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Mineral Beneficiation Potentialities of Archaean Limestone for Cement Manufacture

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Abstract

The highly contaminated and deformed coarse crystalline Archaean limestone along with cement grade limestone is being utilized by nearly 14 major cement plants with an installed capacity of 17.36 million tonnes per annum in India , distributed mainly in the states of Rajasthan, Orissa, Jharkhand, Andhra Pradesh, Tamilnadu, Karnataka, Kerala etc.. National Council for Cement and Building Materials (NCB) , India has undertaken studies on the mineral beneficiation potentialities for upgradation of the above limestone exclusively on dry basis, based on the physico-mechanical properties of limestone and the basic principle of optimum size reduction and separation . The low grade limestone sample collected from a working mine of an existing cement plant, is subjected to crushing, grinding with variable time period and its classification through sieving and air classifier. The results are highly encouraging in enhancing CaO content and reducing SiO_2 content in limestone and thus to make it suitable for cement manufacture. The ultimate impact of such studies is that extended life of cement raw material resources, better environment and viability of old cement plants.

Keywords: *Dry Beneficiation, Archaean Limestone, Crushing, Differential Grinding , Sieving, Air Classification, Cement Manufacture.*

INTRODUCTION

The multifold growth in cement industry since 1980 and attaining the 2nd position (Indian Cement Industry-162 million tonnes of installed capacity as on 31.3.2005) has lead to the depletion the cement grade limestone reserves; a major concern of the Indian Cement Industry. This compels the industry to find out a solution by upgrading / utilizing the low and marginal grade limestone available for cement making by adopting advanced techniques right from mining stage to process in the plant. The quality of limestone and its contaminants varies widely from deposit to deposit as the origin envisages right from the oldest Archaean Era to Recent. The authors here discussed the potentialities of Mineral Beneficiation of the contaminated (low/ marginal grade) limestone of Archaean origin. The necessity of the present investigations / experimentations on mineral processing are based on the acute problem that the existing cement plants utilizing the Archaean limestone face and the future prospects of the similar deposits for expansion of the industry. The present experimentations are exclusively based on dry mineral processing techniques as most of the cement plants are based on the dry process.

The fundamental principle " ***Optimum size reduction and Separation***" has been the key for the three stages of experiments i.e. (a) crushing and sieving ; (b) grinding to a defined size fraction followed by air classification; (c) differential grinding followed by sieving, have been successfully conducted for the contaminated coarse crystalline limestone of Archaean origin; the samples being collected from an existing working mine of a cement plant in South India.

Size reduction process involve high energy input, therefore keeping the paramount factor i.e. cost of production into consideration, the processes of mineral beneficiation have been identified to achieve the goal.

ARCHAEAN LIMESTONE OF INDIA

The oldest limestone seen in India occur all along with the other meta-sedimentary –migmatite formation as part of the Archaean Basement Complex. The increased temperature and pressure with time period had altered the original textural, mineralogical and structural characteristics of the calcareous sediments to coarse crystalline limestone (Calcite) with other metamorphic mineral assemblages. The associated rock types, considered as contaminants in cement making process are the *quartzite, slate, phyllite, mica-schist, chlorite-schist, pelitic gneisses, amphibolite, calc-schist, calc-granulite* etc. depending upon the nature of the provenance and the crystalline limestone bands occur as part of the migmatite complex, interlayered with and sometimes cut across by granite rocks. Often gneisses , quartz veins, pegmatites and charnockitic rocks also cut across the crystalline limestone. Crystalline limestone being very plastic material under metamorphic conditions develop thickening and thinning characteristics. Due to plastic deformation, tectonic inclusions are often incorporated by the limestone which float within the limestone as large scale impurities.

These crystalline limestone occur as coarse grained. Minerals such as quartz, feldspar, phlogopite, muscovite, diopside, scapolite, grossularite, tremolite, talc, actinolite, pyrite, apatite, dolomite, chondrodite, graphite etc. may be associated with calcite. The calc-silicate impurities are also coarse grained . The cement grade limestone bands are repeatedly deformed and structurally disturbed with secondary mineralization and intrusions of basic igneous rocks. These limestone are very compact, coarse crystalline and relatively greater resistant to weathering.

The Raialos are overlain by Delhi System of rocks and are underlain by Aravallis which are younger in age than Archaeans but in mining point of view have same characteristics as that of Archaeans.

Geographical Distribution of Archaean Limestone in India

The coarse crystalline Archaean limestone depsoits are geographically distributed mainly in Kheri, Mandaria, Darauli, Rewari area, Pindwara, Raas etc.of Rajasthan ; Hatibari, Gatitangaer, Tikamotoli, Lanjiberna, Biramitrapur etc. of Orissa ; Bandu-Basaria, Kurukutta, etc. of Hazaribagh district of Jharkhand ; The shimoga scist belt of Belgaum district, Shimoga district, Tumkur district and Chitradurga district of Karnataka ; Tirunelveli, Ramanathpuram, Madurai, Trichy, Coimbatore, Salem districts of Tamilnadu. (*The detailed information on the geographical distribution and occurrence of cement grade limestone of Archaean origin can be obtained from NCB's "National Inventory of Cement Grade Limestone Resources of India" project report*).

