

5 Research & Development

The Science and Technology programmes (S & T) of the Ministry of Mines, Government of India, initiated in 1978, cover the disciplines of Geology, Exploration, Mining & Environment, Bioleaching, Beneficiation, Rock Mechanics, Ground Control and Non-ferrous Metallurgy. Fifteen new projects have been received and there were six ongoing projects during 2007-08.

The highlights of work carried out during 2006-07 and 2007-08 by various research organisations and industries relating to mineral beneficiation and mining & environment are given below :

1. BENEFICIATION

1.1 Beach Sand

Beneficiation studies on beach sand samples from Srikakulam district, (AP) (NML).

Studies were undertaken on beneficiation and separation of heavy minerals from beach sand sample from Srikakulam (A.P.). The modal analysis of the sample indicated that it contained about 25% heavies. Initial preconcentration of the sample was carried by spiralling to remove major silica. The heavy fraction was subjected to high tension separation of both the conducting and non-conducting materials to separate ilmenite, rutile, garnet, zircon and sillimanite. The sillimanite was further concentrated to + 98% purity by flotation. The project is under progress to prepare bulk sillimanite concentrate.

Studies on offshore and onshore samples from Ratnagiri (NML).

NML and CMERI scientists collected offshore and onshore samples from Ratnagiri sea bed and coast. Offshore mining technology was developed by CMERI. Mining operation and bulk sample collection were also conducted by CMERI. Spot sample collection was done by NML scientists. Scanning Electron Photomicrograph and EDAX spectral analysis of onshore beach sand and offshore sands were carried out.

1.2 Chromite

R & D studies on Chromite ore sample (IMMT).

Beneficiation studies were carried out on (1) Chromite ore beneficiation (COB) plant middlings (2) plant tailings containing about 20% Cr₂O₃ and (3) low grade ferruginous chromite ore containing about 15% Cr₂O₃. Flow sheets have been developed to recover most of the chromite values from the sample. It is possible to recover good grade chromite concentrate from middling by simple combination of hydrocyclone and tabling.

It is possible to obtain 20 wt% of chromite concentrate containing 48% Cr₂O₃ at around 50% recovery involving gravity concentration and flotation from the COB plant tailing. It was also established that about 22wt% of the concentrate can be obtained containing 48% Cr₂O₃ at around 70% recovery from the sub-grade chromite ore containing 15% Cr₂O₃.

1.3 Copper Ore

Beneficiation of Copper Ore from Khetri Mines (Jhunjhunu) for M/s HCL.(IBM).

A copper ore sample from Khetri Mines of Khetri Copper Complex, Jhunjhunu district, Rajasthan of M/s Hindustan Copper Ltd was received at Modern Mineral Processing Laboratory and Pilot Plant, Nagpur with the objective of developing a process to obtain a copper concentrate assaying more than 19% Cu with more than 90% recovery.

The as received sample assayed 0.83% Cu, 57.95% SiO₂, 3.71% S(T), 16.68% Fe(T). By adopting flotation route a concentrate assaying 19.27% Cu, 11.77% SiO₂, 27.45% S(T), 33.61% Fe(T) with Copper recovery of 89.3% could be obtained at 20% pulp density. When the flotation was conducted at 30% pulp density a copper concentrate assaying 19.54% Cu with 88.5% copper recovery (Weight % yield 3.8) could be obtained. Both the concentrates meet the requirements of the party.

Upgradation of a Copper Ore from Banwas Mines, Khetri Copper Complex for M/s HCL (IBM).

A copper ore sample from Banwas Mines, Khetri Copper Complex, Jhunjhunu district, Rajasthan of M/s Hindustan Copper Ltd was received at Modern Mineral Processing Laboratory and Pilot Plant, Nagpur with the objective of developing a process to obtain a copper concentrate assaying more than 19% Cu with more than 90% recovery.

The as received sample assayed 1.59% Cu, 17.23% Fe(T), 3.47% S(T). By adopting flotation route, a copper concentrate assaying 20.87% Cu with 90.6% Copper recovery (wt % yield 6.6) could be obtained at 20% pulp density. Flotation at higher pulp density - 36% solids, a copper concentrate assaying 20.98% Cu with copper recovery of 90.1% (wt % yield 6.6) could be obtained. Both the concentrates meet the requirements of the party.

Recovery of Bulk Copper-Zinc Concentrate from Cu-Zn ore sample from Khnaiguiyah deposit, Saudi Arabia of M/s SAFCO (IBM).

A copper-zinc ore sample from Khnaiguiyah deposit, Saudi Arabia of M/s SAFCO Geo-Environmental Consultants, Hyderabad received at Modern Mineral Processing Laboratory and Pilot Plant, Nagpur assayed 7.56% Zn, 0.98% Cu, 30.51% SiO₂, 13.17% Fe, 5.46% S, 0.01% Sr and 0.025% TiO₂. The objective was to develop a flow sheet to yield the zinc concentrate assaying 50% Zn with less than 8% Fe and a copper concentrate assaying more than 25% Cu with desirable recovery. The flotation process yielded the bulk copper-zinc concentrate assaying 18.22% Cu, 16.89% Zn, 20.48% SiO₂, 19.98% S, 7.48% Fe(T), 0.12% Cd, 2.733 ppm Au and 29.5 ppm Ag with 74.1% Cu recovery (wt % yield 4.0). Zinc concentrate obtained after one cleaning assayed 55.76% Zn, 1.09% Cu, 8.5% SiO₂, 26.6% S, 3.14% Fe(T), 1.1% Al₂O₃, 0.19% Cd, 2.524 ppm Au and 61.63 ppm Ag with 74.2% Zn recovery (wt % yield 10.1). Due to complex nature of Cu-Zn minerals association with each other, it was inferred that it is not feasible to produce individual Cu concentrate meeting smelter schedule

particularly in respect of Zn concentrate, however, from a bulk Cu-Zn concentrate metal values could be recovered by Toll Smelting or hydrometallurgical operations.

