-product. The red mud contains more than 55% water and is disposed off in the form of slurry in to the nearby red mud pond. The accumulated quantity of red mud in the ponds is estimated to be around 18.5 million tones. The water overflowing the pond after the mud is settled, is recycled to the alumina plant for partial recovery of soda. Therefore, the soda content in red mud is minimized. It was thought prudent to explore the possibilities for utilization of this uncausticised red mud dried in air/sunlight for production of value added items. Development of Ordinary Portland Cement (OPC) was one of the most positive efforts undertaken in this direction [1]. NALCO in collaboration with National Council for Cement & Building Materials (NCB), Ballavgarh, and Haryana, India has developed this process.

Table 1. Chemical Composition of NALCO Red Mud.

Constituents	% By Weight
Al_2O_3	16.13
Fe_2O_3	53.92
TiO_2	04.82
SiO_2	06.29
Na_2O	03.45
CaO	01.88
P_2O_5	00.11
V_2O_5	00.11
LOI	11.78

Sample Collection & Sampling

Five shift samples of red mud, bauxite and fly ash were collected. Red mud samples were designated as RMD-1 to RMD-5.

Red Mud:

Five shift samples of red mud weighing about 25kgs each were dried in electric oven at temperature of 105±5°C. The dried lumps in the samples were crushed. The samples were reduced to ~3kg by coning and quartering procedure and ground to pass through 100 mesh sieve. The laboratory samples were prepared by drawing ~200gms from each shift samples by coning and quartering procedure and were subjected to chemical and mineralogical characterization. The results of chemical and mineralogical characteristics of these laboratory samples are discussed in the following section.

Limestone and Other Raw Materials:

Limestone and other raw materials viz. shale, coal and gypsum samples were ground to pass through 100 mesh sieve. The laboratory samples of these raw materials were prepared by drawing ~200gms from each of the ground by coning and quartering procedure. The results of chemical and mineralogical characterization of these samples are discussed in the following section.

Characterization and Evaluation of Samples

Red Mud Samples:

(a) Quality and quality variation: Five ground samples of red mud (RMD-1 to RMD-5) were subjected to chemical analysis for their major constituents' viz. LOI, SiO_2, Fe_2O_3, Al_2O_3 and alkalies for assessing their quality and the variation therein. The results are presented in Table-2 indicated the variation in the composition of red mud shift samples with respect to major oxides to be low. In view of this, all the five shift samples of red mud were mixed together to make a composite sample. The composite sample was designated as RMD-C. Further investigations were carried out on the composite sample of red mud, RMD-C only.

Table 2. Quality and Quality Variation in Shift Samples of Red Mud.

Sl No	Constituent Determined (%)	Shift I RMD-1	Shift II RMD-2	Shift III RMD-3	Shift IV RMD-4	Shift V RMD-5
1	LOI	11.32	11.86	11.03	11.13	11.64
2	SiO_2	6.32	6.35	6.48	6.07	5.90
3	Fe_2O_3	50.10	49.70	50.15	50.52	49.57
4	Al_2O_3	20.51	20.70	21.07	20.14	20.55
5	Na_2O	4.07	4.11	3.40	3.50	3.78
6	K_2O	0.07	0.08	0.06	0.06	0.06

Red Mud Composite Sample (RMD-C):

(a) Chemical Characterization: The composite red mud sample, RMD-C was subjected to chemical analysis and the results are presented in Table-3.

Table 3. Chemical Analysis of Composite Red Mud Sample (RMD-C)

Sl No	Constituents Determined (%)	Results
1	LOI	11.45
2	SiO_2	6.32
3	Fe_2O_3	49.62
4	Al_2O_3	20.74
5	CaO	2.45
6	MgO	0.15
7	SO_3	0.08
8	Na_2O	3.66
9	K_2O	0.07
10	P_2O_5	0.33
11	TiO_2	4.76
12	Mn_2O_3	0.11

(b) Mineralogical Characterization: X-ray diffraction analysis of the composite red mud sample, RMD-C indicated the presence of gibbsite and hematite as major minerals and goethite as minor mineral.

Other Raw Materials:

Limestone:

(a) Chemical Characterization: The limestone sample was subjected to chemical analysis and the results are presented in Table-4. The sample can be classified as cement grade limestone.

