5 Research & Development

The Science and Technology programmes (S &T) of the Ministry of Mines, Government of India, cover the disciplines of Geology, Exploration, Mining & Environment, Bioleaching, Beneficiation, Rock Mechanics, Ground Control and Non-ferrous Metallurgy. During the current year, eight new projects have been approved along with one modified project. During 2009-10, 3 proposals were scrutinised by Project Evaluation and Review Committee (PERC) in addition to 5 projects which were approved by Standing Scientific Advisory Group (SSAG).

The highlights of work carried out during 2009-10 by various research organisations and industries relating to mineral beneficiation and mining & environment are given below:

1. BENEFICIATION

1.1 BAUXITE

Bench scale beneficiation studies on Bauxite Sample from Sabarkantha area (IBM)

A Bauxite sample from M/s Gujarat Mineral Development Corporation Science & Research Centre was received in Modern Mineral Processing Laboratory and Pilot Plant, IBM, Nagpur, to develop a process flow sheet to produce a usable bauxite concentrate with low silica. The as received sample assayed 35.47% Al_2O_3, 4.44% SiO_2 (T), 32.90% Fe_2O_3 & 18.44% LOI. Dry high intensity magnetic separation produced a non-magnetic fraction assaying 44.81% Al_2O_3, 19.77% Fe_2O_3, 3.62% SiO_2(T) and 23.58% LOI with 18.60% Al_2O_3 recovery (wt% yield 14.7). This non-magnetic bauxite fraction may find application in Metallurgical industry.

1.2 BEACH SAND

Studies on heavies from beach and dune sands of southeastern coast of India with special reference to recovery and in depth characterisation to zircons (BRNS, Mumbai (IMMT)

An attempt is made for value addition from Nalli sediments of Agasti village,Ganjam district, Odisha by recovering heavy minerals for industrial applications. The study reveals that the Nalli sediments contain 43.9% total heavy minerals out of which the total magnetic minerals are 34.9%. Similarly, among the total heavy minerals, the very heavy minerals (>3.3 sp gr) are 39.7% by weight, in which the total non- magnetic heavy minerals are 4.8%. The light heavy minerals (<3.3 sp gr) are 4.2% by weight. The sample also contain reddish coloured slime (27.6% by weight and 11.2% total iron) can be deslimed separately for value addition. A flow sheet is suggested with material balance on the recovery of total heavy minerals. The results indicate that a combined product containing 95.1% total heavy minerals with 44.7% yield and 97% recovery could be achieved from a feed sample containing 43.9% total heavy minerals. The product contains 80.1% ilmenite, 8.6% sillimanite, 6.2% zircon, 3.0% rutile, 0.5% garnet and the rest other minerals including monazite.

1.3 CHROMITE

Beneficiation studies and development of flow sheet on low grade chromite ore lumps (M/s Ashapura Minechem Ltd, Mumbai, Maharashtra) (IMMT)

The main objective of the project is to develop a suitable beneficiation process flow sheet to recover chromite values from low grade chromite ore lumps.

Characterisation studies include size analysis, sink float and magnetic separation. The studies reveal that complete liberation of chromite is not achieved even at below 75-micron size. Mineralogical studies under stereomicroscope as well as petrological microscope and X-ray diffraction (XRD) pattern of a few selected samples indicate that chromite grains are locked either within the iron bearing minerals (goethite/ hematite) or with silicates or the chromite grains contain, inclusions of silicate. Further it is observed that the chromite and hematite are the major minerals present in the sample. The grindability of as received sample indicate that the gbp of the chromite ore sample is 1.37 and the work index calculated from this data is found to be 16 kwh/t.

Results of mineral separator studies on different feed sizes and operating timings indicate that a feed containing 31% Cr_2O_3 has been enriched to 37% Cr_2O_3. This product has been enriched to 39.84% Cr_2O_3 when the mineral separator product has been subjected to magnetic separation. Alternately, a product can be obtained with 40.25% Cr_2O_3 from feed containing 36.35% Cr_2O_3 by using dispersant during the mineral separator studies. It is further observed that ~ 40% Cr_2O_3 grade can be obtained by either calcination or reduction roasting with recoveries 51% and 57% at 45% and 63% yields, respectively, from a feed of 35.7% Cr_2O_3.

Typical test results of continuous semi autogenous ball mill grinding followed by sieve bend classification indicate that a product obtained contains 40.74% Cr_2O_3 from a feed containing 30.0% Cr_2O_3. However, the recovery is limited to 11% only.

1.4 COAL

Washability studies on thirteen borehole samples from Utkal B1 coal seams, JSPL, Angul, Odisha (CIMFR erstwhile CFRI)

The main objective of the project was to characterise the head sample in terms of various analyses and to conduct detailed washability investigations on thirteen borehole samples at 50-5 mm size.

Detailed characterisation of the borehole coal core samples was carried out and it was found that the ash percentage of the raw coal varied between 42.0 and 61.0%. The screen analyses of the raw coal revealed that the fraction of fine coal (5mm-0) varies between 6.5% and 9.5%.

The studies also include generation of cleans at 36% ash level for five selective borehole coal core samples (sample no. 1, 3, 4, 8, 7, 10) and prediction of expected recovery of coal at 36% ash level with Jig and Heavy medium washer by considering normal efficiency of the washing system.

The detailed washability studies of the individual seam samples reveal that most of the samples are amenable to washing with good theoretical yield % at the required ash level. The characteristics of the clean coal showed that these coals can be used for power generation after suitable washing.

Washability studies on three borehole samples crushed to 50 mm, generation of cleans and characterisation of raw coal, cleans and rejects (CIMFR)

Detailed characterisation of the three seam samples was carried out and it was found that the ash percentage of the raw coal varied between 32.0 and 54.0. The detailed washability studies of the individual seam samples reveal that Seam IV and Seam VI samples are amenable to washing with good theoretical yield % at the required ash level where as Seam V sample washability characteristics is poor. The characteristics of the clean coal and rejects showed that these coals can be used for power generation after suitable washing.

Washability studies and generation of cleans from borehole sample of Lohapatti mine, BCCL and characterisation of raw coal and cleans (CIMFR)

The characteristics of the raw coal are good. The coarser size fractions contain higher ash content than the lower size fractions. The washability charcteristics of the coal crushed to 25 mm is good and the recovery is about 55% at desired clean coal quality i.e. at 18.5% ash. The characteristics of the clean coal indicate that the clean coal may be useful for metallurgical industries.

