BENEFICIATION OF LIMESTONE

LIMESTONE is a very essential raw material for the metallurgical industry as flux and in the manufacture of cement. Large deposits of limestone are located all over the country and are being worked out. In addition to this, calcareous material like shells and corals are also worked out on the coastal areas wherever it is necessary.

Usual gangue associated with limestone is silica which is removed only by flotation methods. In addition to this, the nature of terrain and the geological structure of the deposit always adds to the alumina content of the ore as the clay gets mixed up with limestone during mining. This is more so when the mines are mechanised. This clay matter may be discarded by screening or washing and wet screening.

Following limestone samples were successfully beneficiated from the various parts of the country.

A. LIMESTONES FROM ORISSA

The limestone quarries of M/s. Tata Iron & Steel Co. and M/s. Hindustan Steel Ltd. are located at Purnapani and Panposh areas in Orissa from where samples were received for beneficiation studies.

TISCO Limestone

Batch and pilot plant scale investigation were conducted on the limestone samples received from M/s . TISCO, to produce a limestone concentrate for use in the open hearth furnace. The product must be as low as possible in insoluble content.

Sample No. 1

Batch and pilot plant studies were conducted on a 20 tonne sample. The sample consisted of 100 to 25 mm lumps with little amount of fines and analysed as follows :

Constituent	*Assay %*	
CaO	45.28	
MgO	3.10	
SiO_2	7.80 ⎫	9.70 insol.
Al_2O_3	1.90 ⎭	
Fe_2O_3	1.10	
CO_2	38.40	
SO_3	0.10	
LOI	35.60	
P	Trace	

Microscopic examination of the thin sections and the sized fractions of the representative sample indicated that quartz formed the bulk of the gangue with minor amounts of micas. Silica and carbonates were liberated at 150 mesh size.

Flotation tests were conducted using sodium silicate as the depressant for silicates and oleic acid emulsion (soap) as the collector/frother for the carbonates. Frothers like MIBC and pine oil were also used along with soap. Test results indicated that a grind of 67% —200 mesh, 0.75 Kg/tonne of sod silicate and 0.75 kg/tonne of soap were optimum where in a concentrate assaying 5.93% insol. was produced. This product after one cleaning with 0.2 kg/tonne sod. silicate yielded a concentrate assaying 51.04% CaO and 2.37 insol.

PILOT PLANT TESTS

The ore was stage-crushed to 6 mesh and stored in a bin from which it was fed to a ball mill (40×80 cm) operating in closed circuit with a spiral classifier (23 cm dia).

The classifier over flow was conditioned with sod. silicate and soap and then treated in a battery of 9 nos. of sub A-flotation (Denver No. 7) cells. The

tailing was rejected and the concentrate was further cleaned in 2 cells of similar type. The cleaner tails were recirculated to the ball mill.

The concentrate produced from the pilot plant tests analysed 50.49% CaO, 3.16% MgO and 3.31% Insol. with 95.08% CaO distribution.

Based on the pilot plant study flowsheet was drawn alongwith the list of equipment to treat 250 T.P.D. treatment plant.

Sample No. 2

The ROM ore consisted 125 of mm to 25 mm lumps without any fines and analysed as follows :

Constituent	*Assay %*	
CaO	45.90	
MgO	4.70	
SiO_2	7.10 ⎫	9.43
Al_2O_3	2.33 ⎭	
Fe_2O_3	0.57	

The sample was processed as in the case of sample No. 1. The ore was crushed in a primary jaw crusher to 38 mm followed by secondary crushing in a cone crusher operating in closed circuit with a 9 mm screen. The —9 mm crushed ore was stored in a bin and then fed through a constant weight feedometer to a ball mill (1830 mm × 950 mm) working in closed circuit with a rake classifer. The classifier overflow along with the depressant (Sod. Silicate) was pumped to the conditioner where the collector was added to the pulp.

The conditioned pulp was floated in a bank of 12 nos. of Denver Sub-A (No. 8) flotation cells. The tailings with some more collector were treated (scavenging) in a battery of cells of similar type. The concentrate was cleaned once in a bank of 6 nos. of Denver Sub-A (No. 7) cells. The cleaner tails and the scavenger concentrate (from the treatment of the primary tails) was re-circulated to the ball mill along with fresh feed.

The cleaner concentrate was dewatered in a 5 M dia thickner filtered on a disc vaccum filter and then dried in a rotary drier. The dried concentrate was later pelletized.

Pilot plant tests indicated that a grind of 75-80% passing through 200 mesh screen and 1.25 kg/tonne of sodium oleate (soap) were the optimum conditions for the treatment of the sample. About 40% of the collector was added to the rougher flotation cells in stages and the rest to the scavenging cells. The final concentrate analysed 50.30% CaO and 1.90% insol. with 94.7% CaO distribution in it.