Cement Plants Utilizing Archaean Limestone

The following depicts the existing cement plants which are producing cement utilizing the Archaean crystalline limestone in all the states of India. (Table 2.2)

MINERAL BENEFICIATION POTENTIALITIES OF ARCHAEAN LIMESTONE

As discussed in the preceding paragraphs the Archaean limestone are highly contaminated mainly with various intrusives and associated altered meta-sediments which enhances the silica (SiO_2) percentage (Table-3.0) in the Raw Meal which create hindrance in clinker formation. Mineral beneficiation is the solution to separate the unwanted materials so that the upgraded limestone can be fed to the cement raw meal. The broad chemical specifications of cement grade limestone for cement manufacture are : CaO% - 44-52; MgO%- 3-5; (SiO_2%, Al_2O_3%, Fe_2O_3%) – to satisfy the LSF, silica modulous, and alumina modulous; Alkalis % < 0.6. The various contaminant rocks of limestone and their chemical analysis is given in Table-3.0.

Table 2.2: Cement Plants Utilizing Archaean Crystalline Limestone

Sl No.	Cement Plant	State	Installed Capcity (MTA)
1	M/s Lakshmi Cement Ltd.	Rajasthan	2.23
2	M/s Binani Cement Ltd.	Rajasthan	2.15
3	M/s Gujarat Ambuja Cement Ltd.	Rajasthan	1.80
4	M/s Shree Cement Ltd.	Rajasthan	2.60
5	M/s OCL India Ltd.	Orissa	1.28
6	M/s Bargarh Cement Ltd.	Orissa	0.96
7	M/s ACC – Chaibasa Cement Works	Jharkhand	0.61
8	M/s Lemos Cement, Khalari	Jharkhand	0.11
9	M/s ACC – Madukkarai Cement Works	Tamilnadu	0.96
10	M/s India Cements Ltd. Sankari Works	Tamilnadu	0.72
11	M/s Chettinad Cement Corporation Ltd.	Tamilnadu	1.80
12	M/s TANCEM Ltd. Alangulam	Tamilnadu	0.40
12	M/s Madras Cements R R Nagar	Tamilnadu	0.75
13	M/s Mysore Cements Ltd.	Karnataka	0.57
14	M/s Malabar Cements Ltd.	Kerala	0.42
		Total	17.36

Table 3: Chemical Quality of Various Intrusives and Altered Metasediments

Various Contaminant Rocks	Chemical Analysis (%)						
	CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	Na_2O	K_2O
Calc-gneisses	26.05	36.11	1.05	2.96	3.68	0.76	1.53
Pegmatite	07.90	56.50	1.00	17.00	4.00	-	-
Amhpbolite	12.60	47.20	4.30	17.00	6.30	-	-
Phyllite	02.00	71.20	0.70	16.50	0.60	-	-

Materials and Methods

Low-grade limestone samples of 500 kg (approx.) has been collected from a working mine of an existing cement plant from South India for laboratory experiments. The sample is analysed chemically for all the major oxides (LOI, CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO, Na_2O, K_2O) to know the feed quality. Optical microscopic analysis of the samples have been carried out through microscope to obtain the detailed mineralogy, grainsize analysis, liberation trend and other optical properties. The minerals present in the limestone are calcite, quartz, clino-pyroxene, orthoclase feldspar, plagioclase and iron oxide. Sub-hedral calcite grains are well sorted and homogeneously distributed. Sub-hedral quartz, clino-pyroxene and ortho-pyroxene grains, and prismatic plagioclase grains are randomly disseminated throughout the rock. Clino-Pyroxene grains are partially altered and fractured. Intrusions of carbonate micrograins in orthoclase grains are observed. Sub-hedral iron oxide grains are highly corroded on the margins. Based on the preliminary investigations and properties of limestone the size reduction and separation (dry mode) processes have been experimented at NCB laboratories.

Crushing and Sieving

The limestone of –25 mm size fraction has been collected at the primary crusher (Jaw Crusher) for size analysis experiments. The size analysis is carried out into 5 size fractions using the sieves of 10mm, 6.3 mm and 1 mm sieves. The recovery (wt %) and quality (major oxides, mainly CaO% and SiO_2 %) have been determined for all the 5 size fractions. It is observed that the quality up to 1 mm size fraction does not change but the underflow 1mm sieve i.e. material below 1mm size gives significant reduction in SiO_2 % up to 12.43% and enhancement of CaO% up to 7.96%. The results are quite encouraging in the quality point of view but the recovery (wt%) is very low i.e. 13.8 % only. The analysis is given in the following table 3.1.1.