Studies on the Cleaning Potentialities of Low Volatile Coking Coal of Jharia Coalfields (CIMFR)

CIMFR (Digwadih Campus) carried out detailed washability investigation and characterisation studies on various fractions of two coal samples from BCCL mines of Jharia Coalfields. The objective of the programme was to carry out detailed characterisations on ROM/Raw coal & various fractions, washability investigations on the raw coal crushed to 50 mm and deshaled cleans (50-13 mm) crushed to 13 mm along with natural (13-0.5 mm) fractions to develop data for studying the cleaning potentialities and to generate cleans of desired qualities for various characterisation tests. The coal fines generated through various processing routes were tested for upgradation by froth flotation in laboratory.

The detailed washability studies carried out on the two coals indicate that they are amenable to washing. Beneficiation flow scheme was developed and the clean coal of desired quality was generated. The results of characterisation test in terms of carbonisation properties and petrographic analysis suggest that the quality of cleans has improved for both the coals and they may be utilised as blendable coals for metallurgical coke making purposes.

1.5 FLY ASH

Pilot Scale Beneficiation Studies on a Fly ash sample for Kymore Cement Works, Katni Distt., Madhya Pradesh for M/s ACC Ltd (IBM)

A fly ash sample for Kymore Cement Works, Kymore, Katni distt., M.P. assaying 6.55% F.C., 89.43%

ash, 3.53% V.M., 0.49% moisture, 56.05 % SiO_2, 3.95% Fe_2O_3, 22.04% Al_2O_3 and 10.86% LOI was sent by M/s ACC Ltd. The object of the investigation was to confirm the results on RI No. 1860 on pilot scale.

By adopting flotation route, a concentrate (non-float) assaying 97.02% Ash. 2.30% V.M., 0.21% F.C., 62.02% SiO_2, 4.09% Fe_2O_3, 26.58% Al_2O_3, 0.61% CaO, 0.195% MgO and 2.53% LOI was obtained. The concentrate produced met the requirement of M/s ACC and could find application in cement industry.

1.6 IRON ORE

Beneficiation of an Iron Ore Sample from Haraginodar Mines, Bellary, Karnataka (IBM)

An iron ore sample from Haraginoda mines, Bellary, Karnataka received from M/s Allum Prashanth, Mine Owner, Bangalore assaying 58.25% Fe(T), 6.73% FeO, 6.52% SiO_2, 1.82% Al_2O_3, 2.16% LOI, 1.04% CaO, 3.30% MgO, 0.25% P & 0.10% S(T) was sent to RODL, IBM, Bangalore with an object to upgrade the ore to +66% Fe(T) with SiO_2 < 1%, P< 0.06% and S(T) < 0.06% with maximum Fe(T) recovery. Grinding, magnetic separation, tabling and flotation yielded an iron ore concentrate assaying 70.43% Fe(T), 8.69% FeO, 0.71% SiO_2, 0.035% P, 0.008% S with 69.3% Fe(T) recovery (wt% yield 57.8). The concentrate obtained met the requirement of the party and may find industrial use.

Beneficiation and pelletisation studies on low-grade iron ore fines (M/s Yazdani International (P) Ltd, Bhubaneswar, Odisha) (IMMT)

The objective of the project is to develop a suitable beneficiation scheme to upgrade the low grade iron ore fines (-10 mm) with 58-59% Fe to prepare concentrates suitable for sintering and pelletisation.

The low grade iron ore fines sample supplied contains on an average 57.4% Fe, 6.3% SiO_2, 6.84% Al_2O_3 and 4.5% LOI. The various beneficiation techniques such as scrubbing, jigging, spiralling and magnetic separation have been used to recover good grade iron concentrate. Different alternative flow sheets have been sugggested to recover the iron values suitable for both sintering and pelletisation. Detailed investigations have indicated that iron ore concentrate with 63.7% Fe at 68% yield could be obtained by combination of screening, jigging hydrocyclone and magnetic separation techniques. The concentrates thus obtained can be used for sintering and pelletisation purpose. The pelletisation studies reveal that it is possible to prepare quality pellets with jig concentrate using 0.8% bentonite as binder and WHIMS concentrate can also be pelletised with basicity of around 0.5.

Development of integrated flow sheet for complete utilisation of low grade iron ore (M/s Rungta Mines Ltd) (IMMT)

The low grade iron ore fines sample contains 58.2% Fe, 5.0% SiO_2, 5.7% Al_2O_3 and 5.5% LOI. Mineralogically the sample is composed of hematite, vitreous goethite, ochreous goethite (limonite), gibbsite, quartz, kaolinite and montmorillonite minerals. The liberation study revealed that more than 80% of the hematite is present in the size fraction of -300 + 150 microns. Detailed beneficiation studies involving scrubbing, jigging, flotex density separator, hydrocyclone, spiral concentration and magnetic separation have been carried out to develop suitable flow sheet to recover good grade iron concentrates. Different alternative beneficiation schemes for the recovery of iron values were suggested. The results of these studies indicated that iron concentrate with 64.1% Fe at 56.5-64.4% weight could be achieved from the low grade material. Considering the large resources of low grade iron ore fines available at mines site, IMMT, Bhubaneswar has explored the possibility of producing suitable iron concentrates for both sintering and pelletisation.

Pelletisation studies on blue dust and combination of iron ore fine concentrate (M/s Yazdani International (P) Ltd Bhubaneswar, Odisha) (IMMT)

M/s Yazdani International (P) Ltd is interested to put up a beneficiation and pelletisation plant in Barbil area, Odisha to utilise iron ore fines with 58-60% Fe and also blue dust available in Odisha. The firm is also interested to utilise blue dust fines for pellet making either separately or as a mixture with the upgraded concentrate fines obtained from the beneficiation of 58% Fe grade iron ore fines of Barbil area. Recently, a project, sponsored by M/s Yazdani International (P) Ltd, for beneficiation of 58-60% Fe available in Odisha to produce a concentrate with more than 64.0% Fe for use in pelletisation plant has been successfully completed. The studies indicated that it is possible to prepare quality pellets from blue dust using bentonite as binder. Bentonite addition of 1.0% wt./wt. of concentrate is adequate for obtaining pellets with acceptable drop strength and CCS after heat hardening. Induration temperature of 1200°C - 1250°C is required to get the required pellet strength. It is possible to prepare pellets having 0.5 basicity, from blue dust, using limestone and coke. Higher induration temperature is required in absence of coke to compensate for endothermic reactions of limestone calcination. It is possible to prepare quality pellets from the 50:50 mixture of blue dust and concentrate (65.96% Fe) using bentonite as binder. It is also possible to prepare quality

pellets from the 60:40 mixture of blue dust and concentrate (61.43% Fe) using bentonite as binder.