Table 4.Chemical Analysis of Raw Materials

Sl.No.	Constituents Determined (%)	Limestone	Shale	Gypsum	Coal Ash
1	LOI	37.25	2.72	17.10CW	0.87
2	SiO_2	10.78	85.93	11.44(+IR)	58.64
3	Fe_2O_3	0.81	1.14	0.26	6.25
4	Al_2O_3	1.95	7.22	NIL	25.85
5	CaO	44.90	0.58	28.85	3.19
6	MgO	3.06	0.21	0.66	0.67
7	SO_3	0.00	0.13	39.90	1.72
8	Na_2O	0.13	0.18	0.24	0.08
9	K_2O	0.73	1.76	0.04	0.83
10	TiO_2	-	0.27	-	1.56
11	Cl^-	0.008	0.01	-	0.017

(b) Mineralogical Characterization: X-ray diffraction analysis of the limestone sample indicated the presence of calcite as a major mineral and α-quartz, dolomite and muscovite as minor minerals.

Shale:

(a) Chemical Characterization: The shale sample was subjected to chemical analysis and the results are presented in Table-4.

(b) Mineralogical Characterization: X-ray diffraction analysis of the shale sample indicated the presence of α-quartz as major mineral and muscovite, yavapaiite and anorthite as minor minerals.

Gypsum:

(a) Chemical Characterization: The gypsum sample was subjected to chemical analysis and the results are presented in Table-4. The sample is considered suitable as a set retarder in the manufacture of cement.

(b) Mineralogical Characterization: X-ray diffraction of the gypsum sample indicated the presence of gypsum as a major mineral and α-quartz and albite as minor minerals.

Coal:

(a) Chemical Characterization: The results of proximate analysis of the coal sample are presented in Table-5. The ash prepared from the above coal was subjected to chemical analysis and the results are presented in Table-4

Table 5. Proximate Analysis of Coal Sample.

Sl.No.	Characteristics	Results
1	Ash Content (%)	35.34
2	Moisture Content (%)	1.82
3	Volatile Matter (%)	30.04
4	Fixed Carbon (%)	32.80
5	Calorific Value(kcal/kg)	5140

The above results of chemico-minerological characteristics of red mud, limestone and other raw materials indicate that their matrix is compatible with the cement matrix and can be used in the manufacture of cement.

Technical Suitability of NALCO Red Mud for the Manufacture of Cement

Chemical and mineralogical analysis of the NALCO red mud sample indicated that its composition is quite compatible with the cement matrix. Therefore, the NALCO red mud sample was considered prima-facie suitable for its gainful utilization in the manufacture of Ordinary Portland Cement (OPC)clinker in combination of other raw materials viz. limestone, shale and fine coal [2 -5]. The process of making OPC is discussed below.

Raw Mix Design & Its Optimization:

The Approach: While designing the raw mixes, attempts were made to maximize the use of red mud, RMD-C as raw mix component in the raw mix design for the manufacture of OPC. Keeping this in mind a large number of different raw mixes were designed to achieve good quality clinker. The proportions of raw material in the raw mixes designed (RM-1 to RM-5) are shown in Table-6. The design parameters optimized in the designed raw mixes are shown in Table-7-11.

Table-6. Various Raw Mix Designs Prepared

Raw Mix No.	Red Mud (%)	Shale (%)	Limestone (%)	Coal Ash Absorption(%)
RM-1	3.00	2.30	94.70	4.75
RM-2	3.50	2.14	94.36	4.75
RM-3	4.00	1.98	94.02	4.75
RM-4	4.30	1.89	93.81	4.75
RM-5	5.00	1.66	93.34	4.75

Table-7. Design Parameters of Raw Mix RM-1

Raw Materials	Red Mud		Limestone		Shale	Coal Ash Absorption
Proportion (%)	3.00		94.70		2.30	4.75
Composition (%)	LOI	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO Na_2O K_2O
Raw Mix	35.68	12.37	2.28	2.63	42.61	MgO: 2.91 Na_2O: 0.24 K_2O: 0.73
Clinker	-	21.11	3.68	5.13	63.25	MgO: 4.34 Na_2O: 0.35 K_2O: 1.13
Modulii Values	LSF		SM		AM	Liquid Content(%)
RawMix	1.08		2.52		1.15	29.25
Clinker	0.93		2.40		1.40	
Potential Phase Composition(%)	C_3S		C_2S		C_3A	C_4AF
	57.32		17.32		7.37	11.19