Evolution of suitable process flow sheet to obtain Copper concentrate from Banwas mines of M/s HCL (IBM).

The copper ore sample from Banwas mine was sent by Khetri Copper Concentrator of M/s Hindustan Copper Limited with an objective to evolve a suitable process flow sheet to obtain a copper concentrate with more than 90% recovery. The sample contained 1.90% Cu, 19.0% Fe(T) and 7.40% S(T). By flotation process, a copper concentrate assaying 24.98% Cu could be obtained with 93.7% Cu recovery. The grade and recovery achieved is more than the value stipulated by the party.

1.4 Cobalt

Improvement of Cobalt extraction from roastreduced polymetallic sea nodules in ammoniacal solution, supported by Department of Ocean Development, New Delhi (NML).

Polymetallic sea nodule available in the ocean floor is the future resource for Cu, Ni, and Co. NML Jamshedpur has developed a process route comprising reductive roast and ammoniacal leaching for the extraction of these strategically important metals from the sea nodules. Due to various reasons, the Co recovery was never more than 60% through Cu and Ni extraction was more than 90% in this process. Therefore, studies on improvement of the cobalt recovery in the reduction-roast ammoniacal leach process of ocean nodules has been undertaken in this project. Earlier activities in this project were on identifying various reasons of low cobalt recovery and its possible remedy, also development of improved process in bench scale with higher cobalt recovery. During last one year the main activity under this project was scale-up of the developed bench scale process. Accordingly, five large scale roasting and leaching campaigns were conducted. Large scale roasting was carried out by using a vertical retort furnace. Grounded raw nodules were mixed with LD oil, palletised and air & oven

dried. These dried samples were subjected for roasting at 750°C in a continuous mode. Each large scale roasting campaign generated about 300 kg of good quality roasted product. These products were used for subsequent leaching campaigns. The leaching conditions maintained in the large scale studies were similar to that of the bench scale one. Five numbers of leaching campaigns, each comprising six leaching tests (up to 5th recycle) were carried out during this period. The results were almost identical and encouraging with an average of 81.2% Co, 93.5% Cu and 94.8% Ni recovery.

Separation and recovery of copper, nickel and cobalt from leach liquor of sea nodules by bulk sulphide precipitation-chloride leaching-SX-EW route, supported by Department of Ocean Development, New Delhi (NML).

A suitable down stream operation for the large volume of dilute solution generated from the processing of sea nodule by the existing process was needed to be developed. It was planned to adopt bulk sulphide precipitation of the valuable metals like copper, nickel, cobalt and zinc from the dilute leach liquor followed by redissolution in chloride media and SX-EW operation. The present process will substantially reduce the volume of leach liquor and hence will reduce the size of equipment, cost of capital and energy. Earlier the detailed study was made on complete precipitation metal values from dilute leach liquor and dissolution study of bulk sulphide was carried out in chloride media in presence of chlorine gas in order to obtain concentrated leach liquor for down stream processing. To avoid chlorine gas dissolution, electro-leaching of bulk sulphide in brine solution was carried out with simultaneous electro winning of copper. Experiments were carried out in a rectangular glass vessel using graphite electrodes. An average current efficiency of 73% was obtained with applied anode current density of 400 A/m². As a part of separation process of metals from leach liquor, copper was completely separated by selective electro winning and sulphide precipitation followed by zinc extraction using TBP. Cobalt from the leach liquor

was extracted with alamine 336 at higher chloride concentration. Initially, the studies have been made at various operating conditions e.g., at different chloride ion concentration, O:A ratio, etc. using the organic 20% Alamine 336 and 10% isodecanol in kerosene. The results show that with increasing O:A ratio, the percentage extraction of cobalt increases and at O:A of 2:1, almost 96% of cobalt is extracted from 1.78g/L Co, 25.70g/L Ni and 270.0g/L Cl-solution. The two stages counter current simulation study was also validated the results and almost complete extraction of cobalt was possible with negligible amount of nickel extraction.

1.5 Fluorite

Reduction of Silica content in low grade fluorite sample from Dongargaon, Warora (IBM).

A fluorite sample from Dongargaon, Warora of Maharashtra State Mining Corporation (MSMC) was received for bench scale beneficiation studies from M/s Shaila Industries, Yavatmal to develop a suitable process flow sheet that may yield a fluorite concentrate assaying minimum 85% CaF₂ grade along with maximum limitation of 6% SiO₂, 2.5% CaCO₃ and 3.6% R₂O₃, respectively. The as received sample assayed 52.96% CaF₂, 37.41% SiO₂, 3.25% CaCO₃, 0.85% Al₂O₃, 1.14% Fe₂O₃. A fluorite concentrate assaying 88.24% CaF₂, 6.95% SiO₂ and 0.42% Al₂O₃ with 49.9% CaF₂ recovery (wt% yield 30.4) could be obtained. Though the desired 6% SiO₂ limitation of silica could not be achieved, the attained grade of the concentrate in terms of CaF₂ is significant in view of the complex ore nature.

1.6 Graphite

Characterisation, beneficiation and utility study of some graphite deposits from Arunachal Pradesh (NEIST)

An ambitious R & D project for characterisation, beneficiation and utility study of some graphite deposits from Arunachal Pradesh with support from Ministry of Mines, Govt. of India, New Delhi has been initiated.