Beneficiation of low grade iron ore fines by high gradient magnetic separator (Research and Development Division, NMDC Limited, Hyderabad, Andhra Pradesh) (IMMT)

The objective of this beneficiation study is to enrich Fe content to prepare the pellet grade feed material from low grade fines. Various laboratory experiments were designed and performed to achieve the above objectives. The NMDC has supplied two samples for the laboratory investigations:

1. Low-grade iron ore containing about 42% Fe, 38% SiO_2 and
2. Plant tailing containing about 29% Fe and 55% SiO_2.

The magnetic separation studies on low-grade sample was carried out using WHIMS as well as HGMS. The investigations carried out on the low-grade BHJ sample and spiral tailing to enrich the Fe content have revealed that:

- The samples are amenable for beneficiation using magnetic separators.
- Both the samples are very fine in nature and iron is almost uniformly distributed in all the size fractions. It appears that gangue is almost liberated in both the cases.
- Two alternative flow sheets with WHIMS and HGMS have been suggested for both the samples.
- The results of low-grade BHJ sample indicate that it is possible to upgrade the iron content to 62.97% Fe with 58% weight recovery in concentrate by rejecting 10.2% Fe values using two - stage HGMS separation.
- Studies on the spiral tailing indicate that a concentrate with 57.8% Fe at 43% weight recovery can be achieved.
- In both the cases HGMS is giving superior prformance due to fine nature of the sample.
- It is possible to produce rejects with very low iron content by HGMS.
- Both grade and yield is better by HGMS separation.

BHJ sample can easily be beneficiated by HGMS to produce pellet grade concentrate.

Beneficiation of low grade iron ore fines by Jigging (M/s Rungta Mines Limited, Barbil, Odisha) (IMMT)

Large quantities of low grade iron ore fines are available at mines site without proper utility. As a part of ongoing study to utilise the fines, low grade iron ore fines sample from Rungta Mines Limited was taken up for the detailed studies.

Detailed investigations carried out on low-grade iron ore fines reveal that the iron ore fines on an average contain 60.87% Fe, 3.22% SiO_2 and 4.27% Al_2O_3. The size analysis data indicate that iron values are uniformly distributed in all size fractions but particle size (-0.100 mm) contains less amount of iron. Detailed investigations carried out by adopting various beneficiation techniques indicate that the combination of screw classification, screening, jigging, hydrocyclone, and magnetic separation route can be applied to recover most of the iron values present in the low grade iron ore fines. Detailed beneficiation studies indicated that it is possible to generate quality product suitable for both sintering and pelletisation by adopting simple techniques. Two products can be generated by jigging and wet high intensity magnetic separator. Jig product can be used directly in sintering, whereas combined product can be used either for sintering or pelletisation based on requirement. A jig product with 65.9% Fe at 45% yield can be generated. Magnetic product contains 62% Fe with 30.4% yield. It is possible to produce iron concentrate with 64.3% Fe at 75.4% weight recovery. It is thus established that a good grade iron fines suitable for sintering and pellet making can be achieved from the low grade ore present by adopting simple flow sheet as suggested.

Beneficiation of iron ore fines for Finex process of iron making (M/s Mideast Integrated Steel Limited, New Delhi) (IMMT)

Detailed investigations were carried out on low grade iron ore fines to prepare quality products for Finex process of iron making. The low grade iron ore fines on an average contain 58.4% Fe, 4.6% silica and 4.7% alumina. The size analysis and chemical analysis of each fraction indicate that the iron values are equally distributed in all the size fractions above 0.3 mm but the fractions below 0.045 micron contain very low iron value. The mineralogical studies show that hematite is the most dominant mineral present in the ROM sample. The other two abundant constituents are vitreous goethite and ochreous goethite, while gibbsite, quartz and kaolinite are minor to trace constituents. The liberation study reveals that more than 80% liberation of hematite is in the range of size -75 + 45 micron.

Detailed beneficiation studies comprising a combination of screening, scrubbing, jigging, hydrocyclone, spiral and magnetic separation were conducted to enhance the iron values present in the low grade iron ore fines in order to make them suitable for Finex process. The results indicate that combination of simple techniques like screening, jigging, hydrocyclone and magnetic separation is the ideal route to produce a product with 64.7% Fe at the yield of 69.1%. Finex process for iron making requires specific size of raw material. The typical size distribution of Finex process and products size distribution obtained by schemes are comparable. The coarse product obtained from this sample deviates slightly from the lower limit of Finex size distribution while finer products fall within the same size range. Blending of the coarse and fine product in appropriate proportion is required to balance the required size distribution pattern for Finex process as these products were generated separately in the flow sheet.

Beneficiation of low grade iron ore fines for sintering and pelletisation (M/s Bhushan Power and Steel Limited, Sambalpur, Odisha) (IMMT)

The objective of the project is to develop a suitable beneficiation scheme to upgrade low grade iron ore fines (-12.0 mm) with 58-59% Fe to prepare concentrates suitable for both sintering and pelletisation. Two low grade iron ore fines samples designated as A & B were supplied which contain an average 59.74% Fe, 3.48%- 4.6% SiO_2 and 3.48% - 4.7% Al_2O_3. The various minerals associated in these samples are hematite, vitreous goethite, ochreous goethite, gibbsite, kaolinite and quartz. The average hematite in the bulk sample is 46.30%. Various beneficiation techniques such as scrubbing, jigging, spiralling and magnetic separation have been applied to recover the iron values. Different alternative flow sheets have been suggested to recover the iron values suitable for sintering and pelletisation. The investigations on sample have indicated that iron concentrate with 65% Fe at 71.8% yield could be obtained by combination of scrubbing, screening, jigging, hydrocyclone and magnetic separation techniques. More or less similar results were obtained for sample B.

1.7 LIGNITE

Beneficiation of Lignite Sample for GMDC Science & Research Centre, Ahmedabad, Gujarat (IBM)

A ROM sample of lignite from Mata-no-Madh mines of Kachchh area was sent by GMDC Science & Research Centre, Ahmedabad at RODL, IBM, Ajmer with an object to develop a flow sheet to obtain a lignite concentrate with minimum amount of pyrite. The sample as received assayed 14.40% S(T), 26.80% ash, 39.89%V.M., 29.53% F.C. , 3.78% moisture, 0.29% SO_4, 13.65% Pyritic Sulphur and 0.47% Organic Sulphur.

