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A Note on Calcination Study of Sanu and Gotan SMS Grade Limestones of Western Rajasthan, India

KEYWORDS: Calcination, SMS grade limestone, Volume index, Sanu, Gotan, Rajasthan.

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ABSTRACT *Two chemically similar high-grade limestone deposits occurring in Sanu area of Jaisalmer and Gotan area of Nagaur, Rajasthan were studied to determine their suitability for SMS use through the process of calcination. On calcinations at different test temperatures, Sanu limestone shows shrinkage while, Gotan limestone shows expansion, with their volume index of about 1 and 0.9 respectively. It suggests that both the limestones are suitable for SMS use however, the Sanu limestone is superior than the Gotan limestone. The shrinkage and expansion behaviour of limestones of the study area also shows better correlation with their grain morphology and microstructures.*

INTRODUCTION

In India, steel melting shop (SMS) grade limestone deposits occur mainly in Sanu area (N27°15′ : E70°39′) of Jaisalmer and Gotan area (N26°39′30″ : E73°43′00″) of Nagaur, Rajasthan. The Sanu limestone belongs to the Tertiary rocks of Eocene age (Pareek, 1984; GSI, 1999; Singh, 2008) while, Gotan limestone belongs to the Marwar Supergroup of late Neoproterozoic to early Cambrian age (Kumar *et al.*, 1997; Chauhan *et al.*, 2004). Limestone from both the areas is being produced by M/s Rajasthan State Mines and Minerals Limited over the past two decades. The limestone deposits are quarried by open-cast, mechanized methods of mining (Figure 1). Chemically, limestones of Sanu and Gotan areas are nearly similar and meet the specifications required for SMS use (IBM, 2008). However, steel industry of India prefers Sanu limestone due to its superior physical properties causing less size reduction during its handling and minimum generation of -15 mm size lime after calcinations (Prabhulingaiah *et al.*, 2007a, 2007b; Shekhawat and Prabhulingaiah, 2010).

The Atomic Force Microscopic (AFM) study carried out showed that lime particles of Sanu limestone shows a closed and compact network type boundaries while, that of Gotan limestone shows open boundaries (Sen *et al.*, 2006). Similarly, scanning electron microscopic images revealed that Sanu limestone does not show any significant development of cracks after calcinations, whereas Gotan limestone shows cracks after calcinations (Shekhawat and Prabhulingaiah, 2010). These observations indicate that volume changes on calcinations might be different for both the limestones. Thus, in the present study, an attempt has been made to assess suitability of both the limestones for SMS use through the process of calcinations which is a simple and time saving test/technique.

CALCINATION STUDY

Calcination of limestone refers to thermal decomposition or dissociation of calcium carbonate ($CaCO_3$) producing lime (CaO) and carbon dioxide (CO_2 gas). During this process of calcinations, volume changes take place in limestone (Murray, 1954; Oates, 1998) and dissociation of limestone feed starts from the surface forming a shell of CaO which proceeds to its centre. The ratio of volume of limestone to lime is generally referred as Stone to Lime Volume Index (SeLVI). Calcination of limestone is largely affected by size and uniformity of the feed, shape and size of the grains, microstructure, presence of impurities *etc.*

For experimental study, a number of fresh lumpy samples of Sanu and Gotan limestones have been collected from working sections of the quarries. Then four batches of five samples each of Sanu and Gotan limestone were taken and cuboids measuring 1.5 to 2 cm sides were cut using hand cutter for easy measurement of their dimensions before and after calcinations (Figure 2 & 3). These cuboid samples were placed in a muffle furnace and calcined at 900°C, 950°C, 1000°C and1050°C temperatures. The samples were exposed to the test temperatures for 2 hours in the furnace. The volume and weight of the each sample were measured before and after each calcination test temperature using micrometer scale and simple chemical weighing machine. The volume and weight measurements are presented in Table 1 to 4. The average volume of the five samples each of Sanu and Gotan limestone has been used to calculate SeLVI (Table 5).