Table-8. Design Parameters of Raw Mix RM-2

Raw Materials	Red Mud		Limestone		Shale	Coal Ash Absorption
Proportion (%)	3.50		94.36		2.14	4.75
Composition (%)	LOI	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO Na_2O K_2O
Raw Mix	35.61	12.23	2.53	2.72	42.47	MgO: 2.90 Na_2O: 0.25 K_2O: 0.73
Clinker	-	20.08	4.03	5.25	62.97	MgO: 4.32 Na_2O: 0.38 K_2O: 0.76
Modulii Values	LSF		SM		AM	Liquid Content(%)
RawMix	1.08		2.43		1.08	30.03
Clinker	0.93		2.25		1.30	
Potential Phase Composition(%)	C_3S		C_2S		C_3A	C_4AF
	56.64		17.17		7.08	12.27

Table-9. Design Parameters of Raw Mix RM-3

Raw Materials	Red Mud		Limestone		Shale	Coal Ash Absorption
Proportion (%)	4.00		94.02		1.98	4.75
Composition (%)	LOI	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO Na_2O K_2O
Raw Mix	35.53	12.09	2.77	2.80	42.32	MgO: 2.89 Na_2O: 0.27 K_2O: 0.49
Clinker	-	20.65	4.39	5.37	62.69	MgO: 4.30 Na_2O: 0.40 K_2O: 0.76
Modulii Values	LSF		SM		AM	Liquid Content(%)
RawMix	1.08		2.17		1.08	31.17
Clinker	0.93		2.12		1.22	
Potential Phase Composition(%)	C_3S		C_2S		C_3A	C_4AF
	55.94		17.04		6.80	13.35

Table-10. Design Parameters of Raw Mix RM-4

Raw Materials	Red Mud		Limestone		Shale	Coal Ash Absorption
Proportion (%)	4.30		93.81		1.89	4.75
Composition (%)	LOI	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO Na_2O K_2O
Raw Mix	35.49	12.01	2.92	2.85	42.24	MgO: 2.88 Na_2O: 0.28 K_2O:0.72
Clinker	-	20.52	4.62	5.44	62.51	MgO: 4.29 Na_2O: 0.42 K_2O: 0.75
Modulii Values	LSF		SM		AM	Liquid Content(%)
RawMix	1.08		2.11		0.98	31.86
Clinker	0.93		2.04		1.18	
Potential Phase Composition(%)	C_3S		C_2S		C_3A	C_4AF
	55.44		17.03		6.63	14.00

Table-11. Design Parameters of Raw Mix RM-5

Raw Materials	Red Mud		Limestone		Shale	Coal Ash Absorption
Prop-ortion (%)	5.00		93.34		1.66	4.75
Comp-osition (%)	LOI	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO Na_2O K_2O
Raw Mix	35.39	11.80	3.26	2.97	42.04	MgO: 2.87 Na_2O: 0.31 K_2O: 0.48
Clinker	-	20.19	5.10	5.61	62.13	MgO: 4.26 Na_2O: 0.46 K_2O : 0.75
Modulii Values	LSF		SM		AM	Liquid Content(%)
RawMix	1.09		1.90		0.91	33.45
Clinker	0.93		1.89		1.10	
Potential Phase Compo-sition(%)	C_3S		C_2S		C_3A	C_4AF
	54.53		16.78		6.24	15.51

Raw Mix Preparation:

Raw mixes, RM-1 to RM-5 were prepared by taking weighed quantities of raw materials as per the designs, blending them thoroughly and grinding the mixes to fineness of 10% residue on 90μ(170 mesh) sieve. Nodules of about 1 cm in diameter were prepared by mixing about 12% water and were dried in an electric oven at 105±5° C for about 2 hrs before subjecting them to burnability studies.

Burnabilities Studies:

Burnability studies were carried out on all the raw mixes. The dry nodules were introduced in to a laboratory furnace at ambient temperature, which was gradually raised to 1450°C. The raw mixes were fired at 1300, 1350, 1400 and 1450°C with a retention time of 20 minutes. The clinkers, CL-1 to CL-5, prepared from the raw mixes, RM-1 to RM-5 respectively were room cooled and their free lime content determined. The results of free lime determination are presented in Table-12 which indicate that all the raw mixes have good burning characteristics and are capable of yielding quality clinkers even at 1450°C with a retention time of 20 minutes. The free lime content in all the clinker samples was found to be < 0.50% at 1450°C.

