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Washing studies with a limestone sample for reduction of insolubles – A case study

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ABSTRACT

The paper deals with the washing studies conducted with a limestone sample received from Rourkela Steel Plant with a view to reduce the insolubles. The sample analysed 14.88% insolubles and it was required to reduce the same to below 12% level. As the sample contained some amount of clay both in the fines and coating the lumps, it was decided to conduct washing after crushing the sample to the desired size. Bench scale washing studies indicated that, bulk of the clayey matter could be removed. As the insolubles content of the coarser lumps was quite low, pilot plant scale washing studies were conducted both with –50 mm and –25 mm material separately. Results indicated that in both the cases, the insolubles could be reduced to below 12% level with a marginal loss of CaO values.

INTRODUCTION

Steel and cement industries are the largest consumers of limestone. It is used as flux by the steel industry to remove the nonmetallic constituents as slag while it is the basic raw material for the cement industry. India has been blessed with vast deposits of limestone, distributed all over the country.

Limestone beds are covered by a thick crust of clay and/or rock. During mining, the over burdens removed before winning the limestone. Yet some part of the clay gets mixed up with the ore resulting in increase of the insoluble content. In addition, some of the rock beds associated with the deposit also get mixed up in the same process. Yet in some cases, clay would be found filling all the crevices, cavities and the fissures in the limestone beds. Apart from all these extraneous constituents, some minerals like quartz, mica, feldspars etc., that are present in the deposit also add to the insoluble content of the sample. Clayey matter may be easily removed by scrubbing and wet screening, whereas the inherent mineral constituents may be removed only after flotation of the limestone. The present sample is associated with clay contaminated during mining and hence beneficiated by scrubbing and wet screening. NML has conducted studies on various limestone samples for the reduction of insolubles and silica contents by flotation.

Rourkela Steel plant gets lime stone from the quarries at Purnapani. After removing the thick crust of clayey overburden, limestone is mined and crushed to 80 mm size and is screened into the following sizes

1. –80 mm + 25 mm
2. –25mm + 6mm and
3. –6 mm

The –80+25 mm lumps are directly used in the blast furnaces. The –25 + 6 mm portion after crushing is used in the sinter plant. All the –6 mm fines are rejected due to their high insoluble content. At present the –25 mm fraction has been found to be generally high in insolubles due to the presence of the extraneous clay. It is reported that during mining, some amount of clay always gets admixed with limestone. This contamination causes a duel problem viz., increase in the insoluble content and also reducing the handling convenience to a great extent, specially in the monsoon season. With a view to removing the extraneous clay and reducing the insolubles, NML has undertaken studies for washing of the limestone.

SAMPLE

About 17 tonnes of run of mine limestone sample was received at the Mineral Beneficiation Pilot Plant of NML from Purnapani limestone quarries of Rourkela Steel Plant. The sample contained lumps upto 200 mm(8") with considerable amount of fines and clay. Occasionally quartzite lumps of various sizes were also observed in the sample. The sample was crushed to 80 mm size in a jaw crusher after hand cobbling the larger lumps. The crushed ore was further sampled into different lots for preparation of head sample, screen analysis, batch and large scale washing studies. Complete chemical analysis of the sample is given in Table 1.

Table 1 : Complete analysis of sample as received

Constituent	% Assay
CaO	40.16
MgO	4.16
SiO_2	9.40
Al_2O_3	7.55
Fe_2O_3	2.40
SO_3	0.045
LOI	36.50
P	0.025
Insolubles	14.88

Chemical analysis indicated that the sample contained 40.16% CaO and 4.16% MgO with 14.88% insolubles.

Size distribution of the crushed ore with CaO and insoluble contents in the respective fractions are recorded in the Table 2.