Addition of 0.03 Kg/tonne of pine oil as a frothing agent helped in reducing the collector quantity to 0.41 kg/tonne.

The dried concentrate containing about 7% moisture was mixed with 6% of molasses and then pelletized on a disc. pelletizer operating at 42° slope and 10 R.P.M. The pellets were air dried initially and then heat hardened in a rotary kiln at 250-300°F. The hardened pellets had a crushing strength of 297 to 315 lbs/pellet and analysed 47.84% CaO, 1.91% SiO_2, 0.014% P and 0.16 to 0.3% S.

Dungri Limestone

The sample consisting 75 mm to 25 mm lumps was received from Orissa Mining Corporation and analysed as follows:

Constituent	*Assay %*
CaO	33.70
MgO	0.62
SiO_2	25.70
Al_2O_3	2.70
CO_2	27.30
S	0.125
P	0.160
Total Insol.	34.30
LOI	30.37

Microscopic examination of the sample revealed the presence of quartz as the chief gangue mineral followed by chlorite and muscovite. The siliceous and carbonate grains were very closely inter-locked.

A series of tests conducted under different conditions indicated that 87.0% —200 mesh grind, 1.0 kg/tonne of sod. oleate as collector and 1.5 kg/tonne of sodium silicate as depressant were optimum where the rougher concentrate analysed 39.5% CaO and 24.2% insol. with 96.4% CaO distribution in it. Use of pine oil did not show any improvement. The rougher concentrate after three cleanings using 0.25 kg. per tonne of sodium silicate in each stage produced a cleaner concentrate assaying 49.03% CaO and 8.70% insol. with 73.7% CaO distribution in it.

Purnapani Limestones

1. Sample No. 1

The sample was received for the reduction of insolubles below 5% level. Complete chemical analysis of the sample was as follows:

Constituent	*Assay%*
CaO	37.70
MgO	4.00
SiO_2	15.30
Al_2O_3	6.30
Fe_2O_3	3.10
CO_2	33.50
S	Trace
SO_3	Trace

Minerological examination of the sample revealed the presence of quartz as gangue mineral present in the form of grains and veins in the limestone and was liberated at 200 mesh size.

Bench scale tests conducted under different conditions indicated the optimum flotation conditions to be 97% —200 mesh grind, 0.46 Kg/Tonne Sodium Silicate, and 0.57% Kg/Tonne of Sodium oleate, where the concentrate analysed 6.2% insols.

Pilot plant tests were conducted as per flowsheet given in case of TISCO limestone. In this case the rougher concentrate was cleaned twice. The concentrate obtained from the pilot plant tests analysed 47.6% CaO and 3.53% insols. with 78.4% CaO distribution in it. With a slightly coarser grind (88-90% —200 mesh) the concentrate analysed 47.1% CaO and 4.56% insols. with 92.3% CaO distribution in it.

Pelletization tests conducted under optimum conditions of 6-8% moisture and 6% molasses yielded pellets of 13-19 mm size with 3.47 to 3.56 Kg per pellet green strength. After air drying followed by heat hardening at 250-300°C the pellets had an average compression strength of about 80 Kg per pellet. It was observed that due to sudden raise in temp. in the rotary kiln some of the pellets were crushed. But when the hardening was done on a pan, over open fire by burning coal and wood, the results were better. The dried pellets analysed 45.7% CaO, 3.5% MgO, 3.4% SiO_2 and 2.6% Al_2O_3 with 0.01% S in it.

2. Sample No. 2

The sample was received from M/s. HSL Rourkela; to reduce the total insolubles to less than 12% level. The tests were conducted as per the flowsheet given by HSL. Complete chemical analysis of the sample was as follows:

Constituent	*Assay%*
CaO	40.16
MgO	4.16
SiO_2	9.40
Al_2O_3	7.55
Fe_2O_3	2.40
S	0.045
LOI	36.50
P	0.025

The sample in its "as received" state contained a considerable amount of clay which was sticky when wet. Crushing to 80 mm, followed by sizing and chemical analysis of the product indicated that the CaO and insolubles respectively 43.20% and 10.48% varied upto 28.30% and 34.00% in −6 mm fines. Bench scale washing tests with the sized products improved the CaO content from 43.20% to 43.57% case of lumps, while reducing the insolubles from 10.48% to 9.6%. Similarly after washing the −6 mm fines analysed 35.23 % CaO and 19.2% insoluble. 30% of the insolubles were rejected as slimes.

Results indicated that the coarsest lumps did not show any remarkable improvement after washing and were of acceptable grade as such. Hence pilot plant scale tests were conducted after removing the −80 mm +50 mm lumps. The ore was crushed in a jaw crusher to 80 mm size and the +50 mm lumps were removed. Hence −50 mm ore was fed into a balde washer, fitted with water sprays. The washer discharge was fed over a double deck vibrating screen fitted with 25 mm and 6 mm screens and provided with water sprays also. The −6 mm sand and slimes were separated in a spiral classifier. The washed lumps and sand were analysed.