Optimization of Raw Mix Design:

While designing the raw mixes, every effort was made to keep the level of utilization of red mud to the maximum extent possible. All the raw mixes prepared viz. RM-1 to RM-5 yielded good quality clinkers when test fired during burnability studies at 1450 °C with retention time of 20 minutes. But, keeping in view the maximum utilization of red mud, design parameters and process implications there from, raw mix RM-2 was taken as the optimized raw mix design. Although the red mud could be utilized up to 5% in the raw mixes designed, the raw mix RM-2 was selected to avoid process problems attributed to the presence of a high proportion of fluxing agents (Al_2O_3 and Fe_2O_3) in such raw mixes. From Table-7 to 11, it is found that on increasing the red mud content from 3.0% to 5.0%, the liquid content was found to be increased continuously. The presence of increased liquid content known to cause process implications in the cement manufacture and especially beyond 30% liquid content is detrimental to the life of refractory lining of the kiln. Generally, the liquid content has been maintained in the range of 27 to 30% in cement manufacture. 3.5% has been selected as the optimal red mud content keeping in mind the maximum utilization of red mud in cement manufacture. Its liquid content is 30.03% and is on border line but is still in an acceptable range. On going from red mud content of 3.5 to 5%, the liquid content increases from 30.03% to 33.45% and the resultant clinkers were found to be sticky to the refractory linings and will reduce the life of the refractory linings and have many process implications. Also, the presence of high liquid content results in the formation of boulders instead of normal sized clinkers which further makes problems in the process. The role of fluxing agents like Fe_2O_3, Al_2O_3 etc is very critical in the formation of clinker. The general range for Al_2O_3 content is 4 to 7% and for Fe_2O_3 is 2 to 4% in the clinker. The details of the optimized raw mix RM-2 is given in Table-8. The raw mix RM-2 is capable of yielding good quality clinker at 1450 °C with a retention time of 20 minutes.

Table 12.Burnability Studies of Cement Raw Mixes with Red Mud as a Component (Retention Time 20 Minutes)

Sl. No.	Raw Mix	Temperature(°C)	Free Lime %
1	RM-1	1300	1.66
		1350	0.82
		1400	0.32
		1450	0.06
2	RM-2	1300	1.73
		1350	0.88
		1400	0.34
		1450	0.06
3	RM-3	1300	2.44
		1350	1.57
		1400	0.55
		1450	0.13
4	RM-4	1300	2.35
		1350	1.18
		1400	0.44
		1450	0.09
5	RM-5	1300	1.73
		1350	0.61
		1400	0.31
		1450	0.15

Preparation and Evaluation of Bulk Clinker

10 kg sample of optimized raw mix RM-2, selected for detailed investigations was prepared by taking weighed quantities of raw materials viz. red mud, limestone, shale and coal ash as per its raw mix design, blended them in a ball mill and ground to a fineness of 10% residue on 90μ(170 mesh) sieve. The nodules were prepared in a pan nodulizer and dried in an electric oven at 105±5 °C for 2 hrs before introducing in an electric furnace at ambient temperature and eventually firing it at 1450 °C for 20 minutes. The resultant clinker CL-2 from raw mix RM-2 was

studied for chemical, mineralogical and grinding characteristics and the OPC prepared there from was evaluated for performance as per relevant Indian Standard Specifications. Three batches of such bulk clinkers, 10kgs each, were prepared by adopting the same procedure to evaluate the reproducibility of the results.

Chemical Analysis:
The chemical analysis of the bulk clinker, CL-2, carried out as per Indian Standard Specification, IS: 4032-1985 and is presented in Table-13. These results indicated that the quality of the clinker was good and capable of yielding good quality cement.

Table 13. Chemical Analysis of Bulk Clinker

Sl. No.	Constituents Determined	Results Obtained (%)
1	LOI	0.35
2	SiO_2	20.60
3	Fe_2O_3	4.02
4	Al_2O_3	5.30
5	CaO	63.27
6	MgO	4.22
7	SO_3	0.27
8	Na_2O	0.38
9	K_2O	0.78
10	Cl^-	0.003
11	Insoluble Residue	0.38
12	Free Lime	0.25

Mineralogical Analysis:
The clinker sample CL-2 from raw mix RM-2 was evaluated for its mineralogical composition by optical microscopy and the results along with the granulometry of the clinker phases are presented in Table-14. Clinker phases are moderately developed and are homogenously distributed. Majority of alite grains are subhedral in shape. Few pseudo hexagonal alite grains are also developed in the clinker. Transformation of belite into alite has also been observed. Some belite clusters were also presented in the sample. Few crystals of free lime were also present. It indicated that the quality of the bulk clinker sample so prepared was good.