Experimental data (Table 1) reveal that at 900°C temperature all the samples show expansion however, the samples from Sanu area showed less expansion (4.8%) compared to Gotan samples (8.3%). At the test temperature of 950°C, the samples from Sanu area showed shrinkage which was continued at the subsequent temperatures of 1000°C and 1050°C (Table 2-4). Whereas, the samples of Gotan area do not show any shrinkage but showed continous expansion at the subsequent test temperatures of 950°C, 1000°C and 1050°C (Table 2-4). At all test temperatures, the weight loss of the samples from Sanu area is recorded slightly lower as compared to Gotan samples (Table 1 - 4).

Table 1: Calcinations of SMS grade limestone samples at 900°C for 2 hours

S. No.	Volume of limestone (cm^3) = V_1	Weight of limestone (g) = W_1	Volume of lime (cm^3) = V_2	Weight of lime (g) = W_2	Weight loss (%) = W_1-W_2	SeLVI=V_1/V_2
(A) Sanu limestone						
1.	6.32	16.80	6.97	9.96	40.71	0.907
2.	10.08	25.27	10.46	16.45	34.90	0.964
3.	6.28	16.63	6.64	9.38	39.99	0.946
4.	7.53	19.00	7.73	12.21	35.74	0.974
5.	7.74	18.01	7.95	10.50	41.70	0.974

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Av.	7.590	18.942	7.950	11.700	38.23	0.955
(B) Gotan limestone						
1.	7.49	17.78	8.42	10.16	42.86	0.890
2.	9.72	23.73	10.62	13.74	42.10	0.915
3	10.10	24.44	10.86	13.95	42.92	0.930
4	7.01	17.98	7.60	10.26	42.94	0.922
5	7.70	19.13	8.30	10.75	43.81	0.928
Av.	8.404	20.612	9.160	11.772	42.89	0.917

Table 2: Calcinations of SMS grade limestone samples at 950°C for 2 hours

S. No.	Volume of limestone (cm^3) = V_1	Weight of limestone (g) = W_1	Volume of lime (cm^3) = V_2	Weight of lime (g) = W_2	Weight loss (%) = W_1-W_2	SeLVI= V_1/V_2
(A) Sanu limestone						
1.	6.11	15.15	6.03	8.63	43.04	1.013
2.	7.06	17.84	6.80	10.19	42.88	1.038
3.	7.37	18.27	7.22	10.44	42.86	1.021
4.	7.72	19.93	7.60	11.44	42.60	1.016
5.	8.39	21.61	8.28	12.36	42.80	1.013
Av.	7.330	18.56	7.186	10.612	42.82	1.020
(B) Gotan limestone						
1.	9.46	24.37	10.46	13.89	43.00	0.904
2.	8.16	20.85	9.01	12.12	41.87	0.906
3.	9.17	23.33	9.99	13.27	43.12	0.918
4.	7.02	18.48	8.03	10.46	43.40	0.999
5.	5.46	13.23	5.83	7.45	43.69	0.937
Av.	8.054	20.052	8.664	11.438	43.37	0.930

Table 3: Calcinations of SMS grade limestone samples at 1000°C for 2 hours

S. No.	*Volume of limestone (cm3) = V1*	*Weight of limestone (g) = W1*	*Volume of lime (cm3) = V2*	*Weight of lime (g) = W2*	*Weight loss (%) = W1-W2*	*SeLVI= V1/V2*
(A) Sanu limestone						
1.	7.07	16.99	6.46	9.71	42.85	1.094
2.	7.27	17.15	6.70	9.80	42.86	1.085
3.	4.49	12.76	4.28	7.28	42.95	1.049
4.	6.57	16.50	6.22	9.48	42.55	1.056
5.	5.42	12.61	5.28	7.18	43.06	1.027
Av.	6.164	15.202	5.788	8.69	42.85	1.064
(B) Gotan limestone						
1.	6.01	15.57	6.65	8.78	43.61	0.904
2.	5.83	15.26	6.50	8.65	43.32	0.897
3.	4.75	11.84	5.03	6.77	42.82	0.944
4.	4.54	11.40	5.10	6.44	43.51	0.890
5.	5.44	15.22	6.46	8.58	43.63	0.842
Av.	5.314	13.858	5.948	7.844	43.40	0.893