The combined unwashed +50 mm lumps and washed −50 mm lumps and sand analysed 41.49% CaO and 11.76% insolubles with 96.9% CaO distribution. By discarding the −6 mm sand, the product analysed 42.04 % CaO and 11.1 % insolubles with 90.3% CaO distribution in it.

When the washing test was conducted with −25 mm product only, the combined unwashed −80 +25 mm lumps and washed −25 mm lumps and sand analysed

41.54% CaO, 7.6% SiO_3 and 6.23% Al_2O_3, 97.2% CaO distribution in it.

3. Sample No. 3

The sample was comparable to sample No. 2 in all respects and analysed as follows:

Constituent	*Assay %*
CaO	41.30
MgO	5.90
SiO_2	9.80
Al_2O_3	3.66
Insol.	12.14
Fe_2O_3	3.24
P	0.07
S	0.06
LOI	37.50
Moisture	0.72

The sample consisted of 150 mm lumps down to fines with considerable amount of clay in it. The ore was stage crushed to 80 mm top size and then screened on 25 mm screen. The +25 mm lumps were left untreated and the −25 mm portion was subjected to dry and wet screening tests.

Chemical analysis of the sized −25 mm +6 mm lumps indicated the variation of 40.48 % CaO and 13.94 % insol. in −25 +18 mm lumps to 36.0% CaO and 17.72% Insol. in +6 mm portion. The −6 mm fines analysed 32.0% CaO and 23.56% insol.

After wet screening and sizing of the −25 mm lumps the CaO content in the coarse lumps improved to 40.81% with 11.04% Insol., and reduced to 36.36% CaO and 24.6% insol., in −6 mm sand. The −10 mm +6 mm sand analysed 38.09% CaO and 12.92% insol.

Scrubbing and wet screening of the —25 mm portion produced a washed −25 +6 mm portion analysing 41.30% CaO and 10.74% Insol. and a —6 mm sand analysing 38.34% CaO and 12.95% Insol. in it. Treatment of the slimes in hydrocyclones yielded additional 2.7% of underflow assaying 37.21% CaO and 18.08% insol. in it.

Test results indicated scrubbing and wet screening are essential to reduce the insol. content of the limestone below 12% level.

B. MADHYA PRADESH LIMESTONES

Limestone from Nandini M.P.

Three different samples viz. (i) Run of mine ore after crushing to 80 mm size (ii) −12.5 mm fines collected from the dumps and (iii) current —25 mm fines were received for reduction of insolubles in the samples and other tests like screenability etc. The sample was contaminated with murram balls, composed of iron oxides and alumina along with clay. These contaminated gangue were of fine size and may be eliminated partly by screening and gravity separation if necessary.

(i) Run of Mine Sample

The sample was collected from the crushing plant and consisted of 80 to 0 mm lumps and fines. The sample analysed as follows:

Constituent	*Assay %*
CaO	39.22
MgO	7.32
SiO_2	7.30
Insol.	10.62

The sample was wet screened and the washed −80 mm +12.0 mm lumps analysed 41.9% CaO and 7.93% insol. with 81.6% CaO distribution in it. Similar product after scrubbing and wet screening tests analysed 41.52% CaO and 7.5% insol. with 79.6% CaO distribution in it. Wet screening rejected 16.8% of the total insolubles while the washing and wet screening rejected 19.2% insolubles.

The —12.5% mm fines obtained from the washing and wet screening tests analysed 36.21% CaO and 15.31% insolubles. Most of the murram balls were present in this portion. As the murram balls were heavier in nature, jigging tests were conducted with —12.5 mm fines after jigging where the gangue was collected as heavier fractions. The combined limestone concentrate analysed 37.52% CaO and 12.34% insol. with an additional 13.6% CaO distribution in it.

(ii) Sample No. 2

This sample was collected from the old dumps and consisted of —12.5 mm lumps and fines. The sample analysed as follows:

Constituent	*Assay %*
CaO	36.8
MgO	8.8
Insol.	12.7

The sample was wet screened and sized on 12.5 mm screen. The coarser lumps i.e. +12.5 mm size analysed 39.1% CaO and 9.3 insol. with 40.6% CaO distribution. After crushing and wet screening, the product analysed 37.6% CaO and 7.94% insol. By washing 28.4% of the total insolubles were rejected out.

(iii) Sample No. 3

The sample was collected from the crushing plant and composed of —25 mm fines along with clay and murram balls. The analyses of the sample was as under:

Constituent	*Assay %*
CaO	35.97
MgO	8.61
Insol.	12.21

The −25 mm +12.5 mm product obtained after wet screening analysed 39.6% CaO and 8.6% insol. rejecting 24.3% of the total insolubles. After washing and wet screening tests, the product analysed 39.97% CaO and 8.4% insol. with 41.7% CaO distribution. Washing tests rejected 38.3% of the total insolubles.