Utilisation of graphite pre-float (HZL).

During the early years of Rajpura Dariba plant operation, some quantity of lead-graphite bulk concentrate was accumulated due to metallurgical difficulties during lead smelting. Laboratory flotation and gravity separation experiments were conducted to upgrade the graphite pre-float (concentrate) of RDM. Though silver upgradation could take place to some satisfactory levels, lead loss could not be prevented due to close association of the minerals and in the sizes they exist. These studies gave opportunity to derive metallurgical treatment methods by combining with those smelter intermediates presently not consumed.

1.7 Iron Ore***Beneficiation of a low grade iron ore sample from Sub grade dump of Sankalapuram Iron Ore Mine (IBM).***

A low grade Iron Ore Sample No.2 from Sub grade dump of Sankalapuram Iron Ore Mine, Kariganur, Hospet Taluk, Bellary district, Karnataka was received from M/s R.B. Seth Shreeram Narsingdas, Hospet to evolve a flow sheet yielding calibrated lumpy ore (+65% Fe)/Sinter grade concentrate(63.5% Fe)/Pellet grade concentrate (+65% Fe). The as received ore contained 54.29% Fe(T), 10.66% SiO₂, 6.32% Al₂O₃, 1.01% FeO, 0.20% MgO and 2.86% LOI.

Beneficiation process comprising grinding, tabling and magnetic separation produced a concentrate assaying 65.02% Fe(T), 1.62% FeO & 0.95% LOI with 78.0% Fe(T) recovery with a wt.% yield of 63.10. The concentrate produced meets specifications for pellet grade.

Iron Ore sample from Sagar Taluk, Shimoga district, Karnataka (IBM).

Iron Ore sample from Sagar Taluk, Shimoga district, Karnataka sent by Shri B. Kumar Gowda Mine Owner, Sandur Karnataka assayed 33.8% Fe(T), 17.7% FeO, 42.6% SiO₂, 1.13% Al₂O₃ and 4.03% LOI. The objective was to produce an iron concentrate suitable for pellet manufacture. A concentrate assaying, 66.79% Fe(T), 4.09% SiO₂ and 0.60% Al₂O₃, with an over all recovery of 71.0% Fe(T) with wt % yield 37.3 could be

obtained. This concentrate is suitable for application in pellet Industry.

Beneficiation of iron ore fines, sponsored by M/s. Fluid O Bulk, Kolkata (NML).

The iron sample from Hospet was received at NML for beneficiation studies. The sample was of -10 mm fraction. The sample assayed 56.73% Fe, 5.45% Al₂O₃, 7.34% SiO₂ and 6.15% LOI. The objective of the studies was to develop a flow sheet for obtaining a concentrate of +63% Fe. Mineralogical studies revealed that the sample is lateritic type and major iron bearing mineral is goethite. The liberation indicated for complete liberation could be achieved in finer sizes. Beneficiation studies using combination of scrubbing, washing, cycloning, etc. were used to upgrade the ore.

Beneficiation of iron ore fines from Barbil area (NML).

The iron ore fines sample was received from Barbil area to find the suitability of the sample for beneficiation for pelletisation. The prime objective of the project was to carry out a detailed beneficiation studies to develop a flow sheet for beneficiation of low grade iron ore fines for pellet making. The iron ore fines of -10 mm sample were received at NML and the sample assayed 63.2% Fe, 3.46% Al₂O₃ and 3.02% SiO₂. The alumina level has to be brought down to 1.5%. The studies involved scrubbing, grinding to one mm and spiralling. The spiral tail is to be treated by Wet High Intensity Magnetic Separation (WHIMS). The experiments so far have indicated that concentrates from spiral could be obtained with alumina of 1.56%. More experiments are underway to increase the yield through optimisation of spiral and WHIMS.

Column flotation studies on iron ores, sponsored by M /s. JSW Steel Ltd, Vidyanagar, Karnataka (NML).

The project involved beneficiation of iron ore fines of M/s JSW to improve the quality of the concentrate by identifying a suitable reagent and utilising the column flotation technology. Based on laboratory scale flotation studies, the reagent was identified and the process parameters of flotation optimised. The pilot column (0.5 m dia.)

was shifted to the plant site of M/s JSW at Toranagallu and test work was done on the screw classifier overflow under the optimised parameters. The alumina could be reduced to 2.0 - 2.5 from 3.5 - 4.5% with increased weight recoveries as compared to the existing recoveries from the classification by cyclones.

Pilot Plant beneficiation of iron ore fines, sponsored by M/s. Bhahmani Rivers Pellets Limited (NML).

M/s. Bhahmani Rivers Pellets Limited has sponsored the project on iron ore fines samples for beneficiation from Orissa. The samples assayed 59.72% Fe, 3.90% Al₂O₃, 3.45% SiO₂ and 5.78% LOI, respectively. The different schemes for beneficiation studies were followed using combination of scrubbing, washing, cycloning, spiral and grinding of the oversize material and magnetic separation. To improve the recovery of the tailing was further ground and subjected to magnetic separation. The studies indicated that a combined product with a yield of 70-75% assaying 63.6% Fe, 2.4% SiO₂ and 2.6% Al₂O₃ could be obtained which is suitable as pelletisation feed.

Pilot Plant beneficiation of iron ore samples, sponsored by M/s. Essar Orissa Steel Limited (NML).