Table 3.1.1: Crushing and Sieving Analysis of Coarse Crystalline Limestone

Size Fraction (mm)	Recovery (%wt)	Chemical Analysis (%)						
		CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	Na_2O	K_2O
-25 +1.0	86.16	34.74	27.90	2.21	7.08	2.03	0.12	0.04
-1.0	13.80	42.70	15.47	1.86	4.88	1.92	0.14	0.04

It is inferenced from the above study that after crushing through primary crusher, if the limestone will be screened through 1 mm size screen, the <1 mm size of 13.8% (wt%) can be utilized for cement manufacture. As the recovery is very less further experiments were conducted.

Grinding Followed by Air Classification

The limestone of –25 mm size (after the primary crusher) was subjected to further fineness to 90 µm pass through grinding in ball mill. The product is then classified in an Alpine Laboratory Zigzag Classifier A 100 MZR in NCB laboratories, and the two fractions have been analysed chemically for all the major oxides. The results are given in the table 3.1.2.

Table 3.1.2: Air Classification of Low Grade Archaean Limestone

Size Fraction	Recovery (%wt)	Chemical Analysis (%)						
		CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	Na_2O	K_2O
Feed	100	37.90	23.31	1.89	5.78	2.40	0.11	0.04
under	73.8	42.59	14.57	1.82	4.19	2.50	0.90	0.94
over	26.17	33.92	27.73	2.43	6.78	2.67	0.92	0.94

It is observed from the above experiments that SiO_2 % can be reduced up to 8.74% and CaO % can be enhanced upto 4.69% in the contaminated coarse crystalline limestone with a recovery of 73.8 weight percentage. The sample has been drawn from the rejects of a limestone mine meant for cement production. After this it is inferenced that the rejected limestone can be utilized and a huge quantity of cement grade limestone can be conserved.

Differential Grinding and Sieving

The property of differences in hardness of two minerals has been considered in this mineral processing technique i.e. differential grinding and sieving to separate silica from the brittle and softer hardened calcite in the coarse crystalline limestone. Complete liberation of silica and calcite needs very fine grinding and involve high energy consumption.

The differential grinding/sieving tests have been preformed at 5,7,9 and 11 minutes, in the NCB laboratory. The results are given in Table3.1.3.

Table 3.1.3: Differential Grinding and Sieving Studies.

Grinding Time (Minute)	Output Quality (%)		Size Fraction (µm)	Recovery (%)
	CaO%	SiO_2%		Wt.
5	48.17	11.7	-150	42.4
7	48.68	11.11	-150	46.0
9	49.0	12.6	-150	58.0
11	47.1	13.1	-150	69.3

The detail studies of differential grinding and sieving at grinding time 7 minutes can be given in Table: 3.1.3 A.

Table 3.1.3.A: Differential Grinding and Sieving at Grinding Time 7 Minutes

Sample	Particle Size Fraction (in microns)	Average Size (in microns)	Weight Retained		Cumulative Weight		Chemical Analysis		Enrichment W.R.T Feed Quality	
			(in gms)	in %)	(in gms)	(in %)	(CaO %	SiO_2 %	CaO %	SiO_2 %
S_1	-1000 +500	750	34.32	6.90	34.32	6.90	33.40	38.68	-	-
S_2	-500 +300	400	106.56	21.43	140.88	28.33	40.10	27.24	-	-
S_3	-300 +150	225	145.60	29.28	286.48	57.61	43.89	20.16	++0.42	-
S_4	-150 +90	120	65.31	13.14	351.79	70.75	46.37	15.38	++2.90	--4.33
S_5	-90 +45	67.5	63.03	12.68	414.82	83.43	48.02	12.11	++4.55	--7.60
S_6	-45	22.5	82.88	16.57	497.20	100	49.70	8.44	++6.23	--11.27

Feed Quality = CaO%: 43.47%; SiO_2%: 19.71%

The differential grinding for 7 minutes in a ball mill followed by sieving through Alpine Air Jet Sieves experiment has given better results are given in Table 3.1.3.B.

Table 3.1.3.B: The Differential Grinding (7-Min) and Sieving Studies with Alpine Air Jet Sieves

Feed Quality		Size Fraction (µm)	Output Quality		Enrichment CaO%	Reduction SiO_2%	Wt. Rec.%
CaO%	SiO_2%		CaO %	SiO_2%			
43.47	19.71	-300	45.86	12.85	+2.39	-6.86	81.13

The above experimental results are quite encouraging as the SiO_2% has been reduced upto 4% and under Alpine Air Jet Sieves it reduces SiO_2% upto 6.86%.

CONCLUSION

The laboratory scale studies on dry beneficiation of low grade coarse crystalline Archaean limestone through optimum size reduction and suitable separation, has revealed quite encouraging results, thus making the low grade limestone suitable for cement manufacture. Based on the physico-mechanical properties of the mineral constituents in limestone the mineral processing techniques of crushing, grinding and air classification has enhanced the CaO% up to 6% and reduced the SiO2% up to 8% with significant recovery upto 73.8%. These beneficiation techniques has direct impact on the Indian cement industry at its present and future expansion programme as (a) extended life of the raw material resources; (b) improved environment of mines and its surroundings and (c) economical viability of old cement plants.

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