Table 14. Mineral Phase Analysis of Bulk Clinker Sample by Optical Microscopy

Sl. No.	Clinker Sample	Phases	Quantity (%)	Granulometry (μm)		
				Min.	Max.	Avg. Size
1	CL-2	C_3S	48	3	18	12
		C_2S	33	3	17	10
		C_3A + C_4AF	18	-	-	-
		CaO_f	1	1	9	4

The X-ray diffractogram of the bulk clinker sample CL-2 indicated the presence of homogenously distributed and well developed phases.

Grindability Studies:
In order to determine the energy required for grinding clinker, laboratory grindability test was conducted using standard bond ball mill. The Bond Index for clinker, CL-2, has been found to be 10.9KWH/T which lies in between the range of Bond Index 9-13KWH/T. As this value of Bond Index lies on the middle of the range, the clinker appears to be hard enough in nature.

Reproducibility of the Clinker

In order to ascertain the reproducibility of the product i.e. clinker, two more batches of the clinker were prepared in the laboratory from the optimized raw mix, keeping the process parameters same as maintained during preparation of bulk clinker sample, CL-2.

Preparation and Evaluation of Two Additional Batches of the Clinker:
Two additional batches of the clinkers CL-2-A and CL-2-B were prepared by taking 10 kgs of raw mix RM-2 adopting the same procedure as described under Preparation and Evaluation of Bulk Clinker. The resultant clinkers designated as CL-2-A and CL-2-B were studies for chemical and mineralogical characteristics. The results are discussed below.

Chemical Analysis:
The chemical analysis of the two additional batches of clinkers, CL-2-A and CL-2-B, were carried out as per Indian Standard Specification. IS: 4032-1985 and the results are presented in Table-15. Results indicated that the chemical composition of both the clinkers, CL-2-A and CL-2-B, are comparable to the composition of the first batch of the clinker, CL-2.

Table 15. Compositional Variation in Three Batches of Clinkers

Sl. No.	Constituents Determined	Results Obtained (%)		
		CL-2	CL-2-A	CL-2-B
1	LOI	0.35	0.45	0.40
2	SiO_2	20.60	20.48	20.43
3	Fe_2O_3	4.02	4.12	4.18
4	Al_2O_3	5.30	5.29	5.26
5	CaO	63.27	63.24	63.35
6	MgO	4.22	4.23	4.26
7	SO_3	0.27	0.34	0.31
8	Na_2O	0.38	0.37	0.31
9	K_2O	0.78	0.69	0.77
10	Cl^-	0.003	0.004	0.006
11	Insoluble Residue	0.38	0.34	0.36
12	Free Lime	0.25	0.22	0.24

Mineralogical Analysis:
(a) Optical Microscopic Analysis: Samples from the two additional batches of clinkers, CL-2-A and CL-2-B, prepared in the laboratory ascertaining the reproducibility were evaluated for their mineralogical composition by optical microscopy. The results along with the granulometry of clinker phases are presented in Table-16. The alite grains were subhedral in shape. Transformation of belite into alite was observed in both the samples. Most of the belite grains were sub-rounded in shape with corroded margins. Few crystals of free lime were also observed in these two samples. The results have revealed that the granulometry and mineralogical characteristics of the two clinkers of additional batches, CL-2-A and CL-2-B, are comparable to the first batch the clinker i.e. CL-2.

