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Resource Management Strategy of Limestone by Evolution of Nil Waste Process

B. P. Ravi[*1], C. Rudrappa[2], K. Rachappa[3] & M.V. Rudramuniyappa[4]
[1,2,3,4] Mineral Processing Dept., VSKUPG Centre, Nandihalli, Karnataka, India 583119

Abstract: *With exponential demand for high grade limestone both by cement and metallurgical industry of the Bagalkot- Bellary region, beneficiation of limestone from Bagalkot was imperative. Limestone sample assaying 48% CaO, 6.00%SiO_2,1.56% MgO, 1.60% Fe_2O_3, 2.86% Al_2O_3 ,1.97% alkalis and 40.00% LOI was subjected to inverse flotation studies using cationic collectors, varying collector type, collector dosage , mesh of grind and pulp density. Optimum results were obtained on reverse flotation studies using 0.6 kg/t SOKEM 565C, 25% solids, Mesh of grind -100 mesh, D_{80} 120 microns. The final concentrate assaying 52.15% CaO, 1.37 % SiO_2, 0.8% MgO, 1.51% Fe_2O_3, 1.46% Al_2O_3, 43% LOI meeting the specification of local iron and steel industry as an import substitute, was produced at wt% yield of 52%. The float rejects assaying 44.17% CaO, 10.43 % SiO_2, 2.06% MgO, 1.61% Fe_2O_3, 4.15% Al_2O_3, 37.23% LOI with wt% yield of 48, meets the specification of cement industry. The evolved nil waste process is simple, leading to sustainable industrial development of the region offering a pragmatic strategy of natural limestone resource management.*

1. Introduction

Limestone is a sedimentary origin and comprising mainly calcite associated with quartz, mica, clay, iron oxides and feldspar in varying amounts. It is used mainly in cement industry followed by metallurgical industries, like, iron-& steel as fluxes, manufacturing industries, like, glass making, paper, water purification, filler in plastics and in agriculture as soil conditioner [9]. The specification for lime stone for metallurgical industry is CaO > 48%, MgO<3% SiO_2 < 1.5%. The specification for lime stone for chemical industry is CaO >52%, MgO <1%, SiO_2 <1%. The specification for lime stone in glass- ceramics industry is CaO ~54%, SiO_2 <0.1%, MgO <0.1% and S, Cl, Fe <0.01%. An attempt has been made to reduce silica and improve the grade of CaO from limestone of Kaldagi basin, Bagalkot area, so as to utilize limestone most effectively in non cement industries. Many workers [1 -8] have carried out flotation studies by floating calcite and separated from siliceous gangue employing anionic fatty acid salt collectors depressing gangue using sodium silicate as depressant. Straight flotation route was practiced for quite a long time even at industrial scale [10]. However, inverse flotation of limestone by floating the siliceous gangue is practiced owing its ease to float less quantum of gangue float, availability of custom made cheap surfactants having an edge in cost over direct flotation involving large frothy mass handling with a number of cleaner steps.

2. Experimental

2.1. Material

Limestone sample of 200 kg was collected from Limestone mining area of Bagalkot District. The flotation regents were collected from M/s Somu organics Ltd., Bangalore.

2.2. Methods

The as received sample was stage crushed to -10 mesh using primary lab jaw crusher[150 x225mm – 25 mm set], lab roll crusher [200mm x 150mm] 300 mmx600mm 10 mesh screen. The crushed sample was subjected to standard feed preparation by adopting sampling procedures. The sample was ground at 67%S in 175mm x 350 mm rod mill 5 kg rod charge -10 Nos of 40mm, 25mm and 20mm dia varying grinding time. The ground pulp was subjected to froth flotation using D12 a MPE lab sub aeration flotation machine. The feed and products after dewatering followed by drying were weighed, sampled and subjected to characterization studies comprising of chemical, mineralogical and size analysis

3. Results and discussion

3.1. Characterization studies

The limestone sample consisted of whitish gray coloured hard and compact lumps with little fines with bulk density of $1.7 t/m^3$ and 33^o angle of repose. The Bond's ball mill work index was found to be 7Kwh/short ton. The sample contained fine grained calcite intimately associated with minor amounts of fine grained aggregates of quartz, iron oxides, clay and trace amounts of feldspar. The sample analyzed 48% CaO, 6.00%SiO_2, 1.56% MgO, 1.60% Fe_2O_3, 2.86% Al_2O_3, 1.97% alkalies and 40.00% LOI. The sample was siliceous cement grade lime stone. The diagnostic amenability test on -65 mesh sample involving sink and float test at 2.8 specific gravity were conducted and observed reduction of silica in sink to 2%.-10 mesh samples were ground in rod mill for varying time from 5 to 15 minutes and samples were subjected to size analysis The data is given in Table 1. The grindability data indicated that the sample was medium soft in nature