At the instance of Essar Orissa Steel Limited beneficiation studies were carried out on iron ore fines samples from Orissa. The samples assayed 60.39% Fe, 3.85% Al₂O₃, 3.45% SiO₂ and 4.70% LOI, respectively. The objective of the study was to develop the flow sheet for obtaining a concentrate of +64% Fe for pellet feed. Difference schemes were followed for beneficiation studies using combination of scrubbing, washing, cycloning, spiral and grinding of the oversize material and magnetic separation. Recovery from tailing was attempted by further grinding and subjecting to magnetic separation. The studies indicated that a combined product with an yield of 70-75% assaying 64.2% Fe, 2.35% SiO₂ and 2.55% Al₂O₃ could be obtained which is suitable as

pelletisation feed. About 5 tonnes of concentrate was produced for evaluation by the sponsor.

R & D Studies on Iron ore Samples (IMMT).

An integrated process flow sheet has also been developed to beneficiate low grade lump iron ore (Fe 61.7%, SiO₂ 2.8% and Al₂O₃ 3.4%) from Barbil region to produce quality products for blast furnace, sponge iron, sinter making and pellet making plants. Two alternative flow sheets have been suggested which can produce quality raw materials for iron making such as lumps, calibrated ore, sinter feed and pellet feed with more than 64.0% iron content and less than 2.0% Al₂O₃ at 85% yield. The process ensures super quality pellet feed with 63% Fe. More efforts are required to recover iron values from the tailings which contain 49.1% Fe with 8.8% SiO₂ and 10.9% Al₂O₃.

It has been possible to prepare good quality of pellets after grinding the concentrates from jig and magnetic separator to 80% passing below 45-micron size. It was observed that iron ore fines having specific surface area of 1.31 m²/g or more are required to produce pellets with sufficient strength. The pellets showed good compressive strength of 250 kg/pellet when subjected to heat hardening.

Low grade iron ore fine samples from Kasia, Sesa Goa, Banspani, Rungta and Guali mines from Barbil-Joda region, were taken up to develop suitable flow sheet to upgrade various types of iron concentrates to more than 64% Fe with about 4.0% Al₂O₃ and SiO₂ for its use in pelletisation plant. A concentrate of above 64% Fe with more than 72% yield could be obtained by grinding, hydrocyclone, spiral and magnetic separation techniques.

Another sample from Barbil area was taken up to recover additional iron values from -1 mm fine material by magnetic separation technique. Beneficiation studies have shown that a concentrate of 63.67% Fe with 15% additional yield out of 25.4% natural fines could be obtained from 0.5 mm slimes by Wet High Intensity Magnetic Separator (WHIMS).

Blue dust reject sample from Shree Gulab Mines and Minerals, distt. Jabalpur, M.P. (IBM).

An iron ore (Blue Dust) reject sample from Shree Gulab Mines and Minerals, distt. Jabalpur, M.P. containing around 55% Fe (T) was received for development of flow sheet to produce a marketable grade iron concentrate. The beneficiation process evolved comprised crushing of sample to -30 mesh (0.5mm) followed by hydrocycloning, stub cycloning and wet high intensity magnetic separation which yielded a composite concentrate assaying 63.33% Fe with total iron recovery of 92.8%. Based on the process developed the party has initiated erecting of a commercial plant. The recovery of values from mine rejects is quite significant and addresses aspects of mineral conservation.

Characterisation and bench scale beneficiation studies on a BHQ Sample from Nandi Halli Mines, Hospet, Bellary, distt., Karnataka for M/s BMM Ispat Ltd (IBM).

A BHQ Sample from Nandi Halli Mines, Hospet, Bellary, distt., Karnataka for M/s BMM Ispat Ltd was received with an objective to produce an iron concentrate suitable for industrial use with a high recovery. The as received sample assayed 40.20% Fe (T), 40.60% SiO₂, 0.66% Al₂O₃, 0.0029% TiO₂, 0.01% P, and 0.77% LOI.

Gravity separation of sample ground to minus 200 mesh yielded a composite iron concentrate assaying 64.59% Fe(T) and 5.76% SiO₂ with a Fe recovery of 44.7% (wt % yield 27.5).

Characterisation and mineralogical studies revealed that about 40% of the hematite grains carry extremely fine grained inclusions of quartz. At coarser sizes a high grade concentrate could not be obtained because the interlocking of quartz with iron oxides at places is of very complex nature and most of the quartz grains carry very fine inclusions of quartz. It was observed that even at fine grinding sizes, the grade of the concentrate improved but the weight percent yield and recovery was low due to the fact that the fines generated during grinding are joining the tailings. Hence, a high grade concentrate (+65% Fe) with high recovery could not be obtained.

BHQ Dump Iron Ore sample from Sandur, Bellary dist., Karnataka. (IBM).

A low grade dump iron ore sample designated as BHQ dump sample assayed 44.89% Fe(T), 0.5% FeO, 32.19% SiO₂ and 2.58% Al₂O₃ was received at RODL, Bangalore. The sample was sent by M/s V.S. Lad & Sons, Bellary dist., Karnataka (collected from S.J. Harvi Iron Ore Mines, Laxmipura village, Sandur, Bellary) for upgradation. Hematite was the predominant mineral. A composite magnetic concentrate assaying 64.95% Fe(T), 5.03% SiO₂ and 0.69% Al₂O₃ with 50.3% Fe recovery with 33.8 wt.% yield was obtained. The above concentrate produced from dump is a significant achievement as it may find industrial application after blending suitably.

1.8 Limestone***Bench scale beneficiation studies on low grade sample from M/s Madras Cements Ltd (IBM).***

A low grade limestone sample received from M/s Madras Cements Ltd for bench scale beneficiation studies assayed 42.67% CaO, 72.33 total carbonate, 17.42% SiO₂ and 34.13% LOI. The objective of the studies was to produce a limestone concentrate assaying +80% total carbonate with a silica content below 14%. Flotation was the route adopted to achieve the desired concentrate.