C. UTTAR PRADESH LIMESTONES

1. Churk Limestone

The sample was received from the Government cement factory and was drawn from the Markundi Hills situated in Mirzapur dist. The sample was collected from the rejects of the cement factory and analysed as follows:

Constituent	*Assay %*
CaO	34.45
MgO	2.95
CO_2	30.31
SiO_2	21.09
Al_2O_3	6.00
SO_3	0.14
Fe_2O_3	1.40
LOI at 950°C	30.65

Examination of the sample under microscope revealed presence of clayey matter which contributed to the insoluble content as a cementing medium for the carbonate grains. Shale grains were also present and the carbonates were fairly liberated at 65 mesh size.

Flotation tests conducted under different conditions indicated that the optimum conditions for the flotation of the carbonates were 70% —200 mesh grind, 0.514/tonne of sod. oleate as collector and 1.0 kg./tonne of sod. silicate as the depressant for the gangue where in a concentrate assaying 40.54% CaO with 96.5% CaO distribution was produced. This concentrate after two cleanings analysed 47.06% CaO with 80.0% CaO distribution. Use of sodium silicate in the cleaning stages improved the recovery of CaO to 90.0% but the grade of the concentrate came down to 44.31% CaO. Use of pine oil as a frother did not show any effect. Use of rosin has yielded satisfactory results. After one cleaning the product analysed 44.89% CaO with 86.0% CaO distribution.

2. Toli Limestone

The sample was received from the U.P. State geology department for beneficiation of the same for use in the cement industry. The sample analysed as follows:

Constituent	*Assay %*
CaO	35.40
MgO	1.10
SiO_2	31.80
Al_2O_3	1.16
Fe_2O_3	2.05
CO_2	28.62

The sample was high in silica content; examination of the sample under microscope indicated the presence of quartz and limonitic material as gangue and were liberated at 150 mesh size.

Under the optimum flotation conditions of 61.1% —200 mesh grind, 0.5 Kg./tonne of sod. silicate 0.75 kg/tonne of pine oil, a concentrate assaying 47.15% CaO with 96.5% CaO distribution was obtained. This, after one cleaning with 0.1 kg/tonne of sod. silicate analysed 51.40% and 4.6% SiO_2 with 80.5% CaO distribution.

3. Pundras Limestone

The sample was received from the State geology dept. and the beneficiated product was expected to

be used in the cement industry. The sample analysed as follows:

Constituent	*Assay %*
CaO	35.10
MgO	1.40
SiO_2	31.00
Al_2O_3	0.90
Fe_2O_3	2.43
CO_2	29.02
SO_3	0.15

Microscopic examination revealed the presence of quartz and minor amounts of gluconite, felspar, sphene, etc. which are fairly liberated at 150 mesh size.

The concentrate obtained under the optimum flotation conditions of 63.1% —200 mesh grind, 0.75 kg/tonne sod. oleate, analysed 46.67% CaO with 91.8% CaO distribution. After one cleaning the grade of the concentrate improved to 48.48% CaO with 82.7% CaO distribution. Use of frothers like pine oil and MIBC helped in slight reduction of the collector during the rougher flotation.

4. Tal Limestone

The sample was received from the U.P. State Mining and Geology Department for lowering the silica content to below 12% so as to use the concentrate for the manufacture of cement. The sample analysed as follows :

Constituent	*Assay %*
CaO	38.07
MgO	1.10
SiO_2	24.28
A_2lO_3	2.76
Fe_2O_3	2.10
CO_2	32.50
LOI at 100°C	0.11
LOI at 560°C	5.36

Quartz and clay formed the gangue and were liberated fairly below 100 mesh size. Under the optimum conditions of 81% —200 mesh grind, 2.0 kg/tonne of sod. silicate, and 0.75 kg./tonne of sod. oleate—the flotation concentrate analysed 46.4% CaO and 8.4% SiO_2 with 97.2% CaO distribution in it. Use of Rosin along with the collector had helped in slight increase in the recovery.

PILOT PLANT TEST

The ROM ore was crushed in a primary jaw crusher set to 50 mm followed by secondary gyratory crusher operating is closed circuit with a 12 mm vibrating screen. The crushed —12 mm ore was fed from the bin through a constant weight feedometer to a ball mill (1830 mm × 915 mm) working with a classifier. The classifier over-flow was conditioned with the reagents and then treated in a battery of 12 nos. of 2.75 Cu. ft. Denver Sub A (No. 8 type) cells; collector was added at different points in the flotation cells.

The concentrate was dewatered in a 5 M dia. thickener and the underflow was filtered on disc. type vacuum filter. Overflow of the classifier was recirculated to the mill.