Table 2 : Screen analysis and chemical analysis of the sample

Size (mm)	Wt %	% Assay CaO	% Assay Insol	% Dist CaO	% Dist Insol
–80+50	41.8	43.20	10.48	45.0	29.8
–50+25	30.2	42.20	11.60	31.8	23.8
–25+6	17.1	36.55	18.32	15.6	21.3
–6	10.9	28.30	34.00	7.6	25.1
Head (Calc.)	100.0	40.13	14.72	100.0	100.0

The results indicated that –80+50 mm and –50+25 mm lumps contained less than 12% insolubles, and may be acceptable for use in the blast furnaces. The –25+6 mm lumps analyzed 36.55% CaO and 18.32% insolubles and need washing. The –6 mm fines which contained bulk of the clayey material assayed 34% insolubles.

BATCH SCALE WASHING STUDIES

The crushed sample was sized to –80+50 mm, –50+25 mm, –25+6 mm and –6 mm. Each of the sized products (upto +6 mm) were scrubbed separately with enough water in a concrete mixer for twenty minutes. The turbid water was removed and lumps were washed again to ensure the complete removal of clay sticking to the lumps. The –6 mm fines were deslimed in a spiral classifier for the separation of sand and clay. Results of the batch scale washing test are recorded in Table 3.

Table 3 : Bench scale washing studies

Product	Wt %	% Assay CaO	% Assay Insol	% Dist CaO	% Dist Insol
–80+50 mm	39.8	43.57	9.60	43.2	25.8
–50+25 mm	28.4	42.65	10.30	30.2	19.8
–25+6 mm	15.1	40.80	13.10	15.4	13.4
–6 mm Sand	8.5	35.23	19.20	7.5	11.0
Slimes	8.2	18.30	54.13	3.7	30.0
Head (Calc.)	100.0	40.11	14.79	100.0	100.0

Test results indicated that –80+50 mm lumps assayed 9.6% and 10.3% insolubles respectively, i.e., about 1% less than the feed. Insoluble content of the –25+6 mm lumps which originally 18.32%, was reduced to 13.1%. The classifier sand contained 19.2% insolubles and the combined slime assayed 54.13% insolubles having a distribution of 30% of the total insolubles. From the results it may be concluded that by washing 30% of the total insolubles could be removed. The rest 70% of the insolubles were inherent to the ore. The slime constituting 8.2% of the feed assayed 18.3% CaO having a distribution of 3.7% CaO in it. Overall test results are given in Table 4.

Table 4 : Overall results of the washing studies

		% Assay		% Dist.	
Product Size	Wt %	CaO	Insol	CaO	Insol
–80+50 mm	39.8	43.57	9.60	43.2	25.8
–80+25 mm	68.2	43.00	9.90	73.4	45.6
–80+6 mm	82.3	42.60	10.50	88.8	59.0
–80+ Sand	11.8	35.23	19.20	7.5	11.0
Slimes	8.2	18.30	54.13	3.7	30.0

It may be seen that the combined washed –50+25 mm lumps represented 68.2% of the feed, assaying 43.0% CaO and 9.9% insolubles. But when the –25+6 mm lumps were also mixed with the –80+50 mm lumps, the bulk represented 82.3% of the feed assaying 42.6% CaO and 10.5 insolubles. The total washed sample represented 91.8% of the feed, assaying 41.9% CaO and 11.3% insolubles. The grade of the combined product was within the specification.

PILOT PLANT SCALE WASHING STUDIES

Batch scale washing studies, indicated that –80+50 mm and –50+25 mm lumps did not show much improvement after washing. However, two pilot plant scale tests were conducted with crushed ore samples prepared earlier. In the first test –80+50 mm lumps were screened out before washing whereas in the second test –80+25 mm lumps were removed and the rest of the material was subjected to washing.

The crushed ore was fed from the bin through a constant weight feedometer into a gravel washer provided with blades extending upto half the length. Wash water was added at the feed end. The gravel washer discharge was fed into a double deck vibrating screen provided with 25 mm and 6 mm screens. Water was sprayed on the screen to wash the clayey material adhering to the lumps. The screen oversize was collected separately and the under size i.e., –6 mm fines were fed into a spiral classifier. The classifier overflow was collected in settling tanks and the sand was collected after an additional wash water spray inside the classifier itself. Flowsheet of the washing set up is indicated in Fig. 1.

