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Beneficiation of Limestone from Bagalkot, Karnataka for Metallurgical Industry

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***Abstract*—Lime stone samples from Lokapur area of Bagalkot district, Karnataka, were collected to beneficiate the sample for effective utilization in metallurgical industries. With exponential demand of high grade lime stone both by cement and metallurgical industry of the region, beneficiation of lime stone is imperative to meet the specification for different industries. Lime stone sample assaying 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 was subjected to inverse flotation studies to obtain a concentrate required for steel industry, Inverse flotation studies were carried out to float siliceous impurities 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 test was confirmed using reclaimed water and final concentrate assayed 50-52% CaO,1.2 -1.5% SiO_2, 0.8-1.2%MgO,1.2-1.5% Fe_2O_3 , 1.3-1.66% Al_2O_3, 42-43% LOI with wt% yield varying from 48- 52%. The product meets the specification of local steel industry**

***Keywords*—Flotation;Limestone;**

I. 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. India possesses large deposits of lime stone amounting to l lakh billion ton and South Indian states account for over 48% of the reserves. Though India is bestowed with large lime stone deposits, the quality of lime stone required by iron and steel metallurgical and other manufacturing industries could not be met due to high amounts of silica and iron-aluminum content. 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%. Keeping in view of the above stringent specifications, in the present investigation, an attempt has been made to reduce silica and improve the grade of Cao so as to utilize limestone most effectively in non cement industries. Many workers Rao D S et al [2009], Chinniah et al [2012], Suresh N et al [2002]. Rachappa K et al (2013) 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. 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.

II. EXPERIMENTAL

Material and Methods; Lime stone samples of 200 kgs were collected from Lime stone mining area of Bagalkot District. The flotation regents were collected from M/s Somu organics Ltd., Bangalore. 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 Denver type lab sub aeration flotation machine. The feed and products after dewatering followed by drying were weighed, sampled and subjected to characterization studies.

III. RESULTS AND DISCUSSION

Characterization studies; The lime stone sample consisted of whitish gray coloured hard and compact lumps with little fines with bulk density of 1.7t/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 mill with 5 kg rod charge at 67% S for time varying from 0/5/10/15 minutes

Mesh	Aperture in 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

Effect of mesh of grind on inverse 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.

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

Results;

Mesh of grind	Product	Wt%	% SiO_2	
			Assay	Distn
5' D_{80}880 microns	Float reject	44.0	10.60	77.8
	Non float concentrate	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 concentrate	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 concentrate	44.0	3.74	27.3
	Head Cal	100.0	6.02	100

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. Rao D S et al [2009] incidentally obtained similar results with SOKEM 565C in case of reverse flotation of highly siliceous lime stone from AP to get cement grade concentrate. SOKEM 565C produced concentrate with SiO_2 <3% meeting metallurgical specifications and hence chosen for subsequent test work.

Table 3 ; Choice of collector on flotation

Conditions; Mesh of grind 100 # D_{80}120microns,Flotation pH 8, % S 19

Stage	cell	rpm	Reagent	Dosage kg/t	CT min	FTmin
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 concentrate	44.8	2.16	16.0
	Head Cal	100	6.01	100
SOKEM 565C	Float reject	58.0	9.25	89.5
	Non float concentrate	42.0	1.50	10.5
	Head Cal	100.0	6.00	100

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 4. 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. Rao D S et. al. [2009] recommended 0.7 kg/t as optimum dosage of SOKEM 565C.

Table 4 ; Effect of collector SOKEM565C Dosage variation

Conditions; Mesh of grind 100 # D_{80}120microns,Flotation pH 8, % S 19

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

Collector SOKEM dosage kg/t	Product	Wt%	% SiO_2	
			Assay	Distn
0.4kg/t	Float reject	34.0	13.00	73.9
	Non float concentrate	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 concentrate	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 concentrate	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 concentrate	38.0	1.20	7.6
	Head Cal	100.0	6.02	100.0

Effect of conditioning time of collector: Tests were conducted by varying conditioning time of 1,3 and 5 minutes with collector SOKEM 565C of 0.8kg/t with flotation time of 3minutes at pH8. The results are given in Table 5. Optimum results were obtained at 3' conditioning time. Poor results in extreme conditioning time may attribute to lack of contact time and destruction of collector adsorption.

Table 5 ; Effect of conditioning time variation

Conditions;

Mesh of grind 100 # D_{80}120microns, Flotation pH 8, % S 19 SOKEM 565C 0.8kg/t

Stage	cell	rpm	Reagent	Dosage kg/t	CT min	FTmin
RF	250	1200	SOKEM 565C	0.8	1/3/5	3

Conditioning time	Product	Wt%	% SiO_2	
			Assay	Distn
1 min	Float reject	51.6	9.82	83.9
	Non float concentrate	48.4	2.00	16.1
	Head Cal	100.0	6.04	100.0
3 min	Float reject	58.0	9.25	89.5
	Non float concentrate	42.0	1.50	10.5
	Head Cal	100.0	6.00	100
5 min	Float reject	62.0	8.36	89.5
	Non float concentrate	38.0	1.60	10.5
	Head Cal	100.0	5.79	100.0

Effect of pulp density on flotation; Tests were conducted by varying pulp density (20,25,35) 19/28/35 % S. The results are given in Table 6. Increase in pulp- density decreased the grade of concentrate. Hence, 20 -25% S was chosen as optimum for next tests.

Table 6; Effect of %S

Conditions; MOG 100 # D_{80}120microns, pH 8, % S 19, SOKEM 565C 0.6kg/t,% S 19/28/35

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

%S	Product	Wt%	% SiO_2	
			Assay	Distn
19	Float reject	48.0	12.60	90.6
	Non float concentrate	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 concentrate	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 concentrate	58.3	1.60	16.3
	Head Cal	100.0	5.78	100.0

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. Hence tests were done using fresh water and reclaimed water. The test condition and results are given in Table 7.The results indicate that the process is not significantly sensitive to water quality and concentrates meeting the metallurgical industry specifications can be produced though a marginal fall in yield while using reclaimed water. SOKEM 565C cationic collector are insensitive to water hardness salts, works well at pH 7-8, low consumption levels, less induction time and high contact angles – selectivity [Rao D et. al. 2009].

Table 7 ; Final test

Conditions; MOG 100 # D_{80}120microns, Flotation pH 8, 50%S in conditioning & 20-25%S in flotation

Stage	cell	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 concentrate	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 concentrate	52.6	1.20	9.9
	Head Cal	100.0	6.35	100.0.

IV. CONCLUSIONS

Lime stone sample 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% alkalies and 40.00% LOI was subjected to obtain a concentrate assaying maximum 1.50% SiO_2 required for iron and steel industry. Inverse flotation studies were conducted to float siliceous impurities using cationic collectors varying collector type, collector dosage , mesh of grind and pulp density. Optimum results were obtained by inverse flotation studies using 0.6 kg/t SOKEM 565C, 25% solids, Mesh of grind -100 mesh, D_{80} 120 microns. The test was confirmed using reclaimed water and final concentrate assayed 50-52% CaO,1.2 -1.5% SiO_2, 0.8-1.2% MgO,1.2-1.5% Fe_2O_3, 1.3-1.66% Al_2O_3, 42-43% LOI with wt% yield varying from 48- 52%. The product meets the specification of local iron and steel industry and acts as an import substitute.

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