The final concentrate varied in SiO_2 content from 9.6% to 12.0% and the final concentrate collected from the thickener analysed 46.4% CaO, 10.5% SiO_2, 2.2% Al_2O_3 and 1.1% MgO with 92.4% CaO distribution in it.

D. BIHAR LIMESTONES

1. Rohtas Limestone

The sample was received from M/s. Rohtas Industries for beneficiation and making it suitable for cement industry. The sample had the following analysis :

Constituent	*Assay %*
CaO	38.68
CO	30.48
MgO	1.13
SiO_2	17.92
Al_2O_3	4.03
Fe_2O_3	1.54
Fe	1.07
P	0.065
S	0.09
Total Insol.	21.24
LOI	33.24

Microscopic examination revealed the presence of quartz as principal gangue which was very closely associated with carbonates.

Under the optimum condition of 94%—200 mesh grind, 0.74 kg/tonne of sod. silicate and 1.0 kg/tonne

of sod. oleate, a concentrate assaying 42.4% CaO and 15.60% insol. with 97.6% CaO distribution was produced. This product after one cleaning analysed 44.12% CaO and 10.53% insol. with 92.0% CaO distribution. With two more cleanings i.e. total 3 cleanings, the concentrate analysed 49.29% CaO and 8.05% insol. with 82.3% CaO distribution in.

2. Sirka Limestone

Two samples were received from M/s. Bird & Co., Calcutta for beneficiation and calcination studies.

ROM Sample

The samples consisted of 75 mm to 18 mm lumps and analysed as follows :

Constituent	*Assay %*
CaO	34.95
MgO	4.90
SiO_2	24.30
Al_2O_3	3.50
Fe_2O_3	1.62
CO_2	27.50
P	0.025
S	0.058

Microscopic examination of the sample indicated the presence of quartz, biotite, chlorite and ferruginous matter formed the gangue and were fairly liberated at 150 mesh size.

Calcination, slaking followed by the analysis of the sized slaked lime products indicated that bulk of the silicates were in the + 200 mesh portion only. The sparated —200 mesh fines analysed 54.28% CaO and 12.83% SiO_2 with 76.7% CaO distribution.

Hydro-classification tests with calcined lime under different pressures produced concentrates varying from 48.01% CaO to 67.72% CaO. The later was produced with low water pressure. The combined overflow (lime concentrate) analysed 64.46% CaO and 3.31% SiO_2 with 64.7% CaO distribution in it. Grinding and desliming of the sand portions of the above test yielded a slime assaying 44.62% CaO and 22.38% SiO_2 with additional 4.1% CaO distribution.

Flotation tests with the sand product did not give encouraging results. Flotation tests conducted with the calcined lime with 0.7 Kg/tonne of sod. silicate and 0.6 Kg/tonne of Sod. oleate with 0.07 Kg/tonne of pine oil yielded a cleaner concentrate assaying 51.64% CaO and 15.90% SiO_2 with 64.5% CaO distribution.

Reject Sample

The sample consisted of 75 mm to 13 mm lumps and analysed as follows :

Constituent	*Assay %*
CaO	36.30
MgO	5.45
CO_2	28.60
SiO_2	21.80
Al_2O_3	2.50
Fe_2O_3	1.60

Mineralogical examination of the sample indicated the presence of quartz, muscovite, biotite, and chlorite as gangue.

Calcination and desliming of the sample produced a —200 mesh slime assaying 53.3% CaO and 8.0% SiO_2 with 72.4% CaO distribution. Hydro-classification of the calcined sample yielded a slime product assaying 60.5% CaO and 6.0% SiO_2 with 66.1% CaO distribution in it. Flotation of the classifier-sand did not yield any encouraging results.

Flotation tests with calcined lime ground to 90% —200 mesh with 0.6 Kg/tonne of sod. silicate and 0.4 Kg/tonne of sod. oleate yielded a concentrate assaying 53.9% CaO and 12.1% SiO_2 with 46.5% CaO distribution in it.

E. MAHARASTRA LIMESTONES

Two samples of low grade limestone were received from the Maharastra State Mining and Geology Department to upgrade for the cement industry. The samples were drawn from Khargaon area in Yeotmal dist.

Sample No. 1

This sample was drawn from Chanaka Gubri area in Yeotmal Dt. of Maharastra and consisted of 75 mm to 25 mm lumps and some fines. Complete chemical analysis of the sample was at follows :

Constituent	*Assay %*
CaO	43.44
MgO	1.45
SiO_2	17.50
Al_2O_3	2.00
CO_2	34.14
Fe_2O_3	0.76
K_2O+Na_2O	0.26

Examination of the sample under microscope indicated the presence of fine grained quartz as the gangue mineral which was fairly liberated at —150 mesh size.