The cleaner concentrate was produced at higher pulp density assayed 87.52% T.C. with a total carbonate recovery of 90.7% (wt % yield 75.2). The SiO₂ content is 6.92%.

The rougher concentrate obtained at low pulp density, assayed 85.88% T.C and 7.80% SiO₂ with total carbonate recovery of 94.6% (wt % yield 79.9).

Both the concentrates produced meet the specifications stipulated by the party and are suitable for cement manufacturing.

Pilot plant scale beneficiation studies carried out on a low grade limestone sample from Sattankulam area, Tamil Nadu received from M/s Madras Cements Ltd (IBM).

By adopting flotation a limestone concentrate assaying 49.29% CaO, 7.16% SiO₂ and 0.77% MgO was obtained from a sample assaying 31.10% CaO, 35.58% SiO₂, 0.85% MgO and 25.01% LOI with a

CaO recovery of 86.5%. The concentrate produced meets the specifications for use in the cement manufacture.

Upgradation of Low Grade Limestone from Karikoil (IBM).

A low grade limestone sample from Karikoil Area, Tamil Nadu, sent by M/s Madras Cements Ltd, assayed 30.52% CaO, 36.30% SiO₂, 0.47% MgO, and 24.97% LOI. The object of the investigation was to conduct Pilot Plant scale studies to confirm the laboratory scale results. By adopting flotation route to achieve stipulated specifications, a limestone concentrate assaying 48.16% CaO, 0.34% MgO, 7.80% SiO₂ and 38.96% LOI with 89.8% CaO recovery could be obtained. The flow sheet developed at IBM yielded a high grade concentrate which finds application in cement manufacture.

Beneficiation of siliceous limestone from Jayanthipuram Mine, sponsored by M/s. Madras Cements, Chennai (NML).

Beneficiation of low-grade limestone from Jayanthipuram mines of M/s MCL by flotation is investigated. The microscopic examination of the sample indicated that the calcite is interlocked with gangue minerals and the same can be liberated below the particle size of 40 microns. Direct flotation using sodium oleate and reverse flotation (flotation of gangue minerals) using cationic collector was studied. The flotation data suggest that the beneficiation of limestone both by direct and reverse flotation processes is economically viable. The silica content was brought down to 7% from initial value of 14%. The CaO content was improved to above 50% from its initial value of 42% with a weight recovery of 75%. Further, beneficiation by flotation column was tried and the results were compared to that of conventional flotation. The difference was found to be marginal in terms of grade and recovery. Based on the test work, a flow sheet for the beneficiation of Jayanthipuram limestone was suggested. Draft report has been submitted to M/s MCL for comments.

Upgradation of Limestone samples from Dungri Limestone Quarry for M/s ACC, Orissa (IBM).

M/s ACC Ltd sponsored three low grade limestone samples namely BCW-I, BCW-II and BCW-III from Dungri Limestone Quarry, Bargarh Cement Works, Bargarh, Orissa for assessing the upgradation possible in the sample for application in the Cement Industry.

The beneficiation process developed by O.D. Lab., IBM indicated that a concentrate assaying 75 – 80% T.C. could be obtained except in sample No. BCW-III (R.I. No. 1764) as it is very low grade. The results were evaluated by ACC and helped them in preparing the composite sample to be sent for flotation studies in O.D Laboratory of IBM so that the composite concentrate obtained find its application in Cement Industry.

Dry beneficiation of low/marginal grade limestone for their suitability in cement manufacture (NCBM).

The low grade sample received from Kesoram Cement with the nature of the raw material fine grained highly silicious. The chief contaminants was silica (fine grained crypto crystalline). The results achieved were increase in CaO content from 45.82% to 47.27% and reduction in SiO₂ from 13.34% to 11.55% at minus 60 micron size (weight recovery of 83.5%).

The low grade sample received from Ultra Tech Cement Ltd with the nature of the raw material fine grained, structurally deformed limestone interbedded with carbonaceous shale. The chief containments were silica & sulphur (mainly pyrite). The results achieved were CaO content increased upto 49.3% and silica content reduced upto 5.05%. In case of high silica limestone (weight recovery upto 70%). CaO content increased upto 45.39% and silica content reduced upto 12.19% in case of high silica limestone (weight recovery upto 91.94%). Sulphur content can be reduced upto 0.09% in limestone.

The low grade sample received from Maratha Cement with the nature of raw material fine grained limestone with shale. The chief containments were silica and sulphur (mainly pyrite). The results obtained were CaO content increased upto 45.79% and silica content reduced upto 2.64%. In case high silica limestone (weight recovery upto 85.21%).

Characterisation of limestone resources of NE Region for value addition and rational utilisation (NEIST).

Process for beneficiation of limestone located at Lumshnong, Jayantia Hills, Meghalaya and New Umrangshu, North Cachar Hills District, Assam for making value added process for using in iron & steel, paper, lime, sugar industries, etc. were developed. The project was completed in April 2007 and final report submitted to Ministry of Mines, Govt. of India, New Delhi.

1.9 Lead & Zinc

Recovery improvement in Rajpura Dariba Mine (HZL).

Keeping in mind to enhance the grade and recovery at Rajpura Dariba process in lieu of the complexity of ore from different Rajpura Dariba mine sections, test work was taken up to produce a suitable bulk concentrate with Rajpura Dariba ore instead of separate Lead and Zinc concentrates. For this, closed cycle flotation test work with the laboratory Mini flotation Unit was carried out during November 2007 and March 2008 in two phases. Successfully developed the process to minimise the impurities and achieve desired quality for bulk concentrate at lab scale that could be treated through pyro-process for lead, zinc and silver metals. This has shown considerable step-change in overall metals recovery improvement.