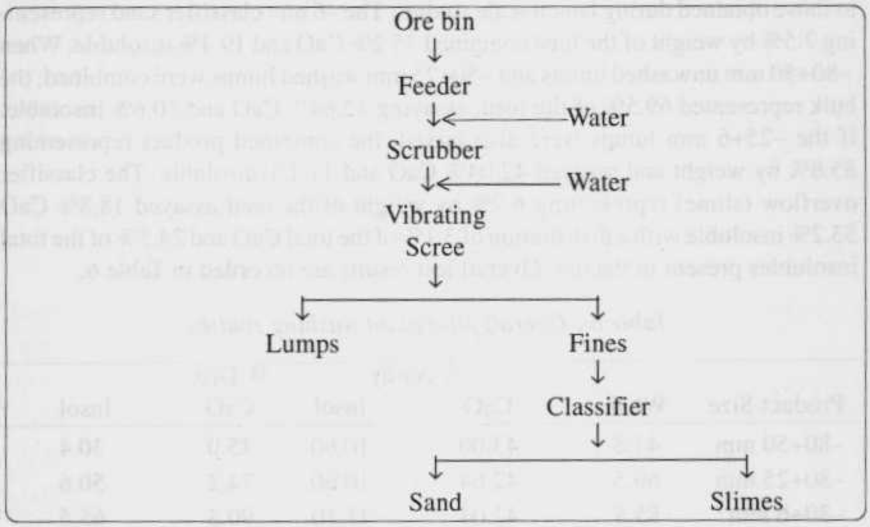

Fig. 1 : Schematic flowsheet for the washing of limestone.

Test No. 1

In this test –80+50 mm lumps were screened out before washing. Only the –50 mm material was subjected to washing under the following conditions:

Feed rate	... ...	1.5 tonnes per hour
Water	... ...	10 G.P.M. in the washer
	... ...	10 G.P.M. on the screen

The test results are recorded in Table 5.

Table 5 : Results of pilot plant scale washing studies

		(%) Assay		(%) Distribution	
Product Size	Wt %	CaO	Insol	CaO	Insol
–80+50 mm	41.8	43.00	10.60	45.0	30.4
–50+25 mm	27.7	42.10	10.60	29.2	20.2
–25+6 mm	16.3	39.50	13.20	16.1	14.9
–6 mm Sand	7.5	35.20	19.40	6.6	10.0
Slimes	6.7	18.80	53.20	3.1	24.5
Head (Calc.)	100.0	39.97	14.54	100.0	100.0

Results indicated that –50+25 mm lumps and –25+6 mm lumps representing 27.7% and 16.3% by weight of the feed assayed 42.1% CaO and 10.6% insoluble and 39.5% CaO and 13.2% insoluble respectively. These results were comparable to those obtained during bench scale studies. The –6 mm classifier sand representing 7.5% by weight of the feed contained 35.2% CaO and 19.4% insoluble. When –80+50 mm unwashed lumps and –50+25 mm washed lumps were combined, the bulk represented 69.5% of the feed, assaying 42.64% CaO and 10.6% insoluble. If the –25+6 mm lumps were also mixed, the combined product representing 85.8% by weight and assayed 42.04% CaO and 11.1% insoluble. The classifier overflow (slime) representing 6.7% by weight of the feed assayed 18.8% CaO 53.2% insoluble with a distribution of 3.1% of the total CaO and 24.5% of the total insolubles present in the ore. Overall test results are recorded in Table 6.

Table 6 : Overall pilot plant washing studies

		% Assay		% Dist	
Product Size	Wt %	CaO	Insol	CaO	Insol
–80+50 mm	41.8	43.00	10.60	45.0	30.4
–80+25 mm	69.5	42.64	10.60	74.2	50.6
–80+6 mm	85.8	42.04	11.10	90.3	65.5
–80 mm + Sand	93.3	41.49	11.76	96.9	75.5
Slimes	6.7	18.80	53.20	3.1	24.5
Head (Calc.)	100.0	39.97	14.54	100.0	100.0

Test No. 2

In this case all the +25 mm lumps were screened out before washing and only the –25 mm fraction was washed in the gravel washer under the conditions as stated earlier. Test results are recorded in Table 7.