Flotation concentrate obtained under the optimum conditions of 94.5% —200 mesh grind, 0.5 kg/tonne of sod. silicate and 0.4 kg/tonne of sod. oleate, analysed 46.5% CaO and 15.5% SiO_2 with 98.2% CaO distribution. After one cleaning, the product analysed 48.73% CaO and 12.05% SiO_2 with 82.5% CaO distribution in it. Regrinding before cleaning during flotation improved the grade to 48.93% CaO and 11.65% SiO_2 with 88.0% CaO distribution.

Sample No. 2

The sample was marked as KAU-1 and consisted of 75 mm to 25 lumps with the following chemical analysis :

Constituent	*Assay %*
CaO	41.52
MgO	0.71
SiO_2	22.37
$Al_2 O_3$	1.00
CO_2	32.80
LOI	33.50

Microscopic examination revealed the presence of quartz as the chief gangue mineral and was fairly liberated at 150 mesh size.

Under the optimum conditions of 97.2% —200 mesh grind, 0.5 kg/tonne of sod. silicate and 0.5 kg./tonne of sod. oleate, a concentrate assaying 43.8% CaO and 18.21% SiO_2 was produced. After two cleanings, the concentrate analysed 49.0% CaO and 10.0% SiO_2 with 75.5% CaO distribution in it. Regrinding and cleaning of the rougher concentrate yielded a grade of 49.58% CaO and 9.95% SiO_2 with 84.5% CaO distribution.

F. MANIPUR LIMESTONES

Two samples were received from the State Directorate of mines and Geology. The high grade sample analysed 44.06% CaO. As there is not much of difference in chemical and mineralogical composition, the two samples were combined in 1 :1 proportion. The mixed sample analysed as follows :

Constituent	*Assay %*
CaO	44.40
MgO	3.16
SiO_2	10.95
$Al_2 O_3$	0.17
CO_2	37.46
LOI	37.95
Fe	1.60
S	0.74
P	Trace
Total Insol.	12.38

Microscopic examination of the sample indicated the presence of quartz and chert as gangue minerals and were liberated at 250 mesh size.

Flotation test conducted under the optimum conditions of 92% —200 mesh grind, 0.75 Kg/tonne of sod. silicate and 1.0 Kg/tonne of sod. oleate, produced a concentrate assaying 48.06% CaO and 8.22% SiO_2 with 94.4% CaO distribution in it. After one cleaning the product analysed 49.00% CaO, 1.84% MgO and 8.1% SiO_2 with 90.0% CaO distribution. Use of 0.02 kg/tonne of 'Katha' in the cleaning stage, improved the grade to 50.60% CaO, 0.8% MgO and 7.8% SiO_2 with 83.1% CaO distribution.

G. GUJARAT LIMESTONES

Two samples were received from M/s. Associated Cement Co., Porbandar for beneficiation and use in the cement industry. The samples contained high iron in them.

Sample No. 1

The sample was 200 mesh powder and analysed 0.64% Fe. After magnetic separation the non-magnetic product analysed 0.63% Fe. Tabling followed by Magnetic separation tests did not show any improvement.

Sample No. 2

The limestone sample analysed 0.33% Fe. Magnetic separation tests at 65 mesh size yielded a non-magnetic product assaying 0.28% Fe.

Rajpipla Limestone

The sample in its as received state contained

200 to 25 mm lumps without any fines and had the following analysis :

Constituent	*Assay %*
CaO	36.14
CO_2	31.52
MgO	3.20
SiO_2	17.10
Al_2O_3	7.30
SO_3	0.73
Fe_2O_3	2.98
S	0.29
P	0.03

Microscopic examination of the sample indicated the very fine grains of silica and felspar dispersed in the sample and needed very fine grinding for their liberation.

Under the optimum conditions of 100% —325 mesh grind (for 50 mts time), 1.0 Kg/tonne of sod. silicate and 1.0 Kg/tonne of sod. oleate, with one cleaning analysed 40.95% CaO and 15.8% insolubles in it. Regrinding the primary concentrate before reflotation helped in reduction of the insolubles in it to 13.4%.

H. KERALA LIMESTONE

(1) The sample was received from M/s. Travancore Electro Chemical Industries, Chingavanam and consisted of 280 mm to 50 mm lumps in size and analysed as follows :

Constituent	*Assay %*
CaO	43.23
SiO_2	4.41
Al_2O_3	2.23
Fe_2O_3	1.06
MgO	0.36
P	0.05
S	0.092
CO_2	40.44
Total Insol.	8.41

Examination of the sample under microscope indicated the presence of mica, Cu & Fe sulphides, sphene, apatite, quartz, graphite sidertite, etc. as gangue minerals which are liberated at 150 mesh size. The sample was to be upgraded for the manufacture of carbides.

Under the optimum conditions of 65.5% —200 mesh grind with 0.2 kg/tonne each of kerosene oil and pine oil to remove a graphite float, and 0.2 kg each katha and Dextrine to collect an apatite float followed by 1.0 kg/tonne of sod. silicate and 0.5 kg/tonne of sod. oleate yielded a concentrate assaying 53.7% CaO, 0.64% SiO_2 and 0.04% P with 83.1% CaO distribution in it.