Table 16. Variation in Mineral Phase Analysis of Three Batches of Clinker Samples by Optical Microscopy

Sl. No.	Clinker Sample	Phases	Quantity	Granulometry(μm)		
				Min.	Max.	Avg. Size
1	CL-2	C_3S	48	3	18	12
		C_2S	33	3	17	10
		C_3A } C_4AF	18	-	-	-
		CaO_f	1	1	9	4
2	CL-2-A	C_3S	45	3	19	11
		C_2S	34	4	17	11
		C_3A } C_4AF	17	-	-	-
		CaO_f	1	1	9	4
3	CL-2-B	C_3S	46	3	18	11
		C_2S	34	4	18	12
		C_3A } C_4AF	18	-	-	-
		CaO_f	1	1	9	4

(b)X- Ray Diffraction Analysis: Samples from the two additional batches of clinkers CL-2-A and CL-2-B, were also subjected to X- Ray diffraction analysis. It indicated the presence of homogenously distributed and well developed clinker phases in these two samples, CL-2-A and CL-2-B, similar to the first batch of the sample, CL-2. The chemico-minerological evaluation of the results of the two additional batches of clinker samples, CL-2-A and CL-2-B, indicated their close resemblance to the clinker, CL-2, prepared in the first batch. Results have clearly established the reproducibility of the product i.e. clinker made from NALCO red mud.

Preparation and Evaluation of Ordinary Portland Cement (OPC)

Ordinary Portland Cement ,OPC-2 was prepared by grinding the bulk clinker CL-2 so prepared with 5.0% gypsum to a fineness of ~300m^2/kg and tested for setting time, compressive strength, Le-chatelier and autoclave expansion tests as per IS:4031-1988 and the results are presented in Table-17.

Setting Time:

The initial and final setting times of Ordinary Portland Cement prepared in laboratory from bulk clinker were determined as per IS: 4031-1988 and the results are presented in Table-17. The results indicated that the cement sample OPC-2 conformed to the requirements of the standard.

Compressive Strength:

The compressive strength of OPC-2 prepared above was determined as per IS: 4031-1988 and the results are presented in Table-17. The results indicated that the OPC-2 sample conformed to all requirements of all the three Indian Standard Specifications for 33, 43 and 53 grades of OPC viz. IS:269-1989, IS:8112-1989 and IS:12269-1987.

Soundness:

Autoclave and Le – chatelier expansion tests on OPC-2 prepared above were carried out as per the procedures laid down in IS: 4031-1988. The results indicated high volume stability of the cement sample and conformed to all the requirements of all the three Indian Standard Specifications for 33, 43 and 53 grades of Ordinary Portland Cements viz. IS:269-1989, IS:8112-1989 and IS:12269-1987 respectively.

Table 17.Performance of Ordinary Portland Cement (OPC)

Sl. No.	Property	Results	Requirement of IS:12269-1987 (53 Grade OPC)
1	Fineness(M^2/kg)	305	Not less than 225
2	Setting time (Min.)		
	Initial	128	Not less than 30
	Final	254	Not more than 600
3	Compressive Strength(N/mm^2)		
	3 Days	29.0	Not less than 27
	7 Days	42.5	Not less than 37
	28 Days	60.8	Not less than 53
4	Soundness		
	Le-chatelier(mm)	1	Not more than 10
	Autoclave (%)	0.073	Not more than 0.8

The above results indicated that good quality clinker can be prepared by using 3.50% red mud, 94.36% lime stone and 2.14% shale. The Ordinary Portland Cement (OPC) prepared from this clinker conformed to all the requirements of three Indian Standard Specifications for 33, 43 and 53 grade of OPC. In addition, OPC made from 3.0% of NALCO red mud, 94.70% of lime stone and 2.30% of shale also confirmed to the above specifications. Complete performance evaluation of different OPC samples prepared from 3.0 and 3.5% of NALCO red mud was conducted.

Conclusions

Chemical and mineralogical analysis of NALCO red mud indicated that its composition is quite compatible with the cement matrix. The NALCO red mud therefore was considered prima-facie suitable as a raw mix component in the manufacture of OPC. While designing the raw mixes, every effort was made to keep the level of utilization of NALCO red mud to the maximum possible extent. Upto 5% red mud could be gainfully utilized in the raw mixes. However, to overcome process problems attributed to the presence of high proportion of fluxing agents (Al_2O_3 and Fe_2O_3) in other raw mixes, the raw mix RM-2 with 3.5% red mud was considered most suitable for the preparation of bulk clinker, CL-2. Physical performance of the OPC made from the bulk clinker, CL-2, utilizing 3.5% of NALCO red mud conformed to all the requirements of all the three Indian Standard Specifications for 33, 43 and 53 grades of OPC viz. IS:269-1989, IS:8112-1989 and IS:12269-1987 respectively. Reproducibility of the clinker made from NALCO red mud is also established.

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