Minimising the misplacement of Zn in Pb concentrate and Pb in Zn concentrate (HZL).

A flotation process for Rampura Agucha ore was developed at laboratory scale using new reagents to reduce the misplacement of Zn in Lead concentrate and Pb in Zinc concentrate. This is an exploratory type work in finding new opportunities in process development. Laboratory test work was

taken up during July-September 2007. Test work was conducted with Sodium bicarbonate, Sodium Phosphate and Sodium Polyphosphate reagents. Results indicated decrease in RAMzinc misplacement with lead concentrate. Considerable reduction in the misplacement of zinc in lead concentrate and some lead in zinc concentrate were achieved using ore sample from Rampura Agucha with sodium phosphate reagent.

Silver concentrate production from Lead-Silver residue (HZL).

This is one of the alternatives tested as a means of producing Ag rich concentrate from lead-silver cake, a leach residue from Chanderia lead-zinc smelter. A novel flotation process was developed to produce silver-rich concentrate from residue. There was considerable silver upgradation in to concentrate produced.

Silver recovery from Moore Cake - a leach residue from Zn Smelter (HZL)

The process developed was tested by producing silver concentrate in the two tonnes per day pilot plant by HZL. The silver was upgraded from 300 ppm in the field to 2800-3000 ppm in concentrate with 50% Ag recovery. The test work based on batch flotation tests was experimented. Later close cycle test was conducted using mini flotation circuit.

Pyrite concentrate from beneficiation plant tailing : (HZL).

Beneficiation tailings contain silver values and rejected pyrite. Due to major proportion as heavy sulphide mineral in the tailing, pyrite concentration recovers some of the silver. Laboratory flotation experiments were conducted to identify the feasibility to produce pyrite concentrate from the lead-zinc flotation tails. Flotation studies with Rampura Agucha tailing, ground to PP80 300 and 400 mesh sizes were carried out in February -March 2008 to recover pyrite and silver in the flotation concentrate. Iron and silver contents were improved with increased fineness but finer grinding reduced their recovery by some extent, indicating further optimisation of different parameters for cost-effectiveness of the process.

Bulk concentrate from beneficiation plant tailings (HZL).

Earlier in June-July 2004, test work on production of Lead-Zinc-bulk concentrate from RAM tailing was undertaken and optimum grade and parameters established. To further optimise zinc grade and recovery in bulk concentrate, a project is undertaken in Oct'07 by gravity and flotation tests. Lab Gravity tests did not indicate scope for improvement. Flotation Test work was planned in early 2008, through recycling the middling and tests with ground tailing. Mini flotation tests under open cycle process could not further enrich bulk concentrate, whereas closed cycle tests indicated a bulk concentrate with 9% Zn at 40% recovery under a set of parameters combination.

Beneficiation of Lead - Zinc Sample from Latio-ka-Khera Project for MECL (IBM).

Mineral Exploration Corporation Limited, Nagpur sent a sample from Latio-ka-Khera Project, Railmagra, Rajsamund, Rajasthan to RODL, Ajmer, with an objective of evolving a suitable beneficiation process flow sheet for the recovery of lead and zinc. The as received sample assayed 0.85% Pb, 4.80% Zn, 15.35% Fe(T) and 21.28% SiO₂. By adopting flotation route, a lead concentrate assaying 62.78% Pb with 48.7% Pb recovery (wt% yield of 0.6) and a zinc concentrate assaying 51.46% Zn with 87.2% Zn recovery (wt% yield 8.5) could be obtained. Both the concentrates are of suitable grade for use in lead & zinc smelting.

1.10 Manganese***Recovery of manganese from leached sea nodules residue and toxicological studies of the waste, supported by Department of Ocean Development, New Delhi (NML)***

During processing of Polymetallic Sea nodules a substantial quantity of residue containing 20% Mn, 10% Fe and 8% Si is generated which constitute 70% of the weight of the nodules treated. In order to improve the overall economics of the process, it is necessary to recover manganese either as metal or Fe-Si-Mn alloy. The objective of the present study is to produce standard grade Fe-Si-Mn from the leached sea nodules residue. For this, leached residue was blended with Mn ore/Fe-Mn slag/Mn metal to have the required Mn/Fe ratio to produce

standard grade Fe-Si-Mn by smelting route. Attempts were also made to recover the manganese as Fe-Si-Mn by two stage smelting of leached sea nodule residue without any blending with the above mentioned Mn containing materials. Several experiments were conducted on 20 kg scale to optimise the various parameters viz quantity of reductant, soaking time etc. to achieve the standard grade Fe-Si-Mn and good Mn recovery. The results of these experiments were presented in the last RC. Based on the above studies, the two stage smelting process was decided to be tried on 350 kg scale in the newly set up Fe-Si-Mn production pilot plant. Six nos. of campaigns were carried out on pilot scale. Standard grade Fe-Si-Mn was produced.

Processing of polymetallic sea nodules for recovery of valuable metals, supported by Department of Ocean Development, New Delhi (NML).