The sandy portion obtained after calcination followed by slaking and desliming, analysed 0.155% P with 79.6% P distribution in it.

Pellets with the flotation concentrates with 4.0% moisture and 2.5% Dextrine produced a compression strength of 18.0 kg/pellet for the air dried ones and 35 kg/pellet in case of heat hardened ones.

(2) Lime shell samples were received from M/s. Travancore Chemical Industries for the production of carbide grade of concentrate. The samples contained clayey matter with them and by simple washing the CaO content has improved from 53.08% CaO to 54.16% CaO with 97.0% CaO distribution.

Pellets produced under the optimum conditions of 83.5% —200 mesh grind with 6% molases and 10.5% Moisture followed by heat hardening at 250°C for 30 mts. produced a compression strength of 56.7 kg/pellet.

Calcination tests indicated that heat hardening of the pellets was essential as the green pellets produced about 45% fines during calcination.

I. WEST BENGAL LIMESTONES

1. Paper mill lime sludge

The sludge sample was received from M/s. Bird & Co., Calcutta for beneficiation studies so as to use the concentrate in any industry. Complete chemical analysis of the sample was as follows :

Constituent	*Assay %*
CaO	44.41
MgO	2.8
SiO_2	11.5
Al_2O_3	2.5
Fe_2O_3	0.9
CO_2	31.6
Na_2O	1.3

Microscopic examination of the sample indicated the presence of quartz, diatomite, felspar, micas, talc and coal formed the gangue.

Flotation tests conducted with the sample in its "as received state" and after grinding using 0.25 kg/tonne of sod. silicate and 0.5 kg/tonne of sod. oleate produced concentrate assaying 47.7% CaO only with 73.0% CaO distribution.

2. Limestone from Jhalda

The sample was received from M/s. West Bengal Cement Ltd., Calcutta for the reduction of Silica content. Complete chemical analysis of the original sample was as follows :

Constituent	*Assay %*
CaO	41.53
SiO_2	10.59
MgO	2.50
Al_2O_3	1.04
Fe_2O_3	1.96
CO_2	31.11
LOI	31.20
Total insoluble	21.59
SO_3	Trace
P	Trace

Microscopic examination of the sample revealed the presence of crystalline calcite as the chief carbonate mineral. The gangue was composed of pyroxenes, amphiboles, quartz, and feldspars. Calcite was liberated from the gangue at about 65 mesh.

Flotation tests with 68% —200 mesh feed using 0.75 kg/tonne of Sodium Silicate and 0.6 kg/tonne of oleic acid emulsion in 3 stages yielded a grade of 45.0% CaO with 95.3% CaO distribution in it. When float-1 was separated and float-2 and 3 were collected separately and combined with float-1 after one cleaning, produced a grade of 49.48% CaO with 90.0% CaO distribution in it. The product contained 3.58% SiO_2, 0.38% MgO, 0.17% Fe_2O_3 and 7.9% insolubles.

Summarised results in tabular form of the limestone samples and their references are given in the Table no 4.1.

TABLE 4.1—SUMMARY OF RESULTS OF BENEFICIATION OF LIMESTONE

State & Locality	Feed Assay %	Beneficiation Method	Concentrate Assay %	Dist. %	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
Orissa					
(1) TISCO I	45.28 CaO, 9.7 $SiO_2+Al_2O_3$ SiO_2=7.8%	Flotation	50.49 CaO, 3.3 Insol.	95.08% CaO	S.M.S. Grade Pilot Plant test
(2) TISCO II	45.90 CaO, 9.43 $SiO_2+Al_2O_3$ SiO_2=7.1	Flotation	50.30 CaO, 1.90 ,,	94.7 CaO	Pilot plant test & pelletization
(3) Dungri Limestone	33.70 CaO, 34.34 Insol. SiO_2=25.7	Flotation	49.03 CaO, 8.7 ,,	73.7 CaO	B.F. Grade
(4) Purnapani I	37.7 CaO, 21.6 $SiO_2+Al_2O_3$ SiO_2=15.3	Flotation	47.6 CaO, 3.53 ,,	78.4	Pilot plant pelletization S.M.S. Grade
(5) ,, II	40.16 CaO, 14.86 Insol. SiO_2=9.4	Scrubbing and wet screening	41.54 CaO, 13.83 SiO_2 $+Al_2O_3$	97.2	Lumps are for B.F & O.H. furnace
(6) ,, III	41.3 CaO, 12.14 Insol. SiO_2=9.8	Wet screening	40.81 CaO, 11.04 Insol.		Comparison of washing and wet screening with sample II
Madhya Pradesh					
(1) Nandini ROM	39.22 CaO, 10.62 Insol. SiO_2=7.3	Scrubbing & washing with −80+12 mm lumps	41.52 CaO, 7.5 Insol.	79.6 CaO	Pilot plant study.
	36.1 CaO, 15.31 Insol.	Jigging with +2 mm fines	37.5 CaO, 12.34 Insol.	13.6 CaO	
(2) Old dump sample	36.8 CaO, 12.7 Insol.	Washing with +12 mm lumps −12 mm fines washing	39.1 CaO, 9.3 Insol. 37.6 CaO, 7.94 CaO	40.6 CaO	-do-
(3) Current fines	35.97 CaO, 12.21 Insol.	Washing & wet screening	39.97 CaO, 8.4 Insol.	41.7 CaO	-do-