Table 4: Calcinations of SMS grade limestone samples at 1050°C for 2 hours

S. No.	Volume of limestone (cm^3) = V_1	Weight of limestone (g) = W_1	Volume of lime (cm^3)= V_2	Weight of lime (g) = W_2	Weight loss (%) = W_1-W_2	SeLVI=V_1/ V_2
(A) Sanu limestone						
1.	6.92	16.72	6.46	9.53	43.00	1.071
2.	9.25	23.97	7.90	13.70	42.85	1.171
3.	7.48	18.28	6.74	10.43	42.94	1.110
4.	8.46	22.20	7.03	12.66	42.97	1.203
5.	8.71	22.38	7.68	12.77	42.94	1.134
Av.	8.164	20.71	7.16	11.818	42.94	1.140
(B) Gotan limestone						
1.	7.94	20.45	8.69	11.59	43.33	0.914
2.	8.38	21.73	9.69	12.52	42.38	0.892
3.	7.71	19.65	8.25	11.12	43.41	0.935
4.	6.55	17.08	7.15	9.62	43.68	0.916
5.	7.76	19.79	8.33	11.05	44.16	0.932
Av.	7.668	19.740	8.362	11.18	43.36	0.917

Table 5: Average SeLVI of SMS grade limestone of Sanu and Gotan area, Rajasthan

S. No.	Sources of limestone	Average SeLVI value at			
		900°C	950°C	1000°C	1050°C
1.	Sanu	0.952	1.020	1.062	1.141
2.	Gotan	0.917	9.33	0.895	0.918

DISCUSSION AND CONCLUSIONS

The lime used in steel plants of India should contain minimum -15 mm size fraction, because -15 mm size lime can not be fed to LD convertors and hence, it causes a direct economic loss. The initial study carried out by M/s Steel Authority of India Ltd. shows that the proportion of +15 mm size lime produced from Sanu limestone is about 49.89% while, in Gotan lime, it is about 38.87% (Sen *et al.*, 2006; Prabhulingaiah *et al.*, 2007a). Sen *et al* (2006) suggested that it is due to difference in internal nanomorphology of the limestones. On calcination, the Sanu limestone shows shrinkage with volume index of about 1 while, the Gotan limestone shows expansion with volume index less than 1 (Table 2-4). The petrographic and SEM studies show that Sanu limestone is uniformly composed of rounded to sub-rounded, fine grained calcite whereas, the Gotan limestone consists of angular to sub-rounded, medium to coarse grained calcite mostly with fine laminations (Shekhawat and Prabhulingaiah, 2010). It implies that during calcination the Sanu limestone acts as an isotropic material while, the Gotan limestone behaves as an anisotropic material. Thus, during calcination, the CO_2 gas evolved from Sanu limestone escaps uniformly without making any significant internal pressure causing minimum development of cracks in the lime. In case of the Gotan limestone, the CO_2 gas produced during the process of calcination does not release uniformly due to its anisotropic nature, hence, it creates internal pressure which results in significant development of cracks in the lime. Thus, it has been concluded that the physical properties of limestone have significant bearing on calcinations and the limestone showing higher volume index is more suitable for its SMS use.

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Figure 1a

Figure 1b

Figure 1: Field photographs showing quarry sections of (a) Sanu and (b) Gotan SMS grade limestone mines

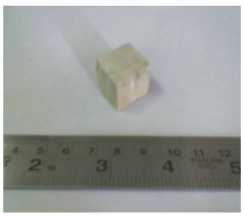

Figure 2a

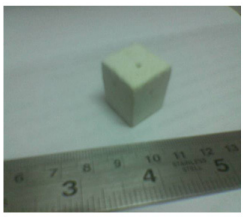

Figure 2b

Figure 2: Cuboidal samples of Sanu SMS grade limestone mines (a) before calcinations and (b) after calcinations

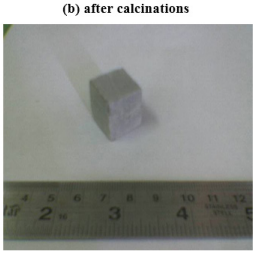

Figure 3a

Figure 3b

Figure 3: Cuboidal samples of Gotan SMS grade limestone mines (a) before calcinations and (b) after calcinations

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