Table 7 : Pilot plant washing studies with 25 mm feed

		% Assay		% Dist.	
Product Size	Wt %	CaO	Insol	CaO	Insol
–80+50 mm	70.1	42.70	10.50	74.5	51.7
–25+6 mm	16.5	39.50	12.20	16.2	14.1
–6 mm Sand	7.4	35.10	20.10	6.5	10.5
Slimes	6.0	19.00	56.10	2.8	23.7
Head (Calc.)	100.0	40.18	14.23	100.0	100.0

Results in Table 7 indicated that the dry screened –80+25 mm lumps representing 70.1% of the feed assayed 42.7% CaO and 10.5% insoluble. This portion may be used in the blast furnace. The –25+6 mm washed lumps representing 16.5% by weight assayed 39.5% CaO and 12.2% insoluble. This product may be used in the sinter plant. If the classifier sand assaying 35.1% CaO and 20.1% insoluble was mixed with –25+6 mm washed lumps, the combined product would assay 38.13% CaO. There was a rejection of 23.7% insoluble in the slime with a loss of only 2.8% CaO. Overall results are given in Table 8.

Table 8 : Overall results of washing studies with –25 mm size

		% Assay		% Dist.	
Product Size	Wt %	CaO	Insol	CaO	Insol
–80+25 mm	70.1	42.70	10.50	74.5	51.7
–80+6 mm	86.6	42.10	10.82	90.7	55.8
–80 mm + Sand	94.0	41.54	11.55	97.2	–
Slimes	6.0	19.00	56.30	2.8	23.7

Results indicated that the unwashed –80+25 mm lumps and –25+6 mm washed lumps when combined, yielded a product assaying 42.1% CaO and 10.82% insoluble. When the classifier sand also was combined the bulk represented 94% of the feed assaying 41.54% CaO and 11.55% insoluble.

CONCLUSIONS

At the instance of M/s. Rourkela Steel Plant, washing studies were undertaken to reduce the insoluble content of the lime stone sample from Purnapani to below 12%. The sample analyzed 40.16% CaO and 14.88% insoluble. Clayey matter associated with the sample indicated the possibility of improving the insoluble content by washing.

The sample after crushing to 80 mm was sized on 50, 25 and 6 mm screens. Chemical analysis of the individual sized fractions indicated that the insoluble content varied from 10.48% in the +50 mm lumps to 34% in the –6 mm fines. Washing studies conducted with the sized portions indicated the improvement in the insoluble content varying from 9.6% in the +50 mm lumps to 19.2% in –6 mm sand. The washing slimes analyzed 54.13% insoluble.

It may be seen that the +50 mm lumps showed marginal improvement in the insoluble content after washing. As this portion of the sample may be directly feed to the blast furnace, pilot plant scale washing studies were conducted with –50 mm and –25 mm material only, bypassing the respective lumps from the circuit.

Washing studies with –50 mm feed indicated the rejection of 6.7% of the feed as slimes assaying 53.2% insoluble. The insoluble content of the various washed and unwashed products ranged from 10.6% to 19.4%. The combined washed material assayed 41.49% CaO and 11.76% insoluble.

Similar studies with 25 mm portion, has eliminated 6.0% of the feed as slime assaying 56.3% insoluble. The unwashed +25 mm fraction assayed 42.7% CaO and 10.5% insoluble. After washing, the insoluble content was found to be 12.2% in the +6 mm portion and 20.1% in the –6 mm sand. With the removal of the slimes, the overall grade of the sample has improve to 41.54% CaO and 11.55% insoluble.

From the results it may be concluded that the insoluble content of the sample could be reduced to the desired level by scrubbing followed by wet screening i.e., washing however, as the +25 m portion constitutes the major portion of the crushed ore, with low insoluble content, this may be taken directly to the plant feed. Only –25 m portion needs washing to reduce the insoluble content. After washing, the handling of the ore particularly in the monsoon season improves along with the advantage of reduction in the insoluble content.

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