TABLE 4.1—SUMMARY OF RESULTS OF BENEFICIATION OF LIMESTONE *(Contd.)*

State & Locality	Feed Assay %	Beneficiation Method	Concentrate Assay %	Dist. %	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
Uttar Pradesh					
(1) Churk Limestone	33.45 CaO, 27.09 SiO_2+ Al_2O_3 SiO_2=21.09	Flotation with two cleanings	47.06 CaO	80.0 CaO	B.F. Grade and Cement grade
(2) Toli Limestone	35.4 CaO, 32.96 SiO_2+ Al_2O_3 SiO_2=31.8	Flotation with one cleaning	51.4 CaO, 4.6 SiO_2	80.5 CaO	B.F. Grade and Cement grade
(3) Pundras Limestone	35.10 CaO, 31.90 SiO_2+ Al_2O_3 SiO_2=31.0	Flotation with one cleaning	48.48 CaO	82.7 CaO	B.F. Grade and Cement grade
(4) Tal Limestone	38.07 CaO, 27.04 SiO_2+ Al_2O_3 SiO_2=24.28	Flotation	46.4 CaO, 8.4 SiO_2	97.2 CaO	Pilot plant test B.F. Grade and Cement grade
Bihar					
(1) Rohtas Limestone	38.68 CaO, 21.24 Insol. SiO_2=17.92	Flotation with 3 cleanings	49.29 CaO, 8.05 Insol.	82.3 CaO	B.F. Grade and Cement grade
(2) Sirka Limestone (ROM)	34.95 CaO, 27.80 SiO_2+ Al_2O_3 SiO_2=24.3	Calcination, slaking, desliming	64.46 CaO, 3.3 SiO_2	64.7 CaO	
(3) Sirka Reject Limestone	36.3 CaO, 24.3 Insol. SiO_2=21.8		60.5 CaO, 6.0 SiO_2	66.1 CaO	
Maharashtra					
(1) Khargaon Limestone	41.52 CaO, 23.37 SiO_2+ Al_2O_3 SiO_2=22.37	Roughing Regrinding and cleaning	49.58 CaO, 9.95 SiO_2	84.5 CaO	B.F. Grade and Cement grade
(2) Chanaka Gurbi	43.44 CaO, 19.5 SiO_2+ Al_2O_3 SiO_2=17.5	Roughing, regrinding and cleaning	48.93 CaO, 11.65 SiO_2	88.0 CaO	" "
Manipur					
Limestone	44.4 CaO, 12.38 Insol. SiO_2=10.95	Flotation and cleaning with katha Mag. Sepn.	50.6 CaO, 7.8 SiO_2	83.1 CaO	" "
Gujarat					
(1) A.C.C. Limestone I	0.64 Fe	Mag. Sepn.	0.63 Fe	—	High Iron No improvement
(2) A.C.C. Limestone II	0.33 Fe	-do-	0.28 Fe	—	-do-
(3) Rajpipla Limestone	36.14 CaO, 24.41 SiO_2+ Al_2O_3 SiO_2=17.1	Roughing, regrinding, and cleaning	42.5 CaO, 13.4 Insol.	—	Cement Grade
Kerala					
Kerala	43.23 CaO, 8.41 Insol. 4.41=SiO_2	Selective flotation for graphite and apatite followed by carbonate flotation	53.7 CaO, 0.64 SiO_2, 0.04 P	83.1 CaO	Carbide grade
Limes shells	53.08 CaO	Washing	54.16	97.0 CaO	-do-
West Bengal					
(1) Paper mill lime sludge	44.1 CaO, 14.0 SiO_2+Al_2O_3 SiO_2=11.5	Flotation	47.7 CaO	73.0 CaO	High insoluble alkalis
(2) Jhalda	CaO = 41.53 SiO_2 = 10.59 MgO = 2.50 CO_2 = 31.11	**Flotation:** Grind 68% —200 mesh 0.75 kg/ton. Sod. Silicate 0.6 kg/ton. Oleic acid emulsion and cleaning	CaO = 49.48 SiO_2 = 3.58 MgO = 0.38	CaO%=90%	S.M.S. Grade, B.F. Grade and Cement Grade

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