By adopting flotation to separate pyrite from lignite and subjecting tails to gravity operation yielded a lignite concentrate assaying 3.52% S(T), 13.22% ash, 43.06%V.M., 34.94% F.C., 8.78% moisture with 79.0% F.C. recovery (overall wt% yield 64.50). Thus, the lignite concentrate as desired by the party could be achieved.

1.8 LIMESTONE

A ferruginous Limestone sample from PNR mines Arayalur District, Tamil Nadu sent by Dalmia Cement (Bharat) Ltd (IBM)

A ferruginous limestone sample from PNR mines Arayalur District, Tamil Nadu sent by Dalmia Cement (Bharat) Ltd. was received at RODL, IBM, Bangalore to develop a process flow sheet to reduce Fe_2O_3 content to less than 3.2%.

The sample as received assayed 40.46% CaO, 5.44% SiO_2, 13.01% Fe_2O_3, 2.00% Al_2O_3, 0.38%MgO and 36.63% LOI. By adopting flotation route, a concentrate assaying 50.11% CaO, 1.00% SiO_2, 2.76% Fe_2O_3 with CaO recovery of 65.1% (wt% yield of 53.1) could be obtained. The concentrate obtained met the specifications stipulated by the party and could find utility in cement industry.

Beneficiation studies on low grade limestone from polished stone mines (M/s Associated Stone Industries (Kota) Limited, Rajasthan (IMMT)

During the mining of hard limestone for the preparation of quality polished Kota stones, some low-grade materials are being generated and discarded. These materials roughly contain 37-39% CaO and 23-25% SiO_2 as the major chemical constituents. Mineralogically the sample consists of calcite ($CaCO_3$) and quartz (SiO_2) as the major mineral phases. Besides, minor phases like diopside ($CaMgSiO_2O_6$) and scawtite ($Ca_7(CO_3)Si_6O_{18},2H_2O$) are also associated with these types of materials. In order to add some values to this accumulated material it is rightly thought to produce cement grade limestone by beneficiating the low value material.

Froth flotation technique is employed to recover the CaO values after grinding the material to below 100 micron size. The results of the investigations carried out reveal that the limestone sample supplied by ASI is amenable to beneficiation by flotation techniques with oleic acid or commercial grade sodium oleate as the collector. The sample can be well floated by grinding to below 100 micron particle size, where the liberation of calcite particles occurs as evidenced from the mineralogical studies. It is possible to obtain a concentrate with 44% CaO at 80% recovery. Taking all the experiments into consideration, it has been concluded that at least concentrate with CaO grade of 44% with more than 65% yield can be obtained. These results clearly indicate that yield and grade are inversely proportional and there is optimum yield at required grade.

Feasibility studies on reduction of silica content from Sattankulam Limestone by VSK separator (M/s Madras Cements Limited, Chennai, Tamil Nadu) (IMMT)

The main objective of the project is to reduce silica content from Sattankulam Limestone by using dry cyclones. The results of these studies reveal that the feed sample contains 31.57% CaO and 35.36% SiO_2. The size analysis data indicate that -45 micron size fraction contains 47.24% CaO and 8.70% SiO_2 with 9.2% yield. Summary of VSK separator results on feed sizes of -2 mm and -1 mm revealed that fines from VSK separator contains maximum of 37.97% CaO with high silica.

Results of continuous studies on VSK separator were carried out on the feed sample ground to below 210 microns and subjected to first stage VSK separator. At this stage first stage coarse and first stage fines were collected separately. The first stage coarse fraction was ground to below 100 microns. The ground product, mixed with the first stage fines were again subjected to VSK separator. The fines obtained in second stage separator contain 44.65% CaO and 11.67% SiO_2 with 29.9% yield and 42% recovery from a feed sample containing 31.6% CaO and 33.6% SiO_2.

1.9 MANGANESE

Production of Marketable grade Manganese concentrate from rejects of Netra Mine, Balaghat, Madhya Pradesh (IBM)

A sub-grade manganese ore sample from Netra Manganese Mines of M/s Pacific Minerals Pvt. Ltd, Balaghat, Madhya Pradesh was sent by IBM, Nagpur Regional Office to explore the possibility of value addition to obtain a marketable grade manganese concentrate with optimum recovery. The sample as received assayed 26.52% Mn, 6.93% Fe(T), 33.03% SiO_2 and 5.68% Al_2O_3. Gravity separation followed by magnetic separation yielded a concentrate assaying 40.12% Mn, 9.01% Fe(T), 15.00% SiO_2 with 76.3% Mn recovery (wt% yield 50.5). The concentrate obtained is of marketable grade and it is appreciable to produce a marketable grade concentrate from rejects.

1.10 ROCK PHOSPHATE

Upgradation of Carbonaceous & Siliceous Rock Phosphate after blending (IBM)

A primary carbonaceous and secondary siliceous rock phosphate samples were received from Jhamarkota works of RSMML, Rajasthan to study the response towards flotation after blending primary & secondary ore in the ratio of 80:20 and 70:30, respectively, at RODL,IBM, Ajmer. The primary ore assayed 14.22% P_2O_5, 39.39% CaO, 12.93% MgO, 25.92% LOI, 5.34% SiO_2 and 0.85% Fe_2O_3. The secondary ore assayed 14.23% P_2O_5, 23.42% CaO, 1.15% MgO, 1.96% LOI, 50.14% SiO_2 and 4.53% Fe_2O_3. After studying various blends, it was observed that the concentrate obtained from flotation of 70:30 blend assayed 34.88% P_2O_5. 49.76% CaO, 1.98% MgO, 4.72% LOI, 4.91% SiO_2 and 1.38% Fe_2O_3 with 71.7% P_2O_5 recovery (Wt% yield 30.4). The concentrate obtained finds application in fertilizer industry.

1.11 SANDSTONE

Upgradation of ROM Sandstone sample for Glass Grade Concentrate (IBM)

A ROM sandstone sample from Chotila Mines, Surendra Nagar, Gujarat assaying 98.28% SiO_2, 0.758% Al_2O_3, 0.093% Fe_2O_3 and 0.093% TiO_2 was sent to Modern Mineral Processing Laboratory and Pilot Plant, IBM, Nagpur by M/s HNG Float Glass Limited, Halol, Gujarat. The object of investigation was to obtain a glass grade silica sand concentrate in the size range of -30+120 mesh and assaying 98.5% SiO_2(min), 0.04% Fe_2O_3 (max), ~1% Al_2O_3 and 0.02% TiO_2 (max).