Polymetallic sea nodules, better known as manganese nodules obtained from deep ocean floor, contain valuable metals like Cu, Ni, Co and Mn. Available estimates show that availability of strategic metals like Ni and Co in manganese nodules is about 5 and 40 times higher, respectively, than that in land based resources. Absence of economic resource of Ni and Co together with fast depleting Cu scenario in India, made policy makers to think of exploiting the polymetallic sea nodules of the adjoining Indian Ocean. It is in this context, NML, Jamshedpur was entrusted with the task on developing a suitable technology for extraction of valuable metals from the sea nodules, by the Ministry of Earth Sciences, Govt. of India. NML has developed a process on pilot scale for the metals extraction from sea nodules following the "Reduction roast-Ammonia Leaching - Solvent Extraction - Electrowinning-Leach residue treatment" route. The recoveries of metals on pilot scale processing of sea nodules are Cu-95%, Ni-95% and Co-80%. Manganese recovery in the form of standard grade Fe-Si-Mn from the leached sea nodules residue has been made by smelting route on pilot scale with the Mn recovery of about 75%.

R & D Studies on Manganese ore sample (IMMT).

Mineralogical and geochemical characterisation of low-grade manganese ores from manganese formations of Koraput-Raigada sector were taken up.

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Representative Mn-ore samples from Koka and Leliguma in Raigad district were collected and characterised in respect of their mineralogy and chemistry. Both the ores are of low-grade type and dominantly contain higher oxy-hydroxide manganese minerals. The gangue constituents are quartz, feldspar and kaolinite. The Koka Mn-ore contains around 17% Mn and 25% Fe, mostly contributed by goethite. In contrast, the Leliguma Mn-ore shows 23% Mn, 6% Fe but is rich in phosphorus (P₂O₅: >1%), mostly contributed by apatite. Preliminary beneficiation through roast reduction followed by magnetic separation techniques showed appreciable upgradation of Koka manganese ore.

1.11 Marble

Ningha Marble quarry of M/s Jaiprakash Associates Ltd. Dalla Cement, Sonbhadra distt., U.P. for development of suitable beneficiation flow sheet for segregation of marble from quartzite (IBM).

A quartzite bearing marble sample was received at Modern Mineral Processing Lab & PP, Nagpur. The concentrate obtained finds application as a sweetener in cement manufacture. The as received sample assayed 67.71% T.C., 35.21% CaO, 30.58% SiO₂, 1.03% Fe₂O₃, 0.08% Al₂O₃, 0.63% MgO and 29.95% LOI. The flotation concentrate obtained assayed 86.8% T.C., 45.91% CaO, 11.85% SiO₂, 0.07% Al₂O₃, 1.39% Fe₂O₃, 0.66% MgO with 87.7% recovery and 68.8% wt. yield. The concentrate obtained finds application in cement manufacture as desired by the party.

2. MINING

2.1 National Institute of Rock Mechanics (NIRM)

The Institute has been extending its R & D support to the industry in the following areas:

1. Hard Rock Mines/Metalliferrous mines.
2. Coal Mines.
3. Hydroelectric & Tunnelling Projects.
4. Other Civil Construction Projects.

The Institute took two S&T projects and 25 industry sponsored projects in 2006-07. By the end of 2007-08 investigations were completed for 25 projects and the work is in progress in 20 - odd projects.

Non-coal mines

The key areas of research were geotechnical studies, numerical modelling, geophysical exploration and ground control investigations for hard rock mines and design of controlled blasting and laboratory testing of samples. The major areas of research included:

- * optimum design of mining operations and excavation systems;
- * design of support system for improving safety, conservation and productivity;
- * prediction of unknown subsurface features; and
- * monitoring stability of excavations.

Support is also extended in areas of environmental studies, exploitation of dimensional stones and seismological studies.

NIRM also investigated ground stability of the open slopes at Hutti gold mine through instrumentation and monitoring. NIRM has been assisting CDOS in setting up a Test House for dimensional stones at Jaipur. In addition slope stability studies were carried out for designing the ultimate angle of the pit slopes in opencast mines of MML in Bellary district, Karnataka.

Coal Mines

One of the major thrust areas of the Institute is to improve safety and productivity of the underground coal mines in the country. NIRM is involved in assessing the feasibility of new mining methods and safe roof supports in coal mines.

The strata control investigations in this sector include:

- * Rock mass characterisation, and RMR studies;
- * Design of rock reinforcement systems;
- * Coal mine pillar design;

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- * Development of new mining methods for increased safety and productivity;
- * Study of parting behaviour in multiple seam extraction; and
- * Mapping of barriers around old workings from underground.

The Institute undertook designing method of work under special conditions studies mostly in the mines of South Central Coalfields Ltd (SCCL). NIRM has also conducted studies of caveability of the roof strata, design of method of extraction of pillars and study into extent of abutment loading trend and design of advance support during pillar extraction by stowin.

The Institute has been awarded a major collaborative S&T project by Ministry of Coal to study the caveability in longwall panels.

Hydroelectric projects

The Institute has been involved in conducting rock mechanics studies required for excavations in several hydroelectric projects in India. Main areas of rock engineering investigations carried out by NIRM in this field include:

- * Investigations for determination of the insitu stress and deformability properties
- * Geophysical investigations for bed rock delineation and stratigraphic mapping
- * Instrumentation and monitoring.
- * Numerical modelling for stress analysis and design of support systems; and
- * Design of controlled blasting parameters.

Investigations were carried out at various projects including Tala hydroelectric project (Bhutan), Sardar Sarovar Project (Gujarat), Koldam hydroelectric Project (Himachal Pradesh), Larji hydroelectric Project (Himachal Pradesh), Dibang Multipurpose Hydroelectric Project (Arunachal Pradesh), Pykara Hydroelectric Project (Tamil Nadu), Malana Hydroelectric Project (Himachal Pradesh), Pala Maneri Hydroelectric Project (Uttarakhand) and Varunavat Parvat in Uttar Kashi of Tehri Project.