Table 1 Size analysis of rod mill grindability

Conditions; 250 Gms of – 10 mesh ground in 175mm x 350mm rod milll with 5 kg rod charge at 67% S for time varying from 0/5/10/15 minutes

Mesh	Aperture microns	Wt% retained			
		0'	5'	10'	15'
-10+12	1700	19.2	10.0	1.6	1.2
-12+16	1400	21.2	1.6	0.8	0.4
-16+22	1000	14.0	13.6	0.4	0.4
-22+30	710	11.2	2.4	1.2	0.4
-30+52	500	9.6	16.4	3.2	0.4
-52+72	300	5.2	4.8	4.8	1.2
-72+100	212	3.2	2.8	5.2	4.8
-100+150	150	1.6	1.6	4.0	7.6
-150+200	106	2.8	3.2	8.0	9.2
-200+300	75	7.2	6.4	14.0	15.6
-300	53	4.8	37.2	56.8	58.8
		100.0	100.0	100.0	100.0
D_{80} microns		1490	880	120	90

3.2 Effect of mesh of grind on flotation

Inverse flotation tests were conducted varying mesh of grinding time 5'/10'/15' with respective D_{80} 880/120/90 microns respectively at natural pH of 8, with 0.8 Kg/t anionic collector SOKEM 565 C. The results are given in Table 2. The results indicated that the grade of silica content reduced to a minimum at mesh of grind of 120 microns and hence was chosen. The fall in grade in coarse grind of 880 microns was due to lack of liberation of silica values while the fall in grade in very fine grind of 90 microns was attributed to interference of slimes. Rao et.al. [1] recommended a fine grind of 90 microns for soap flotation of limestone from AP for cement grade

3.3 Choice of collector

Inverse flotation tests were conducted at D_{80} size of 120 microns varying collectors like SOKEM 565C and SOKEM 504 C maintaining dosage of 0.8 kg/t. The results are shown in Table 3. The results indicated that SOKEM 565C was more selective in flotation of siliceous gangue. SOKEM 565C was chosen in case of reverse flotation of siliceous limestone by previous workers. [1 and 7].

Table 2; Effect of MOG on flotation

Conditions; Mesh of grind 5/10/15' D_{80}880/120/90 microns Flotation pH 8, % S 19,

Stage	Cell gm	rpm	Reagent	Dosage kg/t	CT min	FTmin
RF	250	1200	SOKEM 565C	0.8	3	3

Results;

MOG	Product	Wt%	% SiO_2	
			Assay	Distn
5' D_{80} 880 microns	Float reject	44.0	10.60	77.8
	Non float	56.0	5.10	22.2
	Head Cal	100.0	5.97	100
10' D_{80} 120microns	Float reject	58.0	9.25	89.5
	Non float	42.0	1.50	10.5
	Head Cal	100.0	6.00	100
15' D_{80} 90 microns	Float reject	56.0	7.82	72.7
	Non float	44.0	3.74	27.3
	Head Cal	100.0	6.02	100

Table 3; Choice of collector

Conditions; MOG D_{80}120microns, Flotation pH 8, % S 19

Stage	Cell gm	rpm	Reagent	Dosage kg/t	CT min	FT min
RF	250	1200	SOKEM 565C/504C	0.8	3	3

Results;

Collector	Product	Wt%	% SiO_2	
			Assay	Distn
SOKEM 504C	Float reject	55.2	9.18	84.0
	Non float	44.8	2.16	16.0
	Head Cal	100	6.01	100
SOKEM 565C	Float reject	58.0	9.25	89.5
	Non float	42.0	1.50	10.5
	Head Cal	100.0	6.00	100

3.4 Effect of pulp density on flotation

Tests were conducted by varying pulp density 19/28/35 % S. at MOG D_{80}120microns, pH 8, % S 19, SOKEM 565C 0.6kg/ as per previous tests. The results are given in Table 4. Increase in pulp- density decreased the grade of concentrate. Hence, 25% S was chosen as optimum for next tests. Similar results were obtained in flotation of limestone by previous workers. [1 to 8 and 10] This may be due to entrapment in tough voluminous thick froths with increased viscosity averting drainage leading lack of selectivity at very high % solids.

Table 4; Effect of %S

%S	Product	Wt%	% SiO_2	
			Assay	Distn
19	Float reject	48.0	12.60	90.6
	Non float	52.0	1.20	9.4
	Head Cal	100.0	6.68	100.0
25	Float reject	47.4	12.07	90.1
	Non float	52.6	1.20	9.9
	Head Cal	100.0	6.35	100.0.
35	Float reject	41.7	11.60	83.7
	Non float	58.3	1.60	16.3
	Head Cal	100.0	5.78	100.0

3.5 Collector dosage variation

Inverse flotation tests were conducted at D_{80} size of 120 microns, varying collector SOKEM 565C dosage from 0.4, 0.6, 0.8 and 1 kg/t. The results are shown in Table 5. From the experimental studies, it has been observe that an increase in collector dosage reduced the yield and silica content in the non float. Optimum results meeting the specification were obtained at 0.6 kg/t of SOKEM 565C. Similar dosages of SOKEM 565C were recommended by previous investigators [1 and 7].