A table concentrate assaying 99.07% SiO_2, 0.300% Al_2O_3, 0.041% Fe_2O_3 and 0.004% TiO_2 with wt% yield of 80.9 in the size range of -30+150 mesh. The sample is amenable to beneficiation. The final concentrate meets the stipulated size chemical specification (including -120 mesh ~10%) for glass industry.

1.12 SILICA SAND

Beneficiation Studies on a Silica Sand sample from Ratnagiri district, Maharashtra (IBM)

A silica sand sample sent by M/s Hind Aluminium Industries Ltd, Mumbai was received in the Modern Mineral Processing Laboratory and Pilot Plant, IBM, Nagpur for conducting laboratory scale beneficiation studies with an objective to develop a suitable process flow sheet so as to produce a silica sand concentrate assaying 99.6% SiO_2 and 0.1% Fe_2O_3.

The as received sample assayed 98.312% SiO_2, 0.28% Fe_2O_3, 0.028% TiO_2, 0.61% Al_2O_3, 79 ppm Cr_2O_3, 0.023% CaO, 0.01% MgO, 0.077% K_2O and 0.23% LOI.

Various techniques of beneficiation attempted on sample were sieving of original sample over different sieves, attrition scrubbing cum desliming followed by magnetic separation, tabling followed by magnetic separation, etc. A simple process route comprising (i) desliming, attrition scrubbing, sieving followed by magnetic separation produced a non-magnetic concentrate assaying 99.51% SiO_2, 0.052% Fe_2O_3 (wt% yield 78.1) and (ii) sieving, attrition scrubbing and then magnetic separation of deslimed sand fraction produced a silica sand concentrate (non-magnetic) assaying 99.422% SiO_2 and 0.042% Fe_2O_3 (wt% yield 86.3).

Both the concentrates produced above met the specification of silica sand concentrate as stipulated by the party.

Upgradation of Silica Sand sample from Ramanuj Jhanwar, Chotila Area, Gujarat (IBM)

A silica sand sample from HNG Float Glass Limited, Phase –III, Chotila Area, GIDC, Gujarat was received at Modern Mineral Processing Laboratory and Pilot Plant, IBM, Nagpur for bench scale beneficiation studies so as to evolve a suitable flow sheet to yield a concentrate with specification of 98.5% (min) SiO_2, 1.0% (max) Al_2O_3, 0.04% (max) Fe_2O_3 and 0.02% (max) TiO_2 in the size range of – 30+120 mesh. The as received sample assayed 90.91% SiO_2, 0.46% Fe_2O_3, 5.79% Al_2O_3, 0.085% TiO_2 and 2.29% LOI.

Grinding followed by sieving, tabling and wet high intensity magnetic separation and scrubbing yielded a composite concentrate -30+120 mesh size assaying 99.1% SiO_2, 0.034% Fe_2O_3, 0.40% Al_2O_3, 0.003% TiO_2 and 0.18% LOI with over all wt% yield of 34.1. The concentrate obtained fulfils the specification stipulated by the party.

1.13 TITANO-MAGNETITE ORE

Upgradation of a Lumpy Titano-magnetite ore sample from Gondia, Maharashtra (IBM)

The objective of the ore was (1) to obtain iron concentrate with >62% Fe(T), having magnetic mineral content over 90% and specific gravity over four and (2) and to obtain iron and titanium rich concentrate which may find application in ferro-titanium industry.

The as received sample assayed 51.74% Fe(T), 8.84% FeO, 5.05% Al_2O_3, 4.28% SiO_2, 14.44% TiO_2, 0.290% CaO, 0.400% MgO and 0.54% LOI. The process adopted for upgradation was crushing, grinding and WHIMS. The final magnetic concentrate assayed 54.68% Fe(T), 4.52% Al_2O_3, 2.35% SiO_2 & 13.30% TiO_2 with weight recovery of 83.4%. The magnetic mineral concentrate is having a specific gravity of 4.4, bulk density of 2.14 t/m^3 and particle size of -300 +325 mesh size around 15% and -500 mesh around 40%, This concentrate may find utility as heavy media in HMS process.

The non-magnetic fraction assayed 36.09% Fe(T), 8.58% FeO, 8.03% Al_2O_3, 14.24% SiO_2 and 19.89% TiO_2 with per cent weight yield of 16.6. This titanium rich by-product can be used in ferro-titanium alloy or allied industry after suitably blending with ilmenite or rutile.

Bench scale beneficiation studies on a Titano – Magnetite Ore (Fines) sample from Khursapar Mines for M/s Maharashtra State Mining Corporation Ltd, Nagpur (MS), (IBM)

A titano-magnetite ore (fines top size (-)18mm) sample from Khursapar Mines, District Gondia, Maharashtra was received from M/s Maharashtra State Mining Corporation Ltd, Nagpur, Maharashtra at Modern Mineral Processing Laboratory and Pilot Plant, IBM, Nagpur with an objective to produce an iron concentrate assaying Fe(T) >62% with a magnetic mineral content more than 90% with specific gravity more than 4.0, so that it finds application in ferro-titanium industry. The as received sample assayed 49.11% Fe(T), 8.45% FeO, 6.43% Al_2O_3, 7.92% SiO_2, 14.37% TiO_2 and 0.70% LOI.

Preliminary beneficiation studies indicated that the sample is complex in nature and hence it is difficult to produce marketable grade iron concentrate with Fe >62% or ferro-titanium grade titanium concentrate with TiO_2 45% (min). However, a magnetic concentrate (around 90% magnetic mineral content) having specific gravity of plus 4.4 as desired and bulk density of 2.05 t/m^3 and necessary particle size could be produced which finds utility as heavy media in HMS process.

2. MINING

National Institute of Rock Mechanics (NIRM)

National Institute of Rock Mechanics (NIRM) is a premier research centre in the field of applied and basic Rock Mechanics & Rock Engineering. NIRM is an ISO -9001:2008 Certified Research Institute.

NIRM provides specialised technical servicesto several industrial sectors like mining - coal & non-coal; civil - hydroelectric & tunnelling projects, nuclear power projects, underground storage cavern projects and to other construction industries within India and abroad, stressing upon the need to achieve improved production and productivity, with utmost safety and economy.

The Institute has state-of-the-art facilities and offers services through field and laboratory investigations. During the year, NIRM was involved in 71 projects out of which 45 were completed successfully and 26 projects were in progress.