During 2007-08, in situ investigations were determined for four major hydel projects.

Civil Construction Projects

NIRM has been involved in a big way in various investigations. Investigations were completed of the prestigious Katra-Qazigund rail link project in the

mountainous terrains in Jammu & Kashmir. Geophysical investigations were carried out at various tunnel portals and bridge abutments proposed along the 140 km long railway line. Rock samples from these sites are tested at NIRM to determine their physico-mechanical properties. NIRM has been continuing the investigations related to geotechnical mapping and blast design for the first underground LPG storage cavern of the country being constructed in Visakhapatnam. The institute has also secured the project for surface investigations at an oil storage cavern site in Karnataka. Seismic survey was also done for mapping bed rock profile at Teesta Stage -II and Stage-VI projects in Sikkim.

Testing Services

In addition to these field investigations, NIRM has done extensive testing of rock samples as per international standards. The studies carried out on various rock samples include:

- * Measurement of strain at high temperature under uniaxial and triaxial compressive stress conditions.
- * Thermomechanical behaviour of rocks.

Fundamental research in the area of engineering and mechanical properties of rock joints under shear, and studies on Kaiser effect, were some of the unique research areas of the Institute in the field of Fracture Mechanics. Further, wire rope testing and non-destructive testing (NDT) of mining equipment/components are carried out on regular basis.

3. ENVIRONMENT

Indian Bureau of Mines (IBM)

Mining Research Cell of IBM has rendered charge base consultancy work on environmental Management for the generation of baseline data for the preparation of DIA & EMP, Ground vibration studies due to blasting, Geotechnical Investigation for the design of cut & fill stoping, slope stability investigations, design of tailing dams, waste dump stability analysis, dump management & solid waste management.

Monitoring of Environmental Parameters at Shigao Iron Mine of M/s Fomento Goa.

This consultancy project on environmental quality monitoring at Copila Gaichem Paul (Ghigao) Iron Ore Mine of M/s Fomento Industries, Goa, has

been carried out for all the four seasons to monitor environmental parameters such as air, water, soil and noise at the mine. The monitoring data has been analysed and found that the study has indicated that all the environmental parameters monitored are within the prescribed limits as per the MOEF standards. The final report has been sent to the party. Thus helped the management to develop the proper mitigation measures.

Geotechnical Investigations for Slope Stability at Sanjem Iron Ore Mine of M/s Taulikekar & Sons (P) Ltd, operated by M/s Fomento Goa.

Slope Stability Investigations were carried out at Sanjem Mine, where the footwall benches developed wide tension cracks. Geotechnical investigations include field mapping of tension cracks, monitoring by EDM surveys, installation of borehole pie meters for strata monitoring and laboratory testing samples for physico-mechanical properties. Numerical modelling of slope analysis has been carried out using 'Galena' computer programme. The results indicated that the slopes can be maintained at 28 slope angle with Factor of Safety of 1.5 by detailed geotechnical analysis, proper support techniques and field instrumentation. Pit slope were designed upto a depth of another 40 meters to mine the ore body. Thus, mine management is benefited by results of this investigation and it is producing 2.0 lakh tonnes of iron ore.

Geotechnical Investigations for Design of New Tailing Stacks/Dams at Cuddegal Iron Ore Mine of M/s Fomento Goa.

Two new tailing stacks/impoundments were designed in the form of in-pit dug dams to increase the holding capacity by geotechnical investigations carried out. These dams are designed with a factor of safety of more than 1.5 with environmental considerations. This helped the mine owner in increasing the holding capacity of tailings.

Geotechnical Investigations for Assessment of Stability of Waste Dumps at Deposit No.5 of Bailadila Iron Ore Project Bachel, M/s NMDC Ltd.

Geotechnical investigations were carried out for the assessment of stability of waste Dump Nos. 1, 2, 3 and proposed Dump Nos. 4 & 5 at Bailadila Iron Ore Project of NMDC by collecting samples of dump

material and testing for its physico - mechanical properties. These results were utilised as an input parameters for analysing stability of waste dumps with varying slope angles and slope height, using numerical modelling technique. The study has indicated that it could be possible to maintain dump slope angle of 37 degree with a factor of safety of more than 1.5 limiting maximum height of 59 m. Based on the future quantum of waste generation, two more waste dumps were designed for proper dump management system.

Study of ground Vibrations due to blasting in Amla and Thandiberi limestone mines of M/s Binani Cements Ltd in Sirohi district of Rajasthan.

The study was carried out in two limestone mines to evaluate the effect of blast induced ground vibrations over the nearby surface structure by monitoring with the help of blasting seismograph. The investigation revealed that vibration levels are within the limit, which may not cause damage to nearby residential structure. However, as per the results of regression analysis, the explosive charge per delay for Thandiberi limestone mine is suggested to be restricted to 550 kg.

Study of Ground vibrations due to blasting, near Chittorgarh fort of Rajasthan, in connection with D.B. Writ Petition and compliance report pertaining to half year ending 30.06.2006.

As per the directives of Hon'ble High Court of Rajasthan blast vibrations monitoring was carried out at Chittorgarh fort and submitted the study report to Hon'ble High Court of Rajasthan, Jodhpur. The investigations revealed that vibration levels due to blasting carried out by M/s Birla Cement Works and other nearby stone quarries, are within the limit, which may not cause any damage to fort area.

Study of Ground vibrations due to blasting at Bangur underground Chromite mine of M/s Orissa Mining Corporation Ltd.

Ground vibration monitoring carried out at Bangur underground Chromite mine and its responses on the surface structure were evaluated. It has been revealed that there is no blast-induced damage to the surface structure.