Table 5; Effect of collector SOKEM565C Dosage

Conditions; MOG 10 D_{80}120microns, Flotation pH 8, % S 19

Stage	Cell gms	rpm	Reagent	Dosage kg/t	CT min	FT min
RF	250	1200	SOKEM 565C	0.4/0.6 /0.8/1.2	3	3

Results

Dosage kg/t	**Product**	**Wt%**	**% SiO_2**	
			Assay	**Distn**
0.4kg/t	Float reject	34.0	13.00	73.9
	Non float	66.0	2.36	26.1
	Head Cal	100.0	6.01	100.0
0.6kg/t	Float reject	49.4	11.4	84.5
	Non float	51.6	1.40	15.5
	Head Cal	100.0	6.35	100.0
0.8kg/t	Float reject	58.0	9.25	89.5
	Non float	42.0	1.50	10.5
	Head Cal	100.0	6.00	100
1.0kg/t	Float reject	62.0	8.94	92.4
	Non float	38.0	1.20	7.6
	Head Cal	100.0	6.02	100.0

3.6 Final test

Optimum results were obtained on by inverse flotation studies using 0.6 kg/t SOKEM 565C, 25% solids, Mesh of grind -100 mesh, D_{80} 120 microns. The test condition and results are given in Table 6.The results indicate that the process is not significantly sensitive to water quality and SOKEM 565C collector was insensitive to water hardness, low consumption levels due to less induction time, high contact angles with selectivity [1]. The evolved process is a nil waste process with low water demand of 0.15m^3/t of ore. Fig.1 shows the evolved nil waste process flowsheet.

Table 6; Final test

Conditions; MOG D_{80}120microns, pH 8, 50%S in conditioning And 25%S in flotation

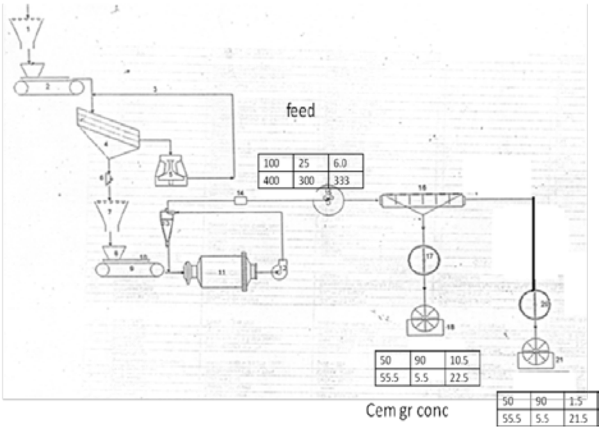
Stage	Cell gm	rpm	Reagent	Dosage kg/t	CT min	FT min
RF	250	1200	SOKEM 565C	0.6	3	3

Results;

Type	**Product**	**Wt%**	**% SiO_2**	
			Assay	**Distn**
Test with Reclaimed water	Float reject	52.0	10.43	89.2
	Non float	48.0	1.37	10.8
	Head Cal	100	6.08	100.0
Test with Fresh water	Float reject	47.4	12.07	90.1
	Non float	52.6	1.20	9.9
	Head Cal	100.0	6.35	100.0.

4. Conclusions

Inverse flotation studies were conducted to float siliceous impurities using cationic collectors varying collector type, collector dosage , mesh of grind and pulp density on a limestone from Lokapur area, Bagalkot, assaying 48% CaO,6.00%SiO_2,1.56% MgO, 1.60% Fe_2O_3, 2.86% Al_2O_3, 1.97% (Na_2O +K_2O) and 40.00% LOI. Optimum results were obtained at 0.6 kg/t SOKEM 565C, 25% S, MOG D_{80}120 microns yielding the met-grade Non-float analyzing 52% CaO,1.2 SiO_2, 0.8% MgO,1.2% Fe_2O_3, 1.3% Al_2O_3, 43% LOI with wt% yield of 52% while final tails meets the cement grade. The process was confirmed with reclaimed water. The evolved zero waste process with minimal water demand, leads to sustainable development of the region, offering strategy for limestone resource, utilization, economic and ecological management.



LEGEND	tph solid	% S	%SiO_2 assay
	tph pulp	m^3ph water	m^3ph pulp

Met gr conc

Fig1 Nil waste Beneficiation of limestone from Bagalkot.

5. References

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