Engineering Geological Investigations (NIRM)

Geological and geotechnical inputs are pre-requisite for economic and safe design civil construction projects in power sector (hydel, thermal, nuclear), communication sector (metros, rails, tunnels, roads, bridges) and mining sector. The department undertakes detailed geological investigations at various stages of the projects, i.e., feasibility report (FR), detailed project report (DPR), construction and post-construction stages. It also undertakes studies related to geohazard assessment and mitigation. Enginering Geology Department has three sections, namely engineering geology, seismotectonics and remote sensing and is equipped with latest hardware and software. During 2009-10, this department has completed two projects and four projects were in progress.

- Construction stage geological/geotechnical investigations at Tapovan Vishnugad Hydro Electric Project (520 MW), Uttarakhand (completed).
- Petrography analysis of rocks - Crude Oil Underground storage Cavern, Padur, Udupi (completed).

Engineering Geophysical Investigations (NIRM)

Engineering Geophysical investigations constitute part of engineering geological studies being carried out by NIRM. In addition, a number of investigations are also undertaken independently for civil, mining and other infrastructure projects. With state-of-the-art facilities for surface and borehole geophysical investigations, the Institute is carrying out subsurface mapping by refraction, reflection, sounding and cross-hole tomography techniques using seismsic, electrical and GPR survey techniques. During 2009-10, this department completed four sponsored research projects, two for hydroelectric projects, one for strata classification work, and one for assessment of the rockmass in the foundation regime of oil storage cavern.

- Resistivity Imaging at the Strategic Petroleum reserve site at Padur, Karnataka.
- Geophysical investigations along the HRT alignment of the Kumaradhara Small HEP at Hire Bandady near Uppingaddi, Karnataka.
- Rockmass characterisation of the sub-surface strata along pre-identified lines at the Domestic, International Terminals and the power substation yard of the Chennai Airport.
- Seismic Refraction survey for bed rock profiling along intake alignment and powerhouse locations at Dhukwan Hydroelectric Project, Uttar Pradesh.

Geotechnical Engineering Investigations (NIRM)

Geotechnical investigations are an essential and integral part of all civil and mining engineering projects. In-situ stress, rock mass deformability and shear parameters are required for analysis and design of underground excavations and dams. During 2009-10, the Geotechnical Engineering Department completed eight sponsored projects for hydropower sector and one sponsored project for mining sector and an in-house research project was in progress.

- Determination of in-situ stress parameters at the powerhouse location of Naitwar-Mori Hydroelectric Project, Uttarakhand, Satluj Jal Vidyut Nigam Ltd.
- Determination of in-situ stress, deformability and shear parameters at Lower Demwe Hydroelectric Project in Arunachal Pradesh.
- Determination of in-situ stress parameters by Hydrofrac method at Devpura soapstone mines for design and development of stopes, Associated Soapstone Distributing Co. Pvt. Ltd, Udaipur, Rajasthan.
- Determination of in-situ stress parameters at the powerhouse location of Naitwar-Mori Hydroelectric Project, Uttarakhand, Satluj Jal Vidyut Nigaj Ltd.

- Determination of in-situ stress, deformability and shear parameters at Lower Demwe Hydroelectric Project in Arunachal Pradesh.

Rock Fracture Mechanics and Material Testing (NIRM)

Rock Fracture Mechanics laboratory is equipped with state-of-the-art facilities to carry out basic research and to determine properties of intact and jointed rocks which are required for design and modelling of underground excavations. This laboratory also has facilities to determine properties of dimensional stones as per ASTM and European standards. The Material Testing Laboratory carries out testing of wire rope samples and non-destructive testing of mining machinery components as per the requirement of the Directorate General of Mines Safety. During 2009-10, laboratory investigations were carried out for various hydroelectric power projects, underground storage cavern and coal mines.

- Laboratory rock mechanics investigations - Tawang hydroelectric project - Stage I & II, NHPC, Arunachal Pradesh.
- Laboratory rock mechanics investigations - Crude oil underground storage cavern, RITES, Padur, Udupi, Karnataka.
- Post Failure studies on Coal - ID BG Panel, GDK 10 Incline, SCCL, Andhra Pradesh.
- Laboratory geotechnical investigations for Shanthikhani LW Block, SCCL, Andhra Pradesh.
- Laboratory investigation of shear behaviour of joint surfaces of sandstone, OC Block - II SCCL, Andhra Pradesh.
- Laboratory geotechnical investigations for Jallaram shaft Block, SCCL, A.P.
- Triaxial compression test on rock samples of Malshej Ghat Pumped Storage Scheme - NPCIL/THDC .

Engineering Seismology (NIRM)

Monitoring of seismic activity is essential for assessing stability of underground and opencast excavations. During 2009-10, the Engineering Seismology department has completed one S&T project and initiated a new S&T project for monitoring seismicity of peninsular India. During this period, rockbursts, local, regional and teleseismic events were monitored using both broad band seismic station and strong motion accelerograph.

- Establishment of Broad Band Seismic Station.

Numerical modelling, instrumentation and monitoring (NIRM)

Numerical modelling deals with the analysis of complex rock mechanics problems using discontinuum and continuum methods. During the year 2009-10, the department dealt with modelling of underground caverns and slopes in hydroelectric projects. The stability analyses for major caverns were carried out using the instrumentation data.

- Instrumentation, monitoring and data analysis of underground powerhouse complex, desilting chambers of Tala Project, Bhutan.
- Analysis of instrumentation data of dam at Tala Hydroelectric Project, Bhutan.
- 3D Stability analysis (Discontinuum) of the right bank cut slopes of Koteshwar HEP, THDC, Rishikesh.

Rock Blasting & ExcavationEngineering (NIRM)

Optimisation of blast design parameters for mining and hydroelectric projects along with monitoring and control of ground vibration, air overpressure and fly rock are needed to solve challenging problems during surface and underground excavations. During 2009-10, Rock Blasting and Excavation Department completed 12 industry-sponsored projects and two were in progress.

- Technical advice for controlled blasting at Gokak Small Hydel Project (4.5MW), Forbes Gokak Limited, Belgaum, Karnataka.
- Technical guidance for site grading at MRPL, Phase III, Part A, Mangalore, Karnataka.
- Optimisation of blast design for Jilling Langalota Iron and Manganese mines, Essel Mining & Industries Limited, Keonjhar, Odisha.
- Study on ground vibration and air overpressure due to blasting near Kasholi adit, Package 1, Rampur HEP, Jhakri, Himachal Pradesh.

- Technical guidance for site grading at MRPL, Phase III, Part B, Mangalore, Karnataka.
- Ground vibration and air overpressure study due to mine blasting at Selianallur Limestone Mine, The India Cements Ltd, Tirunelveli District, Tamil Nadu.
- Study on ground vibration and air overpressure produced from quarry blasting at Survey No. 30 of Gudnapur village, (Quarry lease No. 621), Kolar District, Karnataka.
- Technical note on application of controlled blasting techniques at the toe of the Tunga Bhadra dam and its effect on the dam for construction of a 1.4 MW mini hydel project on Raya Basavanna Canal, Khandaleru Power Company Limited, Karnataka.
- Technical note on application of controlled blasting techniques for excavation of powerhouse for 4.5 MW Siriguppa Mini Hydel Scheme across river Tunga Bhadra, Siriguppa, Bellary, Sri Nirmala Power Pvt. Ltd.
- Ground vibration studies at Sonathi Small Hydro Electric Project, Suganeshwara Hydel Power Pvt. Ltd Gulbarga District, Karnataka.
- Design of controlled blasting pattern for rock excavation and monitoring of ground vibration close to green/matured concrete at 600 MW Thermal Power Plant, Mettur, BGR Energy Systems Limited, Chennai.
- Ground Vibration studies and assessment of flyrock during blasting at portal adit of underground crude oil storage cavern of ISPRL, Mangalore, Karnataka.

Mine Design (NIRM)

In India, large reserves of good quality coal are locked up in developed bord and pillar workings. NIRM has been making efforts for extraction of coal from difficult seams by designing innovative and modern methods of work. Ground control investigations and systematic strata/support monitoring are essential for safe design of underground mining methods and to validate the designs. Mine Design Department is actively involved in rock mass characterisation, support design for underground/opencast mines and strata monitoring. During 2009-10, the mine Design Department of NIRM had one S&T project and a number of industry-sponsored projects.

Stability of workings in hard rock mines

- Instru
- Study on subsidence at Hira Buddinni Gold Mines, HGML.

Stability of Rhombus Shaped Pillars

- KTK-1, 5 and 8 Inclines, Bhupalpalli Area, SCCL.
- Indaram Khani -1A Incline, Srirampur Area, SCCL.
- Design of supports in coal mines.
- Yield Pillars in Continuous Miner Panel at VK-7 Incline, Kothagudem Area, SCCL.

Design of slopes in opencast mines

- Surla-Sonshi Iron Ore Mine of M/s V. S. Dempo, Goa.
- Cudnem Iron Ore Mine of M/s V. M. Salgaocar, Goa.
- Kesari-Phansawde Iron Ore Mine of M/s SMCPL, Maharashtra.
- Basanatnagar Limestone Mine of M/s Kesoram Cements, Andhra Pradesh.

Microseismic/Nanoseismic Monitoring (NIRM)

Microseismic and Automation Department offers services in monitoring stability of underground structures and landslides using advanced Acoustic Emission/Microseismic monitoring technique. This monitoring helps to delineate the structural instability information well in advance. This information in turn helps to adopt suitable support methods at identified vulnerable locations and to take early precautionary measures to control any major disturbances. During 2009-10, this department completed one project.

- Microseismics Application for Stability Monitoring Tala Power House Cavern, Bhutan.

Dimensional Stone Technology (NIRM)

The basic purpose of Dimensional Stone Technology Department is to carry out research and provide technical supports for optimum recovery and economic exploitation of dimensional stones. During 2009-10, the services of this department were utilised for strata classification at two project sites. In addition the following study was compled.

- Scientific studies at PRP Granite Quarries for suggesting eco-friendly quarrying methods, Madurai, Tamil Nadu.

3. ENVIRONMENT

Environmental Quality Monitoring at Shigao and Saniem Iron Ore Mines of M/s Fomento Industries, Goa for the year 2009-10 (IBM)

The study on Environmental Quality Monitoring at Copila Gaichem Paul Shigao and Saniem Iron Ore Mine of M/s Fomento Industries, Goa, has been carried out for all the four seasons for 2009-10 to monitor environmental parameters such as air, water, soil and noise at the mines. The study has indicated that all the environmental parameters monitored are within the prescribed limits as per MoEF standards. The study, thus, helped the mine management to develop proper mitigation measures. The final reports were under preparation for submission to the party.

Environmental Engineering (NIRM)

The Environmental Engineering Department deals with assessment of air, water and soil qualities, noise survey and measurement of meterological parameters. During 2009-10, this department was involved in one S&T project, one in-house project and one sponsored project, out of which one was completed.

- Water and sediment quality analysis of Malshej Ghat Project, NPCIL.

Study for monitoring of ground vibration due to blasting in four limestone mines of M/s Tata Chemicals near Adityana and Zinzerka village, Distt. Porbandar, Gujarat (IBM)

This study has been carried out in the following four mines as per ToR (Terms of References), Government of India-MoEF and to assess the impact of blast induced vibrations in the area, particularly in the nearby Jambuvanti Cave, which is a place of worship for local villagers. The salient features of the study is as follows:

Adityana (12.6 ha) Limestone Mine: The Adityana mine is located in Adityana village and is about 6 km from Ranavav town, a Taluka Headquarters. Ranavav is the nearest railway station on Porbandar-Rajkot broad-gauge section of Western Railway. The Jambuvanti Cave monument which is reportedly a place of worship for the local villagers, is located about 288 m due south-east of this lease area and is maintained by Archaeological Survey.

Normally, in Adityana (12.62 ha) limestone mine, the charge weight per delay is kept below 30.0 kg.as observed during the study period. The calculated peak particle velocity for the charge weight of 30.0 kg., for a distance of 1754.0 m comes to 0.32 mm/sec, which is well within the safe limit of 15.0 mm/sec for structures belonging to the owner, whereas in case of Jambuvanti Cave the instrument triggered and recorded 3.05 mm/sec peak particle velocity level in case of only one blast i.e. Blast No. 5 conducted during this study which is on higher side as per safe limit given by DGMS norms for Archeological & Historical Monuments.

It is, therefore, suggested that maximum charge weight per delay should not exceed 30 kg when the blasting is carried out in extreme southern corner of the mining lease area from which the Jambuvanti cave is at a distance of 288.0 m.

Adityana (9.21 ha) Limestone Mine*:* This Mine is also located in Adityana village. The Jambuvanti Cave which is reportedly a worship-place for the local villagers, is located about 320 m due south-east of this lease area. There is no other important structure, public building or public place, located in the vicinity of the study area.

In Adityana Naviline-A (9.21 ha) Limestone Mine, the charge weight per delay is kept below 30 kg. The calculated peak particle velocity for the charge weight of 30 kg for a distance of 320 m is 1.46 mm/sec, which is well within the safe limit for structures belonging to the owner, whereas, in case of Jambuvanti Cave the instrument did not trigger on its setting at 0.5 mm/sec level in case of all the nine blasts. It is also well within the safe limit as per DGMS for Archaeological and Historical Monuments.

After analysis of the collected data, it is suggested that the present blasting practice adopted during the study may be continued as there is no damage to Jambuvanti Cave by this charge weight of 30 kg per delay. However, maximum charge weight per delay should not exceed the value of 45 kg for the Jambuvanti Cave which is at a distance of 320 m, when the blasting was carried out in extreme corner of mining lease area.

Adityana-Bhimkot (16.8755 ha) Limestone Mine*:* The Jambuvanti Cave monument which is reportedly a worship-place for the local villagers, is located about 2.384 km due south-east of this lease area. There is no other important structure, public building or public place, located in the vicinity of the study area.

In this Adityana-Bhimkot Limestone mine, the charge weight per delay is kept below 30 kg as observed during the study period. The calculated peak particle velocity for the charge weight of 30 kg for a distance of 4200.0 m comes to 0.06 mm/sec, which is well within the safe limit of 15.0 mm/sec for structures belonging to the owner, whereas, in case of Jambuvanti Cave, the instrument kept in the direction of cave triggered and recorded 0.516 mm/sec peak particle velocity level in case of only one blast i.e. Blast No.1, conducted during this study which is well within the safe limit as per DGMS for Archaeological and Historical Monuments.

Based on the observation and analysis of the collected data, it is suggested that maximum charge weight per delay should not exceed 150 kg when the blasting was carried out in extreme southern corner of the mining lease area from which the Jambuvanti Cave is at a distance of 2384.0 m.

Zinzerka (14.27 ha) Limestone Mine: The Zinzerka Limestone Mine is located near Zinzerka village and is about 10 km from Ranavav Town. An Archaeological Survey maintained monument i.e., the Jambuvanti Cave which is reportedly a worship-place for the local villagers, is located about 6.603 km due south-east of this lease area. There is no other important structure, public building or public place, located in the vicinity of the study area. In this Zinzerka (14.27 ha) limestone mine the charge weight per delay is kept below 30 kg. The calculated peak particle velocity for the charge weight of 30 kg for a distance of 3586 m comes 0.13 mm/sec, which is well within the safe limit for structures belonging to owner, whereas in case of Jambuvanti Cave the instrument did not trigger when kept in the direction of cave at a distance of 585 m from the blast and on its setting even at 0.5 mm/sec level in case of all the five blast recorded. It is also well within the safe limit as per DGMS for Archelogical and Historical Monuments.

Based on the observations and analysis of the collected data, it is suggested that the blasting practice adopted during the study may be continued, as there is no damage to Jambuvanti Cave by this charge weight of 30 kg per delay. However, maximum charge weight per delay should not exceed the value of 150 kg for the Jambuvanti Cave which is at a distance of 6603 m, when blasting will be carried out in the extreme southern corner of mining lease area.

However, when the blasting is being carried out in extreme northern corner of Zinzerka Limestone Mine, the farm-house of Shri Heba Kara, which is at a distance of 124 m, the charge weight per delay should not be more than 45 kg to maintain the higher factor of safety so that vibration should not exceed 10.0 mm/sec, the farm-house shall be shifted beyond 300 m when charge weight per delay is more than 45.0 kg.

Study of Monitoring of Ground Vibrations due to Blasting in Adityana Limestone Mines of Shri Hamir Harji Kutana (H.S. Minerals), near Amardal village, Distt: Porbandar, Gujarat

The study has been carried out as per Terms of References (ToR) Govt. of India-MoEF and to assess the impact of blast induced vibrations in the area, particularly, in the nearby Jambuvanti Cave.

In this limestone mine, the charge weight per delay is kept below 3.0 kg. The observed peak particle velocity for the charge weight of 2.0 kg for a distance of 120.0 m is 0.846 mm/sec, which is well within the safe limit for structures belonging to owner, whereas in case of Jambuvanti Cave the instrument did not trigger on its setting at 0.5 mm/sec level in case of all the five blasts, when kept in the direction of cave. It is also well within the safe limit as per DGMS for Archeological and Historical Monuments.

It is recommended that the present blasting practice may be continued as there is no damage to Jambuvanti Cave and other structures by this charge weight of 2.0 kg per delay. Also, it favours to safe mining for the structures nearby the lease area as well as suits to get the required size of material for supply to the consuming industry.

Study for monitoring of ground vibrations due to blasting in Billi Markundi (Julgul) Limestone Mine of M/s Jaiprakash Associates Ltd (Dala Cement) in Sonbhadra Distt. (Uttar Pradesh)

The study has been carried out at Dalla Cement in Uttar Pradesh. Here, in the study area, the high tension lines coming from the Obra Power Plant are passing very near to the mining lease area and two towers on southern side are very near to present working faces at a distance of 100 m. The study was carried out to suggest control blasting techniques for controlng specially fly-rock and ground vibrations to be followed in this mine. Overhead high voltage power transmission lines can induce currents (eddy currents) in blasting circuits. It is recommended that electric firing should not be allowed closer to these transmission lines.

During the study, it was observed that normally, in Billi-Markundi (Julgul) Limestone Mine, the charge weight per delay is kept below 300.0 kg. The calculated peak particle velocity for the charge weight of 300.0 kg for a distance of 376.0 m is 30.98 mm/sec which is outside the safe limit for structures belonging to the owner. Therefore, the charge needs to be restricted to 175.0 kg. By keeping the charge at 175.0 kg per delay, the peak particle velocity at a distance of 376.0 m will be at 23.40 mm/sec which is within permissible limits for structures belonging to the owner, viz, Mine Office.

It is also suggested that when the blasting is being carried out in extreme southern corner of lease area i.e. in Hill-2 from where the Obra Power Plant Colony is at distance of 346.0 m, the charge weight per delay should not be more than 25.0 kg for structures not belonging to the owner to maintain higher factor of safety, that is vibration should not exceed 10.